THE AMERICAN SOCIETY
OF MECHANICAL ENGINEERS

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# INDEX TO THE JOURNAL

THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS

JULY–DECEMBER, 1911

# INDEX TO THE JOURNAL, JULY-DECEMBER 1911

**Note: Items appearing in The Journal as Society Affairs, have the month and page number given. Where the list of discussers of a paper is given, the list appears under the straight title of the paper. Papers published in The Journal previous to July, discussion of which was published during July to December, are indicated by the month, followed by 1911. All papers, reports, etc., of the Gas Power Section appear under that heading. Items regarding Student Branches are so indexed. Miscellaneous items are indexed under Miscellaneous.**

**Miscellaneous**



**Necrology**

THE JOURNAL

OF

THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS

VOL. 33 JULY 1911 NUMBER 7

## RESOLUTIONS OF THANKS TO THE INSTITUTION OF MECHANICAL ENGINEERS

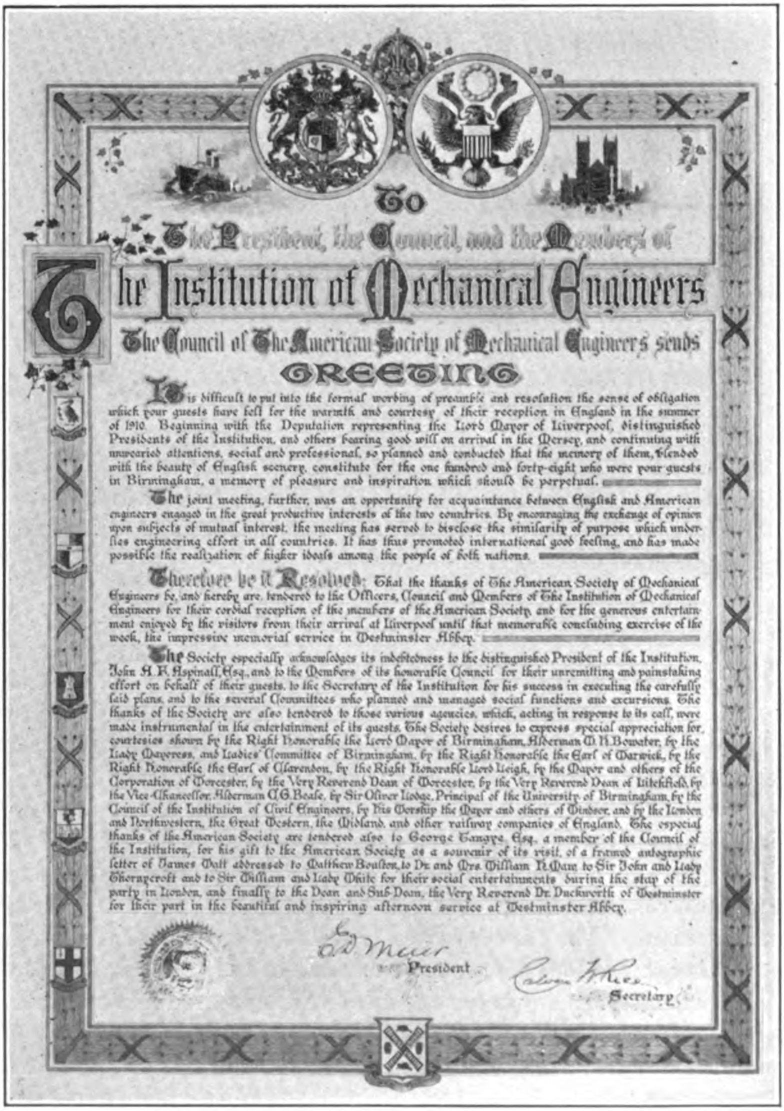
The members of the Society enjoying the hospitality so generously offered at the English meeting are sending to The Institution of Mechanical Engineers beautifully engrossed resolutions of thanks, a photograph of which appears on another page.

## THE SPRING MEETING

The Spring Meeting was held at Pittsburg, Pa., May 30 to June 2, 1911, with an attendance of 307 members and 353 guests. Most of the social gatherings were held at the Hotel Schenley, where the registration headquarters were maintained, but the business meetings and professional sessions were held in the lecture hall of the Carnegie Institute and in the Carnegie Technical Schools.

This meeting was an unusually strong combination of pleasant social features, interesting technical excursions and valuable professional sessions. The papers were of unusual interest, and in spite of many other attractions the professional sessions were all well attended.

The local membership were very effectively organized into an executive committee, E. M. Herr, Chairman; with sub-committees on finance, George Mesta, Chairman; entertainment, J. M. Tate, Jr., Chairman; hotels, C. B. Albree, Chairman; printing and publicity, Morris Knowles, Chairman; and transportation, D. F. Crawford, Chairman. These committees contributed much to the success of the meeting by the painstaking manner in which they provided for the comfort and entertainment of the visiting members and guests.



To

The President, the Council, and the Members of

The Institution of Mechanical Engineers

The Council of The American Society of Mechanical Engineers sends

GREETING

It is difficult to put into the formal wording of preamble and resolution the sense of obligation which your guests have felt for the warmth and courtesy of their reception in England in the summer of 1910. Beginning with the Deputation representing the Lord Mayor of Liverpool, distinguished Presidents of the Institution, and others bearing good will on arrival in the Mersey, and continuing with unwearied attentions, social and professional, so planned and conducted that the memory of them, blended with the beauty of English scenery, constitute for the one hundred and forty-eight who were your guests in Birmingham, a memory of pleasure and inspiration which should be perpetual.

The joint meeting, further, was an opportunity for acquaintance between English and American engineers engaged in the great productive interests of the two countries. By encouraging the exchange of opinion upon subjects of mutual interest, the meeting has served to disclose the similarity of purpose which underlies engineering effort in all countries. It has thus promoted international good feeling, and has made possible the realization of higher ideals among the people of both nations.

Therefore be it Resolved: That the thanks of The American Society of Mechanical Engineers be, and hereby are, tendered to the Officers, Council and Members of The Institution of Mechanical Engineers for their cordial reception of the members of the American Society, and for the generous entertainment enjoyed by the visitors from their arrival at Liverpool until that memorable concluding exercise of the week, the impressive memorial service in Westminster Abbey.

The Society especially acknowledges its indebtedness to the distinguished President of the Institution, John A. F. Aspinall, Esq., and to the Members of its honorable Council for their unremitting and painstaking effort on behalf of their guests, to the Secretary of the Institution for his success in executing the carefully laid plans, and to the several Committees who planned and managed social functions and excursions. The thanks of the Society are also tendered to those various agencies, which, acting in response to its call, were made instrumental in the entertainment of its guests. The Society desires to express special appreciation for courtesies shown by the Right Honorable the Lord Mayor of Birmingham, Alderman W. H. Bowater, by the Lady Mayoress, and Ladies' Committee of Birmingham, by the Right Honorable the Earl of Warwick, by the Right Honorable the Earl of Clarendon, by the Right Honorable Lord Leigh, by the Mayor and others of the Corporation of Worcester, by the Very Reverend Dean of Worcester, by the Very Reverend Dean of Litchfield, by the Vice-Chancellor, Alderman C. G. Beale, by Sir Oliver Lodge, Principal of the University of Birmingham, by the Council of the Institution of Civil Engineers, by His Worship the Mayor and others of Windsor, and by the London and Northwestern, the Great Western, the Midland, and other railway companies of England. The especial thanks of the American Society are tendered also to George Tangye, Esq., a member of the Council of the Institution, for his gift to the American Society as a souvenir of its visit, of a framed autographic letter of James Watt addressed to Matthew Boulton, to Dr. and Mrs. William H. Maw, to Sir John and Lady Thornycroft and to Sir William and Lady White for their social entertainments during the stay of the party in London, and finally to the Dean and Sub-Dean, the Very Reverend Dr. Duckworth of Westminster for their part in the beautiful and inspiring afternoon service at Westminster Abbey.

President

Secretary

RESOLUTION OF THANKS TO THE INSTITUTION OF MECHANICAL ENGINEERS

Registration proceeded during the morning and afternoon of May 30, and in the evening an informal reunion was held by the Local Committee, which gave opportunity for the renewal of acquaintances and the making of new ones. A pleasant feature of the reunion was the presentation to President Meier of an engrossed testimonial of personal esteem and appreciation of his distinguished military and engineering services, by a group of friends in the Society on the occasion of his seventieth birthday. C. J. H. Woodbury made the presentation in the following words:

The flight of time is so noiseless that it requires anniversaries to mark its progress, and at a meeting of engineers in Boston a few weeks ago, it was remarked that you would have a notable anniversary on this occasion which ought to be recognized in a manner similar to that of the seventieth birthday of several of your associates and predecessors, and the matter was placed in the hands of a committee of your fellow-members from various parts of this country.

Your career has been indeed a notable one in its facility of doing many things and doing them well.

In the service of your country in both cavalry and artillery, you became a part of movements of national history. In the reorganisation of the militia of your State, you became a force in the maintenance of law and order.

It is, however, in the greater victories of peace that we have come more closely in touch with your career as an engineer.

You have been connected with the great cotton industry in making improvements in baling the raw material, in mill construction, and also that of the textile machinery which produces the finished product.

In the great problem of transportation you have been connected with locomotive practice and railway management.

The functions of the engineer as an economist have been wrought by you yourself in the generation of steam and in the more radical innovations of the internal combustion engine.

But this recital of deeds well done is trite in comparison with that of the respectful tribute which we give to your sterling manhood which has endeared you to those with whom you have been associated.

Accept then, this engrossed testimonial briefly stating our felicitations; and this will be followed in due time by a folio containing the names of those taking part in this testimonial, and we ask you to give sittings to an artist whose portraiture will I trust be worthy of the subject.

In accepting the testimonial Colonel Meier replied as follows:

DR. WOODBURY AND FRIENDS, MEMBERS OF THE AMERICAN SOCIETY MECHANICAL ENGINEERS:

I receive at your hands this testimonial of friendship and esteem with feelings of deep gratitude and honest pride: gratitude that so many friends in our great Society feel so warmly towards me as to unite in this cordial congratulation; pride in the knowledge that my honest endeavor to do sound engineering work is appreciated by colleagues, who, as I see by the names of your committee, represent all sections of our country.

I have always believed and have acted on the conviction that the first question for an engineer is to determine what his duty is and then to do it with his whole heart; and that he who does his duty need not worry about his rights.

I have not always succeeded in my work but I have at least aimed high. I fully realize that in receiving the honors you bestow on me, I am acting as a representative of many colleagues whose good work has made success possible, and I accept them in the proud feeling that they are the spontaneous offerings of men in that noble profession to which the marvelous development of this Union in all the arts of peace is mainly due.

I feel that by your gracious act you impose on me the welcome duty to remain in harness for a decade or two more, or rather as long as I can be of service to engineers. Again with a full heart, I thank you and your associates.

The testimonial, a photograph of which is shown on the opposite page, reads as follows:

To Colonel Edward Daniel Meier:

The undersigned Committee of your fellow members of The American Society of Mechanical Engineers, on behalf of those associated with them, tender to you their cordial regards in commemoration of your seventieth birthday, in appreciation of your distinguished career in military service and in engineering, to which you have made many notable contributions, and in which you have established an honorable name.

M. L. Holman, *Chairman*

C. J. H. Woodbury, *Secretary*

| | |
|---|---|
| David F. Crawford | William Benson Mayo |
| Charles J. Davidson | R. S. Moore |
| Arthur J. Frith | Henry G. Morris |
| Leonard L. Griffiths | E. Gybbon Spilsbury |
| Andrew M. Lockett | Thomas B. Stearns |
| Charles H. Manning | Max Toltz |

May 30, 1911.

On the opening day also, many members took the opportunity of visiting the exhibit of the Foundry and Machine Exhibition Company, originally provided for the convention of the American Foundrymen's Association during the previous week and held over for the benefit of the members of this Society.


**Testimonial Presented to Col. E. D. Meier**

## WEDNESDAY MORNING, JUNE 1—BUSINESS AND PROFESSIONAL SESSION

The meeting was called to order at ten o'clock by President Meier, the first business being the report of the Tellers of Election to Membership. The following elections to membership and promotions were announced by the President:

### MEMBERS

Albert, Calvin Dodge, Ithaca, N. Y.
Almquist, Karl, New York,
Arnold, Anthony Brown, Boston, Mass.
Baquet, Camille, Jr., Williamsport, Pa.
Bayne, George Henry.
Berresford, Arthur W., Milwaukee, Wis.
Blair, William Richard, Webster Groves, Mo.
Bonnett, Louis Blake, Elizabeth, N. J.
Cole, Fred Baker, Boston, Mass.
Cross, Charles Norman, Palo Alto, Cal.
Dallis, Park Andrew, Atlanta, Ga.
Davis, Leon Keith, Providence, R. I.
D'Olier, William Livingston, Philadelphia, Pa.
Donnelly, James Alfred, New York.
Drew, Wilbert Shepard, Logan, Utah.
Ellis, Halcolm, Newark, N. J.
Ford, William Lucas, Boston, Mass.
Forgee, Frederick Angus, New York.
Forsburg, Henry A., Berkeley, Cal.
Francis, Isaac Hathaway, Jr., Philadelphia, Pa.
Gartley, Alonzo, Honolulu, Hawaii.
Gilbert, E. E., Schenectady, N. Y.
Going, Charles Buxton, New York.
Gordon, Albert Anderson, Jr., Worcester, Mass.
Graham, William Harvey, Sydney Mines, B. C.
Greenwall, Walter L., Milwaukee, Wis.
Hall, Harris Forster, Chicago, Ill.
Hall, Walter Atwood, Swampscott, Mass.
Hammond, Myram Hance, Hudson, N. Y.
Hawthorne, Primm R., Battle Creek, Mich.
Hobbs, Franklin Warren, Boston, Mass.
Houchin, Ernest A., Brooklyn, N. Y.
Howell, Sylvester S., Chicago, Ill.
Jamieson, Charles Clark, Hoosick Falls, N. Y.
Johnson, John Samuel Adolphus, Blacksburg, Va.
Johnson, Raymond D., Niagara Falls, N. Y.
Johnston, William Atkinson, Boston, Mass.
Kendrick, J. W., Chicago, Ill.
Lamar, Philip Rucker, Augusta, Ga.
Law, Frank E., New York.
Leisen, Theodore Alfred, Louisville, Ky.
Lewis, Frederick Humphreville, Birmingham, Ala.
Lindberg, Frits Albin, Chicago, Ill.
Longacre, Fredrieck van Duzer, New York.
Maguire, Jeremiah De Smet, New York.
Morse, Arthur Holmes, Cincinnati, O.
Nailler, Raymond Frederick, Elyria, O.
Newman, Martin Freese, Pittsburg, Pa.
Norton, Arthur Edwin, Cambridge, Mass.
Olivenbaum, John Emmanuel, Cleveland, O.
Parrock, H. P., Buffalo, N. Y.
Perkins, Julius A., New York.
Reid, Joseph Snively, Belmont, N. Y.
Riege, Rudolph, Stamford, Conn.
Rollins, William Benjamin, Kansas City, Mo.
Rowell, Henry K., Waltham, Mass.
Sankey, Capt. H. Riall, London, England.
Scott, Charles Felton, Pittsburg, Pa.
Sessions, Edson O., Chicago, Ill.
Smith, Albert Samuel, Boston, Mass.
Stanley, Frank A., Stapleton, S. I., N. Y.
Stoddard, Elgin, San Francisco, Cal.
Straub, C. Lee, Port Richmond, N. Y.
Sulzer, George H., Arlington, N. J.
Sweet, Ernest E., Detroit, Mich.
Thiemer, William H., Cleveland, O.
Thorkelson, Halsten Joseph, Madison, Wis.
Veness, Alfred E., Bridgeport, Conn.
Vosbury, W. DeWitt, Philadelphia, Pa.
Whitney, Clarence Edgar, Hartford, Conn.
Whitney, William S., Lawrence, Mass.
Wilkie, Donald Cook, Seremban, Federated Malay States.
Woodman, George A., Chicago, Ill.

### PROMOTION TO MEMBERS

Alexander, Ludwell Brooke, New York.
Barstow, Francis L., Mittineague, Mass.
Brooks, J. Ansel, Providence, R. I.
Cluett, Sanford L., Hoosick Falls, N. Y.
Cole, Arthur Williams, Lafayette, Ind.
DeCasenove, Louis Albert, Jr., Wilmington, Del.
Dixon, Charles Francis, New York.
Fox, R. E., Jr., New York.
Gay, Harry, Boston, Mass.
Kenney, Lewis Hobart, Philadelphia, Pa.
Klein, Arthur Warner, Bethlehem, Pa.
Matthews, Fred. Elwood, New York.

PROMOTION TO MEMBERS—CONTINUED

Rautenstrauch, Walter, New York.
Ray, David H., New York.
Ruckes, Joseph John, Jr., Chicago, Ill.
Rutherford, Eugene W., Brooklyn, N. Y.
Sheperdson, John William, Johnstown, Pa.
Van Valkenburgh, Ralph D., Scranton, Pa.
White, John Culbertson, Madison, Wis.
Wyer, Samuel S., Columbus, O.
Yarnall, Daniel Robert, Philadelphia, Pa.
York, Robert, Memphis, Tenn.

ASSOCIATES

Boblett, Kinderman M., Toledo, O.
Hunt, Samuel J., St. Louis, Mo.
Israel, Charles Henry, Baltimore, Md.
Klockars, Charles Oscar, Newark, N. J.
McIntosh, Walter S., West Roxbury, Mass.

JUNIORS

Andrei, Camillo, Milan, Italy.
Arter, Wilbur D., Mt. Vernon, N. Y.
Bausch, Carl L., Rochester, N. Y.
Briggs, Leroy Edmund, Boston, Mass.
Buck, Lucien, Canton, N. C.
Burroughs, Joseph Howell, Jr., Westmont, Pa.
Cariss, Carington Carysfort, London, Ontario, Canada.
Clayton, Jean Paul, Urbana, Ill.
Cullen, William Vincent, Buffalo, N. Y.
Dennis, Basil Wrenn, Muskogee, Okla.
Douglas, Walter Cooley, New York.
Downes, Nate Worswic, Kansas City, Mo.
Dunsford, Jan R., Alliance, O.
Fabens, Andrew Lawrie, New Kensington, Pa.
Finch, Ellis Jerome, New York.
Flickinger, Harrison William, Clairton, Pa.
Gamble, William John, Buffalo, N. Y.
Garrahan, Frederick Benton, West New Brighton, N. Y.
Gates, John George, Port Chester, N. Y.
Hall, Carl Albe, Concord, N. H.
Hartwell, Arthur Edward, Houston, Tex.
Hatman, Julius G., Kansas City, Kan.
Hider, George Turner, Greenloch, N. J.
Honywill, Albert William, Jr., New Haven, Conn.
Howard, Henry Sherwin, San Francisco, Cal.
Hubbard, Carleton Waterbury, Greenwich, Conn.
Humes, W. Sharon, Chicago, Ill.
Humphrey, Charles Scranton, South Bethlehem, Pa.
Knox, Clarence M., Hartford, Conn.
Koester, Herman, Waterbury, Conn.
Lindquist, Eric Adolf, Pottstown, Pa.
Loeb, Leo, Troy, N. Y.
Lydecker, Kenneth, New York.
McCollum, Caleb Addison, Wilkinsburg, Pa.
Magrath, Charles Bolton, Boston, Mass.
Mann, Harvey Blaine, Philadelphia, Pa.
Marshall, John Henderson, Diamon City, Alta., Canada.
Meyer ,Erwin Charles, New York.
Milner, Bert Branson, Philadelphia, Pa.
Mullhaupt, Alfred, Jr., St. Marys, Pa.
Munson, Stanley, South Bend, Ind.
Murphy, Thomas Robert Hoysted, New York.
Murphy, William T., Providence, R. I.
Nickerson, John Winslow, Saylesville, R. I.
Packard, Horace Nelson, Milwaukee, Wis.
Prout, Henry Byrd, New York.
Randall, John Arthur, Brooklyn, N. Y.
Rea, James Childs, Pittsburg, Pa.
Rentschler, Gordon Sohn, Hamilton, Ohio.
Rowe, Don Ray, Dayton, O.
Ruddy, William, Hoosick Falls, N. Y.
Sawyer, Luke Eugene, Brighton, Mass.
Schiefer, Fred. William, Buffalo, N. Y.
Stix, Lawrence Cullman, Cudahy, Wis.
Tallmadge, Webster, Brooklyn, N. Y.
Towne, Willis Lyman, Southbridge, Mass.
Truette, Arthur Pierce, Brookline, Mass.
Wentworth, Reginald Andrew, Southbridge, Mass.
Zimmermann, William Frederick, Newark, N. J.

The following amendment to C 21 of the Constitution was proposed by the Committee on Meetings in New York, which will be acted upon later in the usual manner:

Members of all grades residing in New York and vicinity and represented by the Committee on Meetings in New York City, should have the privilege and authority by majority vote of such membership to increase their annual dues by the sum of $3.00, such increase to be applied to financing such entertainment features of the Annual Meetings in New York City and its own local meetings as their Committee on Meetings in New York City may elect.

Reports were received from the Committee on Identification of Power House Piping and from the Committee on Standard Flanges. The former was published in The Journal for June 1911, and the latter was distributed in pamphlet form. No action was taken on either of these reports, pending the receipt of discussion, which may be received up to August 1.

Announcement was made that the Society had been invited to meet in 1912 at St. Paul, Cleveland and Baltimore. The claims of each city to consideration were set forth and the members present were asked to indicate to the Council their preferences. Following the receipt of these expressions the Council carefully considered the matter and finally decided that the Spring Meeting of 1912 should be held in Cleveland. This city presents many points of general and industrial interest, and arrangements for the meeting will be in charge of a large and active organization of engineers.

The remainder of the session was devoted to the presentation and discussion of three papers on various phases of the mechanical engineering of cement manufacture. The first of these papers was upon Some Problems of the Cement Industry, by W. S. Landis, of South Bethlehem, Pa., outlining the directions in which improvements in processes must take place and calling attention to some of the ways in which better economy is being obtained abroad. The author stated that the development of the cement industry was dependent on better engineering, and he invited the attention of mechanical engineers to the unsolved problems.

W. H. Mason, of Stewartsville, N. J., then presented his paper on The Edison Roll Crushers, in which were set forth the theories on which Mr. Edison based his development of this apparatus for reducing the cost of quarrying and crushing stone. The machinery was described in detail and data were given regarding horsepower required, cost of maintenance, and time lost due to repairs over a period of years.

L. L. Griffiths then followed with his paper on Power and Heat Distribution in Cement Mills, in which he gave data regarding five different types of power equipment, together with unit costs and outputs of the various types. These papers were discussed by F. B. Gilbreth, R. K. Meade, W. R. Dunn, H. Struckmann, C. J. Reilly, G. P. Hemstreet, F. L. Schwenk, H. E. Brown, W. B. Ruggles, W. M. Kinney, and Paul C. Van Zandt.

At the close of this session it was announced that a committee was being formed, with the coöperation of the Association of American

Portland Cement Manufacturers, to conduct investigations, secure papers and reports and to hold meetings on questions concerning the mechanical engineering features of the cement industry. Considerable interest was shown in this movement and it is believed that great progress may be made through the efforts of such a committee.

### WEDNESDAY AFTERNOON

Immediately following the adjournment of the morning session, a special train conveyed the members and guests from the Union Depot to the works of the Universal Portland Cement Company, at Universal, Pa., where guides conducted the party through the plant, which is producing 12,000 barrels of cement per day, using slag from the Bessemer furnaces of the Carnegie Steel Company, and electric power generated from blast furnace gas at the Carrie furnaces of the Carnegie Steel Company. On the return a stop was made at East Pittsburg, where the party was shown through the works of the Westinghouse Electric & Manufacturing Company and of the Westinghouse Machine Company adjoining. Opportunity was given to inspect the large electric locomotives being built for the Pennsylvania Railroad, as well as steam turbines and gas engines in various stages of construction. Owing to the short time available for this excursion, luncheon was provided on the train.

In the evening two well-attended sessions were held simultaneously. One of these, the Machine Shop Session, was held in the lecture hall of Carnegie Institute, while the Gas Power Section met in the Carnegie Technical School.

### MACHINE SHOP SESSION

The first three papers, constituting a symposium on the subject of the production of small interchangeable parts, were presented and discussed together.

John Calder, of Ilion, New York, under the title The Assembly of Small Interchangeable Parts, treated the subject broadly, with special reference to the methods used by the Remington Typewriter Company, calling attention to the importance of proper design as affecting the economical production of the parts, and outlining the methods used in preparing for the production of each part, in fixing the rate, and in dividing the labor to the best advantage.

The second paper, The Process of Assembling a Small and Intricate Machine, by Halcolm Ellis, was presented in the absence of the author by Nathan W. Perkins, Jr., of Newark, N. J. This paper described the methods used in designing an intricate machine so that it might be assembled quickly and economically, and developed quite fully the methods employed in gathering together the large number of parts of which it is composed.

Another phase of the same subject was treated by F. P. Cox, of West Lynn, Mass., who discussed in his paper, Quantity Manufacture of Small Parts, the ways in which an organization for this purpose differs from that in the usual manufacturing plant. Discussion on these papers was participated in by Hugo Diemer, E. Puchta, J. P. Johnston, W. J. Kaup and A. C. Jackson.

A. L. DeLeeuw, Cincinnati, Ohio, in a paper on Milling Cutters and their Efficiency, outlined briefly a large number of experiments made to determine the most efficient forms of milling cutters. The paper was discussed by W. S. Huson, John Parker and A. F. Murray.

### GAS POWER SECTION

A topical discussion on large blast-furnace gas-power plants was opened by A. E. Maccoun, superintendent of furnaces at the Edgar Thomson Works of the Carnegie Steel Company, and a great deal of valuable material regarding gas engine design and operating difficulties was brought out. The discussion was continued by R. H. Stevens, mechanical engineer, Homestead Steel Works; A. N. Diehl, superintendent of furnaces, Duquesne Steel Works; A. L. Hoerr, steam and hydraulic engineer, National Tube Company; H. J. Freyn, assistant engineer of construction, Illinois Steel Company, and others.

This was followed by a report on the recent work of the United States Bureau of Mines, prepared by S. B. Flagg and C. D. Smith, engineers connected with the Fuel Testing Station at Pittsburg, and presented by the latter. This paper related principally to the recent work in gas producers, and the experiments in briquetting low-grade fuels for various uses.

On Wednesday morning the ladies were conducted through the Margaret Morrison Carnegie School for Women, connected with the Carnegie Technical Schools, after which they proceeded through Schenley Park to the Pittsburg Golf Club, where luncheon was served.

In the afternoon, the Ladies' Committee gave a tea for the visiting ladies at the Hotel Schenley, and in the evening a visit was made to the International Art Exhibit at the Carnegie Institute, adjacent to the hotel.

THURSDAY MORNING—MISCELLANEOUS SESSION

At the session on Thursday morning, four papers on miscellaneous subjects were presented, and one was read by title. R. T. Stewart, of Pittsburg, presented in connection with his paper Stresses in Tubes, the results of a very elaborate investigation which showed that the stresses in the wall of a tube exposed to external fluid pressure are of the same character as those in a column having ends fixed in direction. In connection with the presentation of this paper, Professor Stewart contributed to the Library of the Society a large volume containing detailed records of tests on tubes extending over a number of years. A unanimous vote of thanks was tendered to Professor Stewart for his gift.

In the absence of the author, Perry Barker presented a paper on The Purchase of Coal, by D. T. Randall, in which attention was called to the possibilities of greater fuel economy through the purchase of coal suited to the particular use for which it is intended, under detailed specifications and guaranteed analyses. Discussion on this paper was offered by R. C. Carpenter, W. F. M. Goss, E. D. Meier, C. W. Rice and C. W. Baker.

The next paper, Energy and Pressure Drop in Compound Steam Turbines, by F. E. Cardullo, of Durham, N. H., proposed an empirical formula and a graphical method for determining the power development in each stage of a turbine. Discussion was offered by W. H. Herschel, C. H. Peabody and W. D. Ennis.

The paper by L. S. Marks, The Pressure-Temperature Relations of Saturated Steam, not being adapted for discussion in open meeting, was read by title only, publication having been made in The Journal for May 1911.

G. C. Anthony, of Tufts College, Mass., presented the last paper of the session on A Pressure Recording Indicator for Punching Machinery, a summary of a large number of experiments made to determine the power required for punching plates of various materials with punches of different types. This was accomplished by the use of an ordinary steam-engine indicator operated by hydraulic pressure transmitted from a specially constructed punching die. R. C. Carpenter and Julian Kennedy discussed the paper.

## THURSDAY AFTERNOON AND EVENING

After an early luncheon, those who desired to visit the works of the National Tube Company at McKeesport took special cars from the hotel and proceeded directly to the works. At the same time the remainder of the members and ladies started on an excursion up the Monongahela River by special boat, stopping on the return trip at McKeesport for the party which had meanwhile completed its inspection of the tube plant. Music and refreshments were provided on the boat, and the trip proved most enjoyable in every way, giving an opportunity also to view many of Pittsburg's most notable industries.

Thursday evening was devoted to a reception by the local membership to the visiting members and guests at the Hotel Schenley. A number of persons prominent in social and business circles in Pittsburg had been invited to attend, and the evening was greatly enjoyed by all. There was dancing throughout the evening and supper was served from 10:30 to 12:30.

## FRIDAY MORNING—STEEL WORKS SESSION

At the session on Friday morning, some of the recent developments in steel works practice were brought up and discussed. Methods of supplying air to blast furnaces were covered by the paper, Commercial Application of the Turbine Turbo-Compressor, by R. H. Rice, of West Lynn, Mass., and another on Reciprocating Blast Furnace Blowing Engines, by W. Trinks, of Pittsburg. These papers were discussed together by J. E. Johnson, Jr., C. J. Bacon, Julian Kennedy, F. E. Cardullo, H. J. Freyn and Joseph Morgan.

The Society was privileged to have another new development presented by Barthold Gerdau, of Düsseldorf, Germany, who came to this country for the purpose of presenting his paper on Power Forging, with Special Reference to Steam-Hydraulic Forging Presses. Discussion was offered by J. I. Rogers and W. E. Hall.

## FRIDAY AFTERNOON

Two inspection trips were available for Friday afternoon and the parties formed proceeded, one to the works of the Carnegie Steel Company at Duquesne by special cars, and the other to the works of the Mesta Machine Company at West Homestead by special cars and train from the Union Depot. At the steel works opportunity was given to inspect every stage of the manufacture of steel, from the unloading of the ore to the shipping of the finished material. Notable features were the freezing process for drying air supplied to the blast furnaces, and blowing engines operated by blast furnace gas.

At the Mesta Machine Company's works the party saw in process of erection a large four-stage air compressor, a twin rolling mill engine of 20,000 horsepower, a large gas engine, and a motor-driven shear capable of cutting a bar of cold steel 7 inches square. In the foundry, gear molding machines were in operation, and a heat of vanadium steel was poured, while in the forge shop steam-hydraulic forging presses were seen in operation. After luncheon had been served, the party returned to Union Depot by special train.

### FRIDAY EVENING—SMOKER

The Spring Meeting was enjoyably concluded on Friday evening with a smoker and entertainment given to The American Society of Mechanical Engineers and guests by the Engineers Society of Western Pennsylvania, in the rooms of the Union Club, in the Frick Building. Brief speeches were made by E. M. Herr, Elmer K. Hiles, E. D. Meier, and Calvin W. Rice. George H. Neilson, of Pittsburg, delivered a very amusing address under the title, A Near History of Crucible Steel. Throughout the evening entertainment and refreshments were most generously furnished, and a spirit of good fellowship prevailed. This smoker formed a most pleasing climax to a very successful meeting.

The ladies were entertained throughout the day beginning with a trip through the parks and residential parts of the city in motor cars, after which the party inspected the works of the H. J. Heinz Company, where the officials entertained at luncheon. After leaving the works, the party motored to the Allegheny County Club at Sewickley, sixteen miles below Pittsburg on the Ohio River, where tea was served.

During the entire meeting the Ladies' Committee, Mrs. Chester B. Albree, Chairman, provided most hospitably for the pleasure of the visiting ladies, and in many other ways added greatly to the social features of the convention.

At the closing session on Friday morning, the following resolution was adopted by rising vote, in order to express to all concerned the appreciation of the visiting members for the elaborate preparations made for their convenience and pleasure by the local members, companies and institutions and for the cordial hospitality displayed on every side:

WHEREAS, The American Society of Mechanical Engineers, assembled in convention May 30 to June 2, 1911, at Pittsburg, Pa., has received a most cordial and spontaneous welcome from the members and friends of the Society in Pittsburg and vicinity; and has had the splendid coöperation and support of the local committee, through their tireless efforts on behalf of the Society, and their faultless preparation for the meeting, without which a convention of so marked a degree of excellence would have been impossible; and

WHEREAS, the visiting members and guests have been the recipients of the delightful entertainment bountifully provided, and have had the opportunity to view many of the industrial wonders and other notable attractions of this remarkable center;

BE IT RESOLVED: That on behalf of the Society and of the visiting members and guests, a vote of thanks be extended to all who have participated in these substantial evidences of friendship and good-will, with the assurance that such a formal resolution is but a poor and outward symbol of the deep sense of gratitude which each visitor personally feels; further, that the Secretary be instructed to extend the thanks and appreciation of the Society, by written letter, to the local Executive Committee, the Ladies' Committee, and the other local committees; to the Foundry and Machine Exhibition Company, the Universal Portland Cement Company, the Westinghouse Companies, the National Tube Company, the Mesta Machine Company, the Carnegie Steel Company, and other organizations which have opened wide their doors or provided entertainment; to the educational and art institutions and clubs of the city, which the guests have taken great pleasure in visiting; to the Engineers' Society of Western Pennsylvania for their hospitable entertainment; and to Dr. Barthold Gerdau, who came from abroad to present his important paper.

## MEETINGS OF THE SOCIETY

### PHILADELPHIA MEETING, JUNE 3

A meeting of the Society was held in Philadelphia on June 3, at which the subject of Fuel Testing, presented at the meeting in that city on April 22, was continued. S. B. Flagg read a paper on the work of the United States Fuel Testing Bureau, in which, in addition to outlining the work on fuel testing and the testing of furnaces for proper combustion of the fuels, he showed slides and explained the work of prevention of mine explosions and the training of rescue parties. The paper was discussed by Messrs. J. C. Parker, James Christie, J. E. Gibson, C. A. Blatchley, Schwaab, Ray and Kriesinger.

### ST. LOUIS MEETING, JUNE 7

Engineers of all branches of the profession, to the number of 220, assembled at dinner in the large dining room of the Mercantile

Club, St. Louis, on June 7, the arrangements for the occasion being in charge of the Engineers Club of St. Louis. At the conclusion of the dinner J. D. von Maur, President of the Engineers Club, explained, in his capacity of toastmaster, how the five societies, the American Society of Civil Engineers, the American Institute of Electrical Engineers, The American Society of Mechanical Engineers, the American Society of Engineering Contractors, and the Engineers Club, had got together and held a number of joint professional meetings, each under the auspices of one of these organizations, that all had found pleasure and profit in the discussions and that the social features had created better understandings and professional acquaintances which had generally ripened into friendship.

M. L. Holman, Past-President of The American Society of Mechanical Engineers and of the Engineers Club, was then introduced and told humorously of many personal reminiscences of early engineering in St. Louis, including the development of the water works and the building of the great Eads Bridge. In conclusion, he urged close association among all engineers.

E. D. Meier, President of The American Society of Mechanical Engineers, who followed Mr. Holman, congratulated the Engineers Club on its success in bringing engineers of all branches together. He explained how various societies were formed in the past in the belief that three or four great national bodies could divide the profession according to natural cleavage, and how it had now become apparent that perhaps a hundred or more branches of engineering must be recognized, although the professional needs of these could be satisfied by existing societies, delegating experts in each such branch to look after its interests, and possibly forming sections where the importance of the subject required it. This, he said, would at the same time make the administrative activities of the national body available for all these branches and recognize the advantages of social gatherings at conventions in familiarizing engineers with the work and capacity of others in the same or correlated lines, and would finally raise the profession in the social recognition of the American people to the high position to which it is entitled. He compared the scepticism of the community less than forty years ago regarding the St. Louis bridge with the readiness with which much greater and more hazardous works of engineering are today accepted as possible.

C. M. Woodward, Past-President of the Engineers Club and founder of the first manual training school of the country in St. Louis, followed with a happy speech, replete with personal reminiscences, expressing his rejoicing over the fact that whereas he had only taught engineering, many present who had graduated from his training had done things. He related also how he with his students rode on the first of the fourteen locomotives assigned to test the Eads Bridge and how the engineer was so agitated at the supposed danger of the trip that he reversed his engine at the signal to go ahead.

Col. Ed. Devoy followed with a humorous account of his own trepidation over hauling a three-and-a-half ton block of coal over the bridge to take part in the procession. He urged engineers to stand together and make their influence felt at the very inception of public works, thus preventing them from becoming the playthings of politicians who did not understand their merits.

The enthusiasm in the new-found sense of comradeship among engineers of all branches was proof that this get-together movement fills a genuine need and will spread country wide to the benefit of the profession. The plan of a simple dinner followed by a free discussion of the good of the order was so successful that it may be urgently commended to members of the Society in other engineering centers.

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## AN EFFORT TOWARD COÖPERATION

On June 15, the President of the Society, Colonel Meier, invited several members to a luncheon at the Machinery Club to meet Capt. A. M. Hunt, chairman of the Committee on Meetings of this Society in San Francisco, and prominent also in the work of other engineering societies. Those invited were A. C. Humphreys, Charles W. Baker, E. G. Spilsbury, W. M. McFarland, H. G. Stott and Calvin W. Rice.

A topic discussed was one which The American Society of Mechanical Engineers has been specially active in promoting, through meetings with other societies in different cities, that of the getting together of engineers in different fields for coöperation and the general advancement of the profession as a whole. Prominent among these efforts have been the meetings at Boston at one of which eight presidents and the representatives of many organizations were present and the recent meeting in St. Louis noticed elsewhere. The work of Captain Hunt in bringing together, as he has, engineers on the Pacific slope irrespective of their society affiliations, was most highly commended.

From the composition of the party called together for this occasion it is evident that each is representative of the spirit of coöperation through association with various engineering societies and the belief was expressed that definite plans which were discussed would serve as a means of promoting some general meetings to which the members of all engineering societies would be invited.

## STUDENT BRANCHES

### MISSOURI UNIVERSITY

The Missouri University Student Branch held the concluding meeting of its season on May 22, the Freshmen and Sophomore classes of the University being invited guests. Short talks on subjects of interest to the membership were given by Prof. H. W. Hibbard, Mem. Am. Soc. M. E., Prof. E. A. Fessenden, Jun. Am. Soc. M. E., O. N. Edgar, P. A. Tanner, H. W. Price, F. B. Thacher, F. T. Kennedy, and A. C. Edwards.

### PENNSYLVANIA STATE COLLEGE

At the meeting of the Pennsylvania State College Student Branch on May 19, the following officers were elected for the year 1911-1912: J. A. Kinney, president, R. M. Diehl, vice-president, H. S. Rodgers, secretary, and H. E. Davis, treasurer. An interesting lecture on Cleaning of Blast Furnace Gas was given by S. K. Varnes.

### SIBLEY COLLEGE

At the meeting of the Sibley College Student Branch held on April 26, Prof. C. F. Hirshfeld, Jun. Am. Soc. M. E., addressed the membership on Modern Tendencies in Gas Power Machinery.

The following officers were elected at the meeting of May 10: F. E. Yoakem, president, G. W. Curtiss, vice-president, L. B. Timmerman, recording secretary, S. D. Mills, treasurer. Certain changes in the constitution and by-laws of the organization were also considered and approved.

On May 13, L. R. Pomeroy, Mem. Am. Soc. M. E., gave an address upon Scientific Accounting, in which he emphasized the importance of the human element in applying the methods of scientific management.

LELAND STANFORD UNIVERSITY

The meeting of the Leland Stanford Mechanical Engineering Society on May 3 was devoted to the election of the following officers: C. H. Shattuck, president; A. G. Budge, vice-president, and C. W. Scholefield, secretary-treasurer. A number of applications were approved for membership.

UNIVERSITY OF CINCINNATI

At the regular monthly meeting of the Student Branch of the University of Cincinnati on May 26, the following officers were elected: C. J. Malone, president, C. W. Lytle, vice-president, Joseph Herman Schneider, secretary-treasurer. A paper on Molding and Foundry Practice was presented by C. W. Lytle and was discussed by the members.

UNIVERSITY OF ILLINOIS

The final meeting of the season was held by the University of Illinois Student Branch on May 12. A paper on a filing system used in a drafting room of a plumbing concern was read by A. F. Connard, and F. J. Schlink gave a talk on the filing system used in a drafting room of a construction and drainage company.

YALE UNIVERSITY

At a meeting of the Student Branch of Yale University held on May 3, a paper on Scientific Management, with special reference to the Piece Rate System, was presented by Frank B. Gilbreth, Mem. Am. Soc. M. E. F. M. Jones was elected president of the organization for the year 1911-1912.

# MEETING OF THE COUNCIL

**MAY 30**

A meeting of the Council was held on Tuesday, May 30, in the Hotel Schenley, Pittsburg, Pa. There were present, E. D. Meier, presiding, Charles Whiting Baker, George M. Brill, W. F. M. Goss, James Hartness, E. M. Herr, H. G. Reist, Jesse M. Smith, Worcester R. Warner, C. J. H. Woodbury, representing the Committee on Meetings, and the Secretary.

The Council received a delegation from Cleveland, Ohio, which presented an invitation from the Cleveland Engineering Society, the Cleveland Chamber of Commerce and the Cleveland Manufacturers Club, offering the City of Cleveland as the meeting place of the Society in the Spring of 1912.

The resignation of Alex. C. Humphreys as a member of the Executive Committee was received and accepted with regret. H. G. Reist was elected to fill this vacancy.

*Voted:* That advance copies of papers may be printed for local committees and professional sections without consideration by either the Committee on Meetings or the Publication Committee, when within the appropriation of the local committee or section, as the case may be.

*Voted:* That the following note appear on all copies of such papers: This paper is to be presented at a meeting of The American Society of Mechanical Engineers in ———————— on ———————— and is printed by the Committee in charge of that meeting under its authority.

*Voted:* To confirm the basis of affiliation between this Society and the Providence Association of Mechanical Engineers.

*Voted:* That the following Committee, nominated by the members of the Society in New Haven, E. S. Cooley, E. H. Lockwood, L. P. Breckenridge, F. L. Bigelow, H. B. Sargent, be appointed in charge of the meetings of the Society in New Haven for the remainder of the present calendar year.

*Voted:* To appropriate $75, subject to the approval of the Finance Committee, for the conduct of meetings in New Haven for the balance of the fiscal year.

*Voted:* To approve the recommendation of the Publication and Finance Committees for the following appropriations:

| | |
|---|---|
| Distribution of Transactions, Vol. 30 | $209.00 |
| Distribution of Vol. 30 and Vol. 31 to members joining the Society December 1908–1909 | 316.83 |
| For completion of Transactions, Vol. 31 | 500.00 |
| For text section of The Journal | 1400.00 |
| For advertising section of The Journal | 3900.00 |
| | $6325.83 |

*Voted:* That the policy of the Committee on Meetings be heartily commended in its provision of sub-committees to deal with special industries or departments of engineering. Such sub-committees appear to be an excellent method by which the Society can give proper attention to departments of engineering not represented by organized groups or sections of the Society. When, however, any group of members of the Society, interested in a special branch of engineering, desires to organize as a professional section under the Rules, the sub-committee dealing with said branch should be discontinued or merged into such section.

*Voted:* To approve the recommendation of the Committee on Constitution and By-Laws, presented by Jesse M. Smith, temporary Chairman.

*Voted:* To appoint H. G. Stott, upon the recommendation of the Committee on Constitution and By-Laws, to fill the vacancy on that Committee caused by the death of Charles Wallace Hunt.

The following proposed amendment to By-Law 20 was read:

The annual subscription price of The Journal shall be one dollar to Honorary Members, Life Members, in the various grades, Members, Associates, Juniors and Student-Affiliates; two dollars to Affiliates of the Society paying dues, members of affiliated societies who do not pay dues, members of the American Institute of Electrical Engineers, members of the American Institute of Mining Engineers, members of the American Society of Civil Engineers, libraries and colleges; five dollars to non-members not included in the above.

*Voted:* To amend Rule 24 to read as follows:

Engineers and others not members of the American Society, but desiring to participate in the meeting of the section, may enroll themselves as affiliates as heretofore provided, with the approval of the Executive Committee of the section. Such affiliates shall have the privilege of presenting papers and taking part in the discussions. They shall pay three dollars per annum, which shall be due and payable in advance, on October 1, of each year of their enrollment, and shall thereby be entitled to receive the regular issues of The Journal for a period covered by their dues.

*Voted:* To approve the following new rule, to be inserted between the present Rules 27 and 28:

The dues of a student to secure affiliation with the Society shall be one dollar per annum, which shall be due in advance of January 1st, of each year.

*Voted:* To amend Rule 29 to read:

The American Society of Mechanical Engineers will furnish monthly issues of The Journal to all members of affiliated organizations who are not members of The American Society of Mechanical Engineers upon the payment by each of one dollar per year, such payment being due in advance on January 1 of each year. The American Society of Mechanical Engineers will furnish gratis to each affiliated body, extra copies of advance papers for use at its meetings, the number furnished to be agreed upon at the discretion of the Secretary.

*Voted:* To accept the resignations of R. S. Woodward, E. P. Jump and R. E. Lee.

*Voted:* To appoint William Kent, W. B. Snow, M. L. Cooke and J. R. Bibbins a committee, with power to increase their number, on the subject of the standardization of catalogues, to report to the Council at a later date.

*Voted:* To refer to the Tellers of Election of Officers a letter received from George A. Orrok, in regard to improving the form of ballot for officers, with the request that they prepare a report to the Council at a later meeting.

*Voted:* To confirm the appointment by the President of Charles R. Richards as Honorary Vice-President to represent the Society at the National Irrigation Congress in Chicago, December 5–9, 1911.

*Voted:* To appoint H. G. Reist on the Council of the American Association for the Advancement of Science.

*Voted:* To appoint, on the recommendation of the Executive Committee, W. F. M. Goss, on the John Fritz Medal Board, to fill the vacancy caused by the death of Charles Wallace Hunt.

*Voted:* To appoint, on the recommendation of the Executive Committee, F. R. Hutton, on the Committee of Society History, to fill the vacancy caused by the death of Charles Wallace Hunt.

The minutes of the meeting of April 10 were approved as written.

The meeting adjourned to June 1.

JUNE 1

A meeting of the Council was held on June 1, on board the boat "Sunshine," during the Pittsburg meeting. There were present E. D. Meier, President, Charles Whiting Baker, E. M. Herr, H. G. Reist, W. F. M. Goss, George M. Brill, Jesse M. Smith, and the Secretary.

*Voted*: That the Spring Meeting of 1912 be held in Cleveland.

*Voted*: That the matter of second-class rates of postage be referred to the Executive Committee with power.

*Voted*: To approve the formation of a Student Branch at Lehigh University.

# NECROLOGY

## MORRIS LANDA ABRAHAMS

Morris Landa Abrahams died on March 28, 1911, at San Antonio, Texas. Mr. Abrahams was born on March 21, 1885, at Austin, Texas, and after a preparatory education at the Hogsett Military Academy, Danville, Ky., and the Agricultural and Mechanical College of Texas, entered Cornell University, from which he was graduated in 1905 with the degree of M. E. Previous to his matriculation at Cornell he had acquired practical experience with the Deming Company, Salem, Ohio, in their drafting room, and with the Dean Brothers Steam Pump Works, Indianapolis, Ind., as assistant to the foreman of the testing floor. In 1907 he entered the employ of Walter S. Timmis, consulting engineer, New York City, where he engaged in power plant design, printing plant layouts, the development of a patent elevator safety device, heating and ventilation, and other similar phases of mechanical engineering. Later in the same year he left Mr. Timmis to become a member of the engineering force of the Victor Talking Machine Company in Camden, N. J. In 1910 he entered the service of the Government as assistant chief inspector attached to the Canal Commission, with headquarters at Washington, and retained this position until shortly before his death, when illness obliged him to resign his duties.

## PAUL RAYMOND BROOKS

Paul Raymond Brooks was born in Chicago, Ill., August 17, 1877, and was educated at the Chicago Manual Training School and the Massachusetts Institute of Technology, from which he was graduated with the degree of B.S. in 1900. Following his graduation he entered the employ of the Chicago, Burlington & Quincy Railroad, where he began in the locomotive shop as an apprentice and worked his way through successive promotions to the position of acting foreman of the Burlington roundhouse of the company. In 1904 he became Western mechanical editor for the McGraw Publishing Company, New York. The following year he became a sales engineer for the Railway Appliances Company and the Otto Gas Engine Works, and in 1908 general sales manager for the Machine Sales Company, Peabody, Mass. In 1909 he associated himself with the Union Bag & Paper Company, Sandy Hill, N. Y., as mechanical engineer, and at the time of his death on March 11, 1911, was president and superintendent of the Del Monte Irrigation Company, Texas.

## JOHN A. CALDWELL

John A. Caldwell was born August 12, 1849, at Johnstone, Scotland, and was educated at the Glasgow School of Design and Mechanical Engineering, from which he was graduated in 1867. He served his apprenticeship as a pattern maker with the firm of Tweedale & Robinson, Johnstone, and as draftsman with Lawson & Son, Glasgow, from 1863 to 1868. In 1870 he came to the United States and was employed by Mackintosh, Hemphill & Company of Pittsburg, for whom he designed large rolling mills and blast engines, and had entire charge of relining the Schoenberger blast furnaces and rebuilding the hot blasts at Pittsburg, as well as the erection of two new blast furnaces at Port Washington, Ohio. He subsequently designed all the locomotives built by the National Locomotive Works, Connellsville, Pa., the Alice stamp mill and the Moulton mill at Butte, Mont., the elevator service for Z. C. M. I. at Salt Lake City, Utah, the stamp mill at Parrall, Mexico, the numerous filter plants for the Hyatt Pure Water Company, including the installation of the city plant at Oakland, Cal., and was in charge of the new engine and boiler installations for the H. W. Johns Manufacturing Company, Brooklyn, N. Y., contracted for and superintended the erection of numerous blower plants, water pumps and pumping stations for the P. H. & F. M. Roots Company, including the pumping station at Little Falls, N. J., and contracted for, designed and superintended the erection of numerous water-tube boiler plants, including piping, in conjunction with James Beggs & Company. In 1899 Mr. Caldwell became business manager for the American Stoker Company, New York, and in 1901 opened an office of his own in the same city, making a specialty of boiler room economies, particularly stokers and $CO_2$ recorders. He died on April 7, 1911.

## CHARLES J. LARSON

Charles J. Larson was born on March 2, 1872, at River Falls, Wis. His early education was obtained at the State Normal School, Morehead, Minn., and at Macalester College, St. Paul, Minn., and his technical training at the Rose Polytechnic Institute, Terre Haute, Ind., from which he was graduated in 1900 with the degree of B. S., and from which he also received the degree of M.E. in 1909. In 1900 he entered the employ of the Allis-Chalmers Company at Milwaukee, as erecting engineer, and from 1905 to 1907 had supervision of the installation, operation and testing of machinery furnished by this company in the Eastern territory. Among the prominent engineering works which he superintended in this capacity were the Washington drainage system and water works, the Boston sewerage system, the Boston elevated railway, the New York subway engines, the New York high-pressure service, and the Midvale Steel Company's plant and machinery for the Connecticut Railway Company. In 1904 he installed and had charge of the operation of the 6000-h.p. Allis-Chalmers-Bullock exhibit at the St. Louis Exhibition.

He was forced to resign his work in 1908, because of ill-health and accepted a position as chief engineer of the Union Electric Company, Dubuque, Iowa, which he held at the time of his death on April 6, 1911.

Mr. Larson was a member of the American Institute of Electrical Engineers and the National Electric Light Association, and had made many valuable contributions to technical journals.

## EDWARD B. YARYAN

Edward B. Yaryan who was born in Toledo, Ohio on April 10, 1881, died in that city on April 28, 1911. Mr. Yaryan began his professional career in 1896 with the Toledo Heating and Lighting Company as a steam engineer. From 1900–1902 he was manager of a central station at Evanston, Ill., and was at the same time employed as superintendent of construction for the Oak Park Yaryan Company of Oak Park, Ill. The following year he re-entered the service of the Toledo Heating and Lighting Company as its superintendent, leaving there in 1906 to become vice-president of the Maclaren & Sprague Lumber Company of Toledo. In 1908–1909 he became superintendent of the Yaryan Process Company of the same city, and in the following year of the Yaryan Naval Stores Company, in the service of which latter firm he later went to Gulfport, Miss., where he remained until shortly before his death.

# RECIPROCATING BLAST-FURNACE BLOWING ENGINES

By W. Trinks

ABSTRACT OF PAPER

The causes for the gradual change and progress in reciprocating blowing-engine practice are set forth. An elementary study of valve motion is given and the valve gears of present standard American practice are described. It is shown that these engines are very successful at the speeds for which they were designed, but that at higher speeds they cannot be used successfully, so that new designs had to be brought out in order to meet the pressing demand for higher speeds and lower first cost. Two American designs are described. It is shown that these valve systems, although much superior to the so-called standard gears when used for high speeds, have not yet broken with the idea that smallness of clearance is required for economy, whereas German builders have demonstrated that by the use of multi-ported plate valves large valve areas and economy at high speed operation can be obtained in spite of large clearance. The foremost European types of plate valves are described and the results of tests are given.

It is pointed out that the bringing up of the piston speed of the blowing engine to the standard piston speed of the power gas engine or the power steam engine reduces the first cost of the reciprocating blower and that the combination of the high-speed blast-furnace gas engine with a high speed blower constitutes the most economical method for the production of furnace blast.

# RECIPROCATING BLAST-FURNACE BLOWING ENGINES

By W. Trinks, Pittsburg, Pa.
Member of the Society

In the last 20 years American blowing-engine practice has assumed rather set forms. The growing size of furnaces has increased blast pressures to a point where the heat of compression has made the use of felt, canvas, or leather valves impossible. Certain forms of valves and engine types have been developed which have dominated the market for a number of years, and their operation furnishes today the blast for more than 90 per cent of the pig-iron capacity of the United States. But a few years ago the contentedness of American builders and users of blowing engines was rudely shattered by a double European invasion: the gas engine and the turbo-blower.

2 The gas engine, although much more economical of fuel than the steam engine, is more expensive with regard to first cost. To reduce the cost per horsepower, high piston speed must be employed; thus the piston speed has been increased from the 300 ft. per min., heretofore considered standard in steam-driven blowers, to 600 ft. per min. in modern American gas-driven blowers. In Europe reciprocating blowers run at piston speeds of 750 ft. per min.; the gas engine for generation of power runs today at piston speeds very close to 1000 ft. per min.

3 The turbo-blower appeared on the market a few years ago first on the European continent, where its progress was completely checked by the price of coal. The steam turbine could not compete with the low fuel consumption of the gas engine. Recently the turbo-blower has also been introduced in this country. Here the lower price of coal and the higher price of operating labor will favor its introduction in a few districts, but the old law that progress in one line of business invariably begets progress in a competing line is true also in this case, and thus we find builders of reciprocating

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engines busy making improvements and raising the standard of their product.

4 The understanding of the reasons why the standard types of American blowing engines are so successful at medium speeds and what their shortcomings are at high speeds will be much facilitated by a short study of valve motion and of throttling losses through valves.

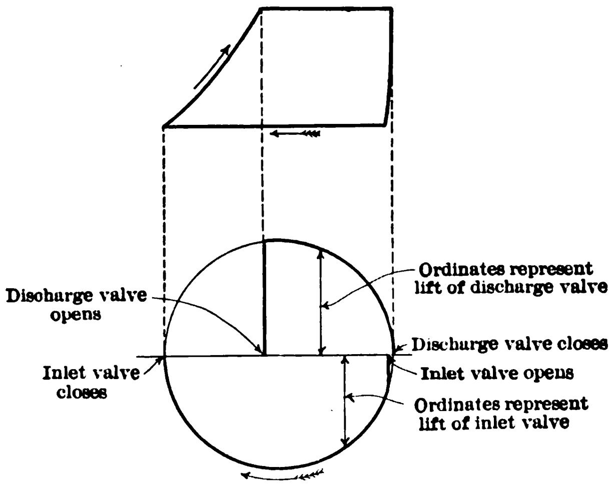



FIG. 1 IDEAL VALVE MOTION OF PUMPS OR COMPRESSORS ON DISPLACEMENT BASIS

5 It is proved below that high velocity through valves is harmful; the tendency is therefore to keep the velocity at a fairly constant low value; and since the piston of an engine has very nearly harmonic motion, it follows that the valve should also have harmonic motion, if a constant and small pressure drop is desired. On a displacement basis harmonic motion becomes a circle. Fig. 1 shows the valve lift on a displacement basis. The inlet valve is open practically throughout the stroke; the outlet valve should pop open near the middle of the stroke and close at the end.

6 Fig. 2 shows this same ideal diagram on a time basis. It will be noted that the curves intersect the base line at an angle, indicating that if these ideal motion curves are realized the valve will strike a blow in seating. The velocity of striking depends upon the lift of the valve and upon the time of one revolution, which

means that high-lift valves, while successful for low rotative speeds, become impractical for high rotative speeds.

7 Consciously or unconsciously, engineers have striven to design valves and valve gears for blowing engines so that the above valve motion curves are approximated. Two circumstances interfere with attaining the ideal; one is the quantity of air under a lift valve, which lessens the discharge through the valve during its lift and increases the discharge during the closing period; the other is the mass of the valve which has baffled designing engineers quite

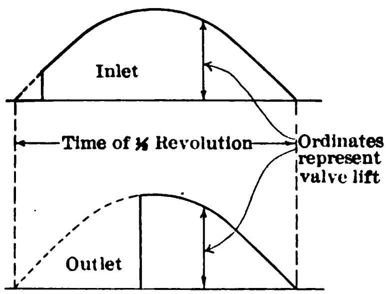



FIG. 2 IDEAL VALVE MOTION OF PUMPS OR COMPRESSORS ON TIME BASIS

often. The author published 12 years ago, when his experience was mainly theoretical, formulae for designing valves and springs in such a way that the pressure difference on the two sides of the valve and the impact of the air flowing through the valve would be nicely balanced by the spring and that the ideal valve lift curve could be attained. He was very much surprised by valve vibrations, when the formulae were put to a test. As a pendulum swings about its position of equilibrium, so a valve will vibrate about its ever changing position of equilibrium, if it is designed to float between the air pressure and current on one side and the spring on the other side. A typical (diagrammatic) valve lift curve is shown in Fig. 3. A diagrammatic or made-up curve was preferred to a curve taken from a particular engine, because an endless variety of vibrations is possible depending upon the mass and shape of the valve and upon the spring loading. It should be understood that the fluttering of the valve occurs to this extent only if no means have been provided for damping it, and that the heavier the valve the more energy the damping consumes. In Fig. 3 the valve is shown to close late.

Practically all automatic lift valves close late, depending upon rotative speed of engine, lift of valve and spring loading. The lower the rotative speed and the valve lift and the greater the spring load closing the valve, the nearer the valve is to the seat in the dead center position of the crank. Tests and calculations show that in ordinary American blowing-engine practice the valves close so near the dead center that for all practical purposes they may be considered as closing "on time" and without the injurious effects of late closing, namely, slipping back of air and hammering of valve.

8 The behavior of the outlet valves is similar to that of the inlet valve with two exceptions. First, the valve has to open when the piston moves fastest; secondly, the pressure difference on both sides of the valve increases rapidly at the dead center. In Fig. 4 the

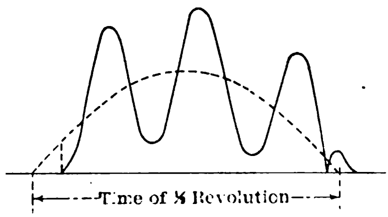



FIG. 3 ACTUAL MOTION OF HEAVY, NON-CUSHIONED INLET VALVES (TIME BASIS)

ideal and the actual valve-lift curves are shown in connection with an indicator card on a displacement basis. The slower the rotative speed of the engine, the lighter the valve and the smaller its lift, the more perfect is the approximation to the ideal lift curve. High rotative speeds, heavy valves and small areas uncovered by the valve for a given lift cause the pressure in the cylinder to rise considerably over that existing in the blast space and store up considerable amounts of kinetic energy in the valve which must be taken care of by a cushioning device; otherwise fluttering or hammering results. As already stated, the pressure drops rapidly under the valve immediately after the crank has passed the dead center, and particular care must be taken to have the valve close promptly in order to avoid hammering.

9 Throttling loss through valves involves two factors: loss of velocity head and surface friction. The vast majority of valves are so designed that surface friction, such as occurs in long pipes or ducts, is practically absent. For this reason, losses due to velocity

head only will be investigated here. Fig. 5 gives the throttling loss for various piston speeds and for various ratios of valve area to piston area. In this chart, valve area does not mean the so-called free valve area which is a rather imaginary or conventional quantity, but it means the area actually offered to the air-flow at the narrowest place of the valve. It is assumed that the valve has harmonic motion and that the coefficient of discharge is 70 per cent. For a number of valves this latter figure was found to agree most closely with tests.

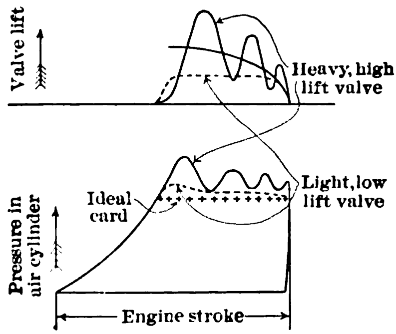
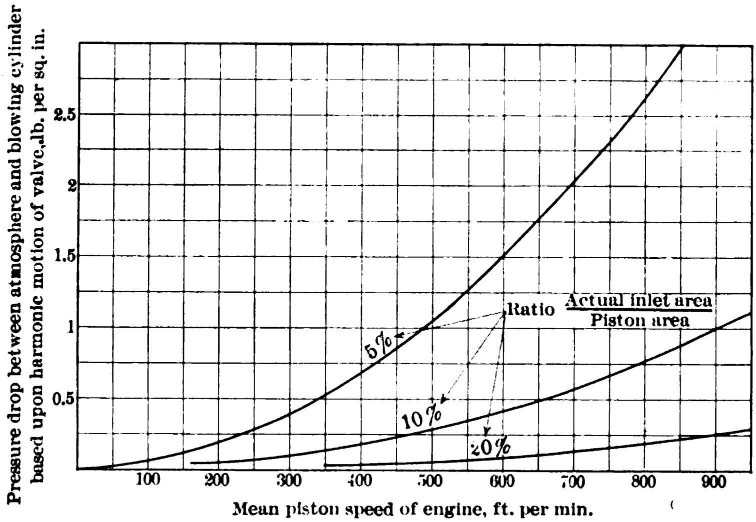



FIG. 4 ACTUAL MOTION OF OUTLET VALVES (DISPLACEMENT BASIS)

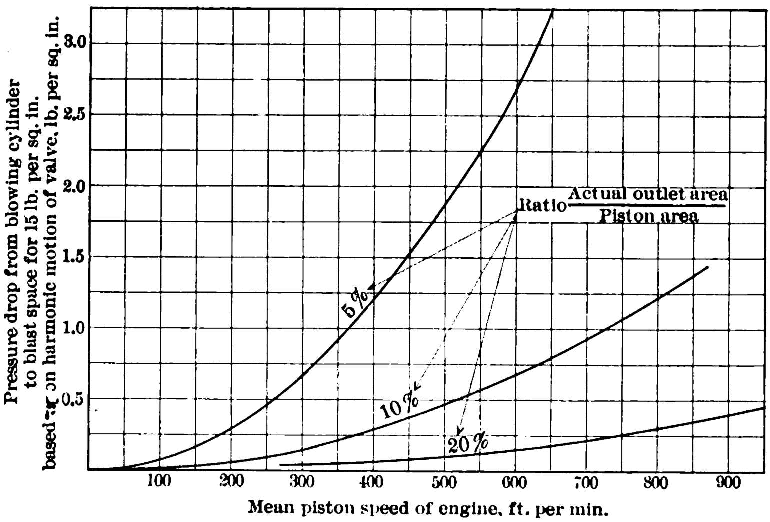
10 It will be observed that for a piston speed of 300 ft. per min., which up to a few years ago was standard in this country, and for inlet areas of 12 per cent, outlet areas of 9 per cent, the pressure drop due to throttling is a negligible quantity compared with the mean effective pressure (say 11 lb. per sq. in.) of the air card.

11 With a stroke of 60 in., so common for blowing engines, a piston speed of 300 ft. per min. means 30 r.p.m. At this low rotative speed the spring loading required to close the valves on time is so small that the inlet and outlet areas of 12 and 9 per cent can be realized.

12 Further penetration into theory would be out of place here. A better idea of the evolution of the modern blast-furnace blowing engine may be gained by the study of standard types. Fig. 6 illustrates a design which for the last 15 years has been very popular in the United States. The inlet valve is mechanically operated throughout and is a balanced piston valve. Mechanical operation of valves has been practised for over 20 years and avoids many of the troubles incidental to an improperly designed automatic valve. No fluttering




(a) INLET VALVES




(b) DISCHARGE VALVES

FIG. 5 PRESSURE LOSS IN BLOWING-ENGINE VALVES DUE TO VELOCITY HEAD or chattering can occur, a full port opening may be obtained and the valve may be made to open and close even more rapidly than is required by the ideal sine curve. The breaking of a mechanically operated slide valve is also highly improbable and great reliability therefore results. The outlet valve is a cup, opening automatically by air pressure and closing by mechanical means. The cup cushions

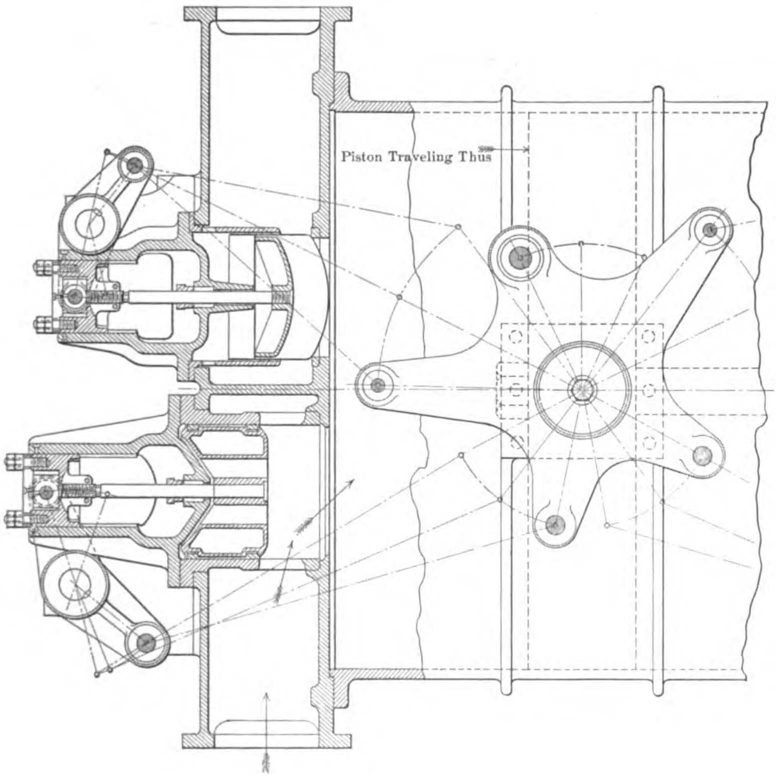



FIG. 6 VALVE GEAR BUILT BY ALLIS COMPANY

without springs against the movable plug, so that fluttering or chattering is impossible; it is fairly light and at rated speed opens with small throttling loss. If the valve gear is properly adjusted, the outlet valve closes at the right time, so that hammering, due to late closing, cannot occur. The number of valves to be looked after is small because a few large, light-lift valves are employed, usually two inlet valves and two or three outlet valves. The valve gear pins are made so large that very little wear can occur. This precaution keeps the valve gear in correct adjustment.

13 The principles underlying this design are very sound, and its success is well deserved. With engines of 60-in. stroke it is at its best with speeds between 30 and 40 r.p.m. The builders do not recommend it for speeds exceeding 50 r.p.m. At that speed the pressure in the cylinder at the end of the suction stroke is ½ lb. per sq. in. below that of the atmosphere.

14 A very similar valve gear is illustrated in Fig. 7. Here the inlet valve is double-ported for the purpose of quick opening and closing. The outlet valve cushions in opening against a station-

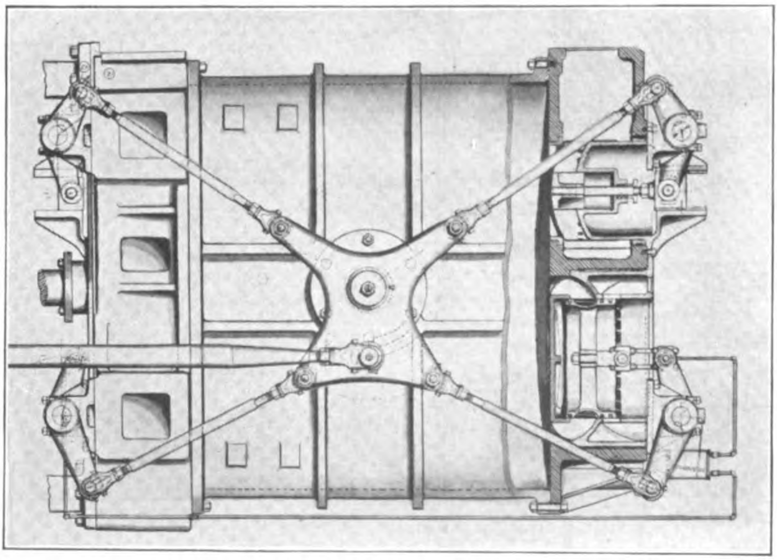


FIG. 7 VALVE GEAR BUILT BY WM. TOD COMPANY

ary plunger and is mechanically closed by a central pusher. In design it is similar to Fig. 6.

15 The fact that two valve gears of such close resemblance, and built by competing firms, could have been patented independently indicates that the valve gear must have good features. It would also seem probable that it was originated in one place and copied in another. As a matter of fact, the outlet valve originated in one concern, the inlet valve in another, and by mutual borrowing two good valve gears were produced.

16 These two valve gears as well as others of standard American design employ mechanically operated, or positively driven, inlet valves. As long as the clearance volume of the engine is small, mechanical operation of the inlet valve is scientifically correct, because the opening and closing points of the valve (Fig. 8) remain practically fixed in spite of variations of blast pressure. Matters are quite different with the outlet valve. Its correct opening point varies with the blast pressure and losses occur, as indicated in Fig. 8, if the valve opens at a fixed point and if the blast pressure differs from the one for which the engine was designed. Julian Kennedy, of Pittsburg, reasoned, however, that the gain in reliability by the use of mechanically operated outlet valves would easily offset these

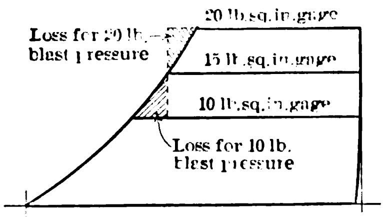



Fig. 8 Loss caused by Mechanically Operated Outlet Valves

losses and that the "work on the engine, due to advance opening of the valve, is probably not in excess of the work required in the case of a poppet valve due to the crowding of the pressure above the receiver pressure due to the opening of the valve." Fig. 9 shows his design and Fig. 10 indicator cards taken from an engine of this type. It will be noted that inlet and outlet valves are balanced piston valves. The piston which is not shown in Fig. 9 is scalloped out to fit around the valves with a view to reducing clearance volume. The outlet valve opens when a pressure of 7½ lb. has been reached in the cylinder. From that point to the reaching of the blast pressure (Fig. 10) the indicator card is a combination of compression and air discharge from the receiver back into the cylinder. An inspection of the indicator card with regard to smallness of lost work shows that Mr. Kennedy is right. The engines built on this principle are outwardly quite successful, and no repairs have been necessary on engines now in operation for over seven years.

17 It is somewhat surprising that a valve gear which positively opens large areas, avoids valve fluttering and prevents slip by timely

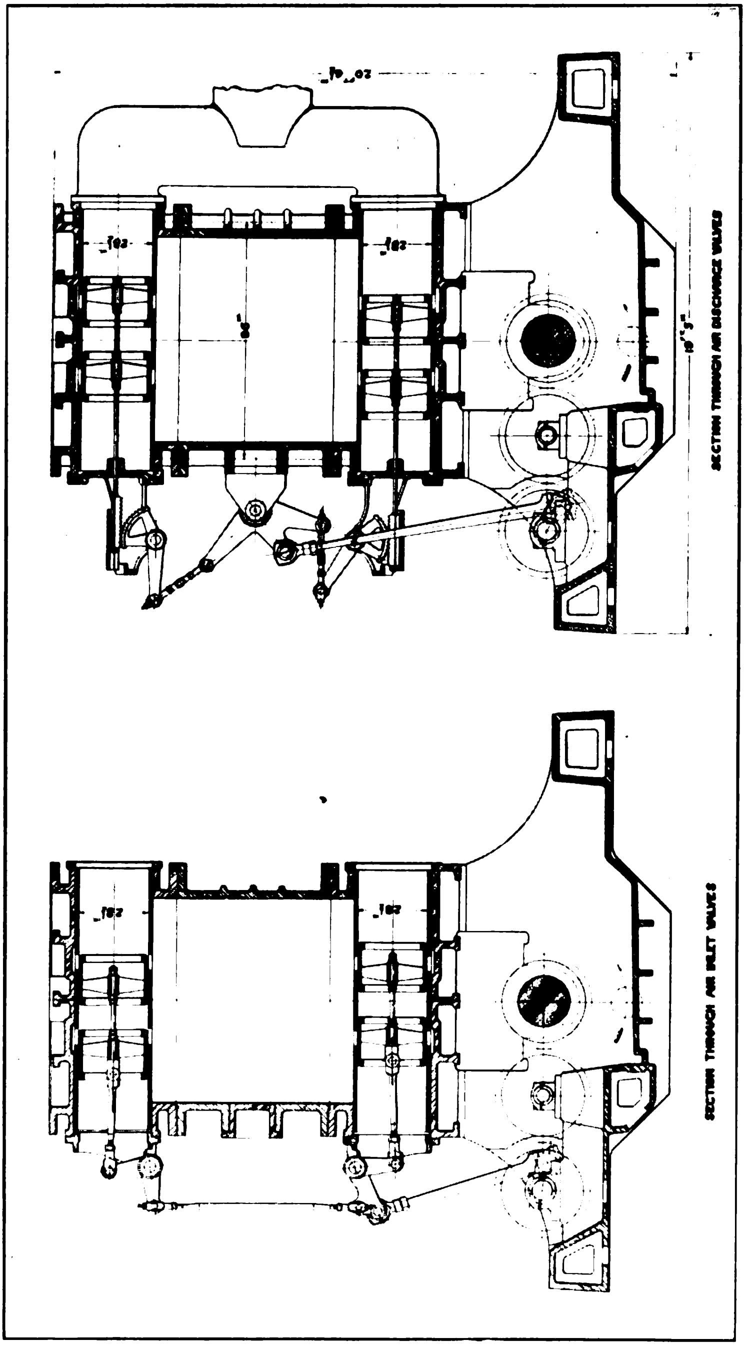



FIG. 9 CYLINDER WITH MECHANICALLY OPERATED INLET AND OUTLET VALVES (DESIGN OF JULIAN KENNEDY)

closing of valves should have been limited to less than two dozen engines. The author believes that the following reasons may have contributed in preventing a more general adoption of the system: (*a*) the large number of pins, rods and levers create the impression of complication; (*b*) large relief valves must be provided to prevent wrecking of the engine in case of accident to the valve gear; and (*c*) the slower the speed of the engine, the greater the work required per stroke due to the pre-opening of the outlet valve. Below a certain speed, if the engine is run with wide-open throttle on the governor, a peculiar tendency to hunt is the result.

18 Among the means employed to prevent fluttering of lift valves the dash pot has always played a prominent part. Fig. 11 shows a typical outlet valve in connection with a dash pot or cushioning chamber. Regulating valves or pet cocks are placed above

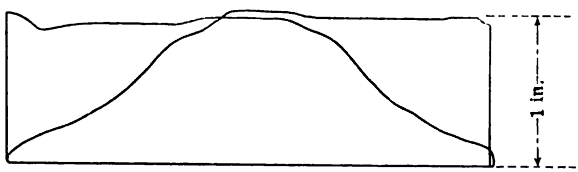



Fig. 10 Indicator Card taken from Engine shown in Fig. 9

and below the cushioning piston to provide for any desired or necessary degree of sluggishness. This type of valve has been used by several engine builders.

19 Fig. 12 shows a design employing the outlet valve described in Par. 18. As usual the inlet valve is mechanically operated. It is of the rocking valve type and is so arranged that clearance volume is kept down to a small value. The power required for operating the inlet valve is quite small, because the latter moves very little when it is unbalanced. When this type of valve was first used by the present builders about ten years ago, the author expressed the opinion that the valves would be very short lived, owing to wear by the dust laden atmosphere of furnace plants. Actual experience, however, has proved that these valves do very well and that the wear is small. Free inlet areas amounting to 11½ per cent of the piston area can easily be obtained by this valve and a greater per cent be secured by a slight increase in the clearance volume. The area through the

holes under the outlet valve discs is 16½ per cent of the piston area. To utilize this area to the fullest extent the outlet valves would have to lift 3½ in. For reasons which will be explained, a lift of this size is impractical, except for low rotative speeds, when it is of course not needed, so that in practice a lift of only 2¼ in. is used, cutting the available outlet area down to 11 per cent of the piston area. A large number of blowing engines with this valve gear are in successful operation both in the United States and in Canada.

20 What may be termed the most original of all blowing-engine valve gears is shown in Fig. 13. Inlet and outlet valves are of the gridiron type of 1⅞ in. stroke. The inlet is controlled by a cam

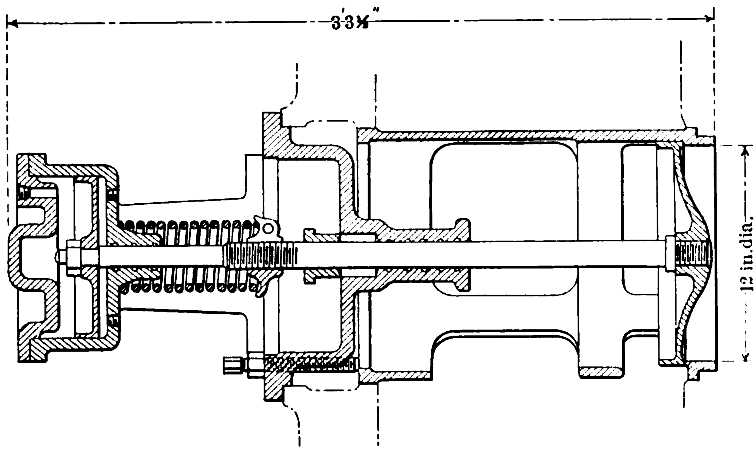



Fig. 11 Automatic Discharge Valve with Dash Pot

acting in pair closure and the outlet valve is pulled open by the piston of an actuating cylinder. One side of the piston is open to atmosphere, the other side to the blowing cylinder. As compression proceeds in the latter, the friction holding the valve in position becomes less, and the force tending to displace it grows. The actuating cylinder is so proportioned that for a given speed of engine, for a given blast pressure and for a given method of lubrication, the valve opens at the correct instant. The kinetic energy of the moving valve is dissipated in a cam-operated dash pot which closes the valve at the dead center of the engine.

21 Fluttering of valves is most successfully avoided, large areas for inlet (14 per cent of piston area) and for outlet (11 per cent) can

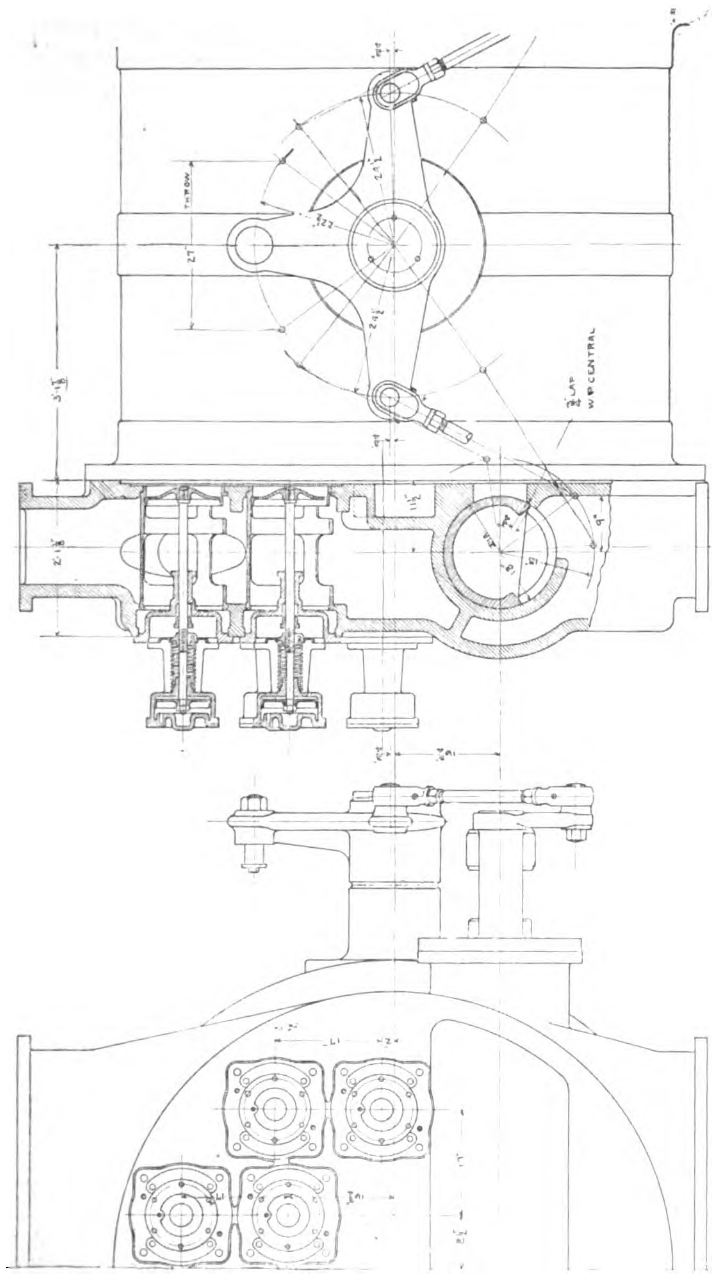


Fig. 12. Original Mesta Valve Gear

be obtained, and the power requirements are small. Ten and twelve years ago this type of valve gear (Fig. 15) was very popular in the United States and several engines of this type have been built in England and Belgium, but comparatively few have been constructed in recent years. It is not easy to determine the reason for the rise and fall of popularity in blowing-engine valve gears, but the following

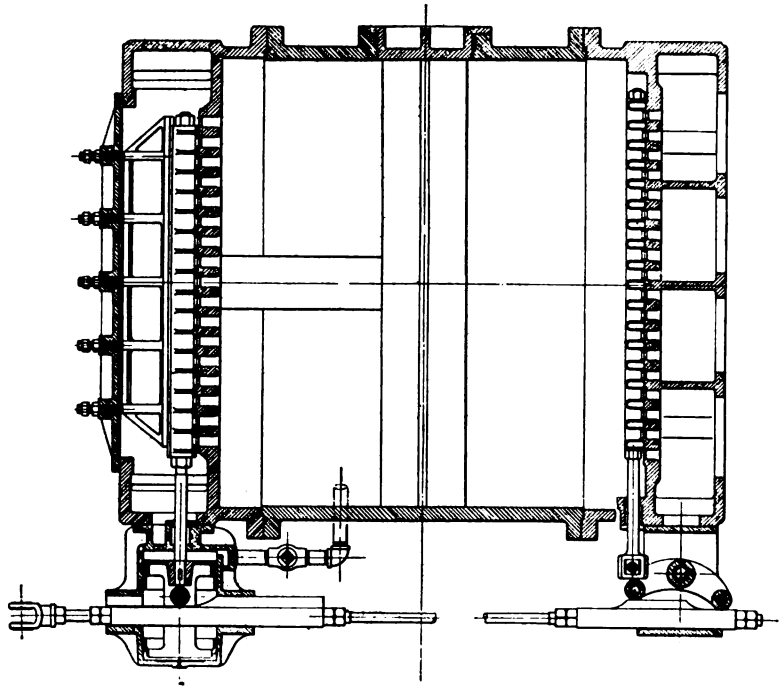


FIG. 13a SECTION THROUGH THE SOUTHWARK VALVE GEAR

statements may throw light upon the subject. In several furnace plants the wear of the gridiron valves caused leakage losses so that replaning of the valve seats became necessary.[1]

The air cylinder needs large relief valves to prevent injury to the engine in case of accident to the valve gear. Owing to the fact that at slow speeds the outlet valve opens much too early, more work is done per stroke at low speeds than at high speeds, even more than that done in the design of Fig. 9, and serious hunting occurs, when the engine is run on the governor with throttle wide open.

[1] Since this paper was read the author has been advised by the builders that in the engines in question aluminum valves were used which imbedded dust and grit and ground out the valve seat. Where cast iron valves are used, the wear is considerably smaller.

22 Every one of the valve gears so far described gives most satisfactory results at a piston speed of about 300 ft. per min. In Par. 2 the fact has been mentioned that the insistent demand for lower first costs requires higher piston speeds, not only temporarily in emergency cases, but continuously. Naturally, the experiment of running the standard types of valve gears at higher speeds was tried. Comparatively little trouble was experienced with the mechanically operated inlet valves, except that in some of the designs the throttling loss is much greater than might be expected from Fig. 5. This is due to the passing of the air around corners in the valves, while it is flowing at high speed (see Fig. 6 and Fig. 7). Since it is easy to observe the inlet throttling loss on an indicator card by drawing the atmospheric line, it attracted attention and was probably

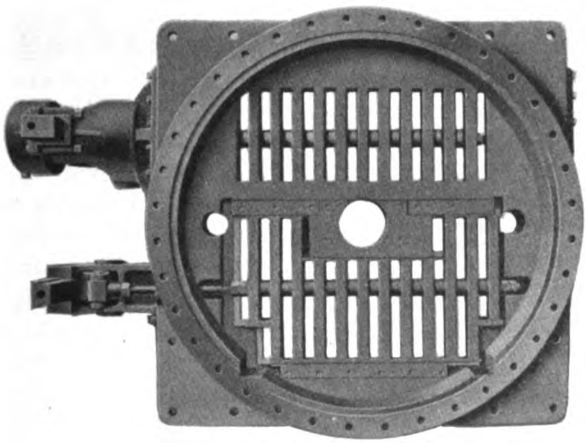


FIG. 13b VIEW OF SOUTHWARK CYLINDER HEAD

given undue prominence. Phrases such as "small volumetric efficiency," and "inability to fill the cylinder" were often heard. The much greater, but invisible, loss of volumetric efficiency, due to heat interchange between air and cylinder walls, was hardly ever mentioned in this connection.

23 Thus the "standard" valve gears gave at 600 ft. per min. throttling losses ranging from 0.4 to 1 lb. per sq. in., and engineers were trying to increase inlet valve areas up to 20 per cent or more. At the discharge end serious troubles occurred with increase of speed. In the designs of Fig. 6 and Fig. 7 rapid wear of the valve seat and hammering of the valves occur. Whether this is due to a throwing of the valve against its seat by the plunger or to other causes is not certain.

24 In the design shown in Fig. 12, quietness of operation can always be enforced, even at the highest speeds, but the spring loading on the valve must be increased and its lift in the dash pot must be reduced. Considerable throttling loss is then encountered. All designs using large, heavy, high-lift valves experience in common an excessive hump on the card at the time of the opening of the discharge valve, because it takes too long to provide the necessary area for discharge. The type shown in Fig. 13 is free from this evil provided very large actuating cylinders are used, but their size only accentuates the trouble in regulation mentioned above.

25 If the American standard valve gears are used for 600 ft. per min. piston speed or above, inlet throttling losses of 3 to 6 per cent of the ideal blowing work occur, and outlet throttling losses of 7 to 12 per cent of the ideal blowing work occur. Besides, power for mechanical operation of valves increases, and other troubles of wear, breakage, or regulation appear depending upon the valve gear.

26 One of the first men to judge the situation correctly was E. E. Slick of Pittsburg. He realized that large areas are necessary and that the periphery of the cylinder may be used for obtaining area, if the cylinder head does not suffice. Attempts to use the periphery are old, but all of them introduced additional clearance volume. The design of Mr. Slick is free from this fault. Figs. 14 and 15 illustrate Mr. Slick's engine as built by two different firms. The cylinder proper or tub is made movable and serves as a mechanically operated inlet valve. Unobstructed inlet areas of 18 to 20 per cent are easily obtainable and practically without clearance space. The outlet valves in Fig. 14 are a modified form of the type shown in Fig. 6 except that the number of valves has been doubled. The outlet valves of Fig. 15 are also an invention of Mr. Slick. They are flexible plates and open against a curved guard. Here, too, large valve areas can be obtained and what is very important, they can be obtained with small valve lift.

27 For piston speeds up to 600 ft. per min. and for rotative speeds up to 65 r.p.m., the Slick tub has been very successful. The design has been severely criticized as "wagging the dog and holding the tail still" and the author confesses that he felt the same way when he saw the first Slick compressor more than ten years ago at the Edgar Thompson Steel Works, but the ingenuity of the design is forcibly impressed upon anybody who attempts to produce the same combination of large areas and small clearance space in some other way. If 65 r.p.m. are exceeded with this type. trouble begins. The

inertia forces of the heavy cylinder are hard to take care of and heat the eccentric which moves the cylinder.

28 In the design of Fig. 14, wearing of valves and seats and hammering of the valves occur. In the design of Fig. 15, the valves break. They are not protected against lateral wind currents which

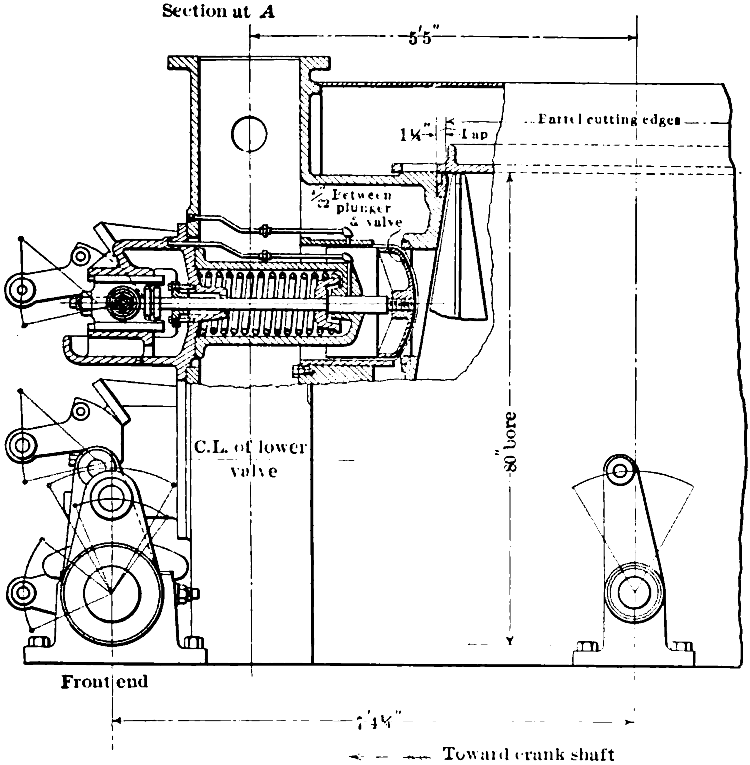



FIG. 14 BLOWING TUB WITH MOVABLE CYLINDER (SLICK DESIGN) BUILT BY ALLIS COMPANY

exert a tearing action; furthermore the valves close late, and therefore with a slap, because no closing spring is provided beyond the elasticity of the valve plate itself.[1]

29 Another engineer who realized that the standard valve gears will not do for piston speeds of 600 ft. per min. is George Mesta of Pittsburg. Fig. 16 illustrates the manner in which he obtained large inlet and outlet areas and enforced quiet operation of valves. Rock-

[1] The engineers of the Snow Steam Pump Company, who also build blowing engines on the basis of Slick patents, advise the author that their firm makes the valve seat of Fig. 15b slightly curved, so that the plane valve rests against the seat with an initial tension. The result is that higher speeds can be attained without breaking of valves.

ing valves, two for each head, control both inlet and outlet; the inlet passes at the side of each valve, the outlet through the center of the valve. Automatic cup outlet valves are located beyond the rocking valves and are protected against the return closing slam by the mechanical closing of the rocking valves. This latter design has been used on vacuum pumps and compressors for over 20 years. Its adaptation to high-speed blowing-engine practice required doubling the valve equipment for the purpose of obtaining large areas without excessive diameter of rocking valve. The pot outlet valve is cush-

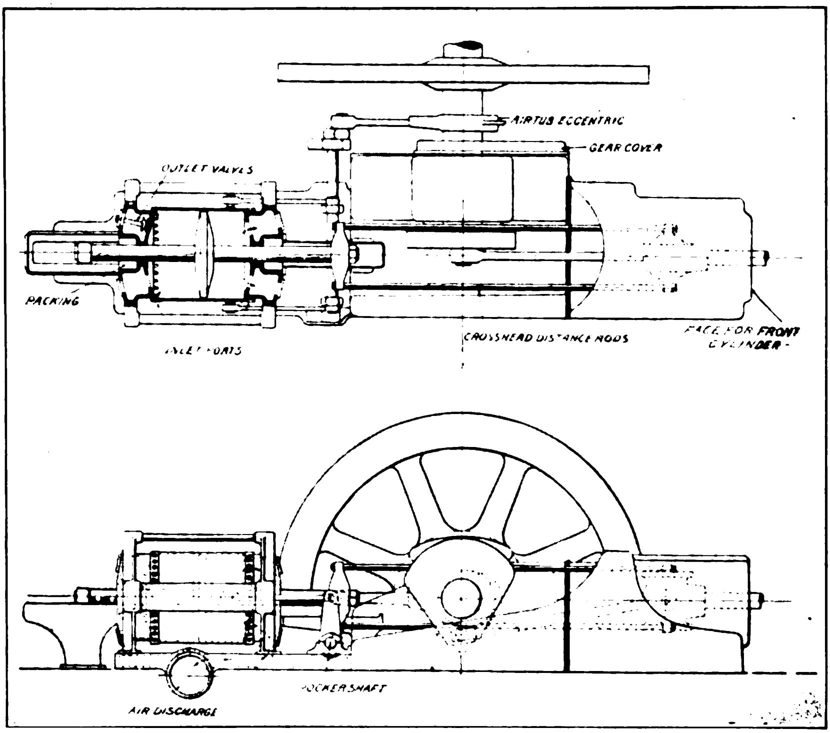



FIG. 15a BLOWING TUB WITH MOVABLE CYLINDER (SLICK DESIGN) BUILT BY WESTINGHOUSE MACHINE COMPANY

ioned very little and is loaded lightly so as to fly out of the road of the blast without fluttering.

30 In Fig. 17 two indicator cards taken from an engine of this type are reproduced. It will be noticed that in spite of the large inlet valve area, 18 per cent, some throttling appears at 70 r.p.m., 700 ft. per min. piston speed. The pressure line in the blast-receiver space has been entered, so that an idea may be gained of the outlet-

throttling loss. Actually the loss is slightly greater than here shown, because calibration of the indicators revealed the fact that their scales were not quite alike.

31 The design of Fig. 16 has been very successful and has been used up to 820 ft. per min. piston speed, 82 r.p.m. with 60 in. stroke. With the exercise of care in finishing the large rocking valves and their seats the resistance of these valves consumes less than 2 per cent of the ideal blowing work (air card). The principal drawback of this type of engine probably lies in its cost and in the oil consumption of the rocking valves.

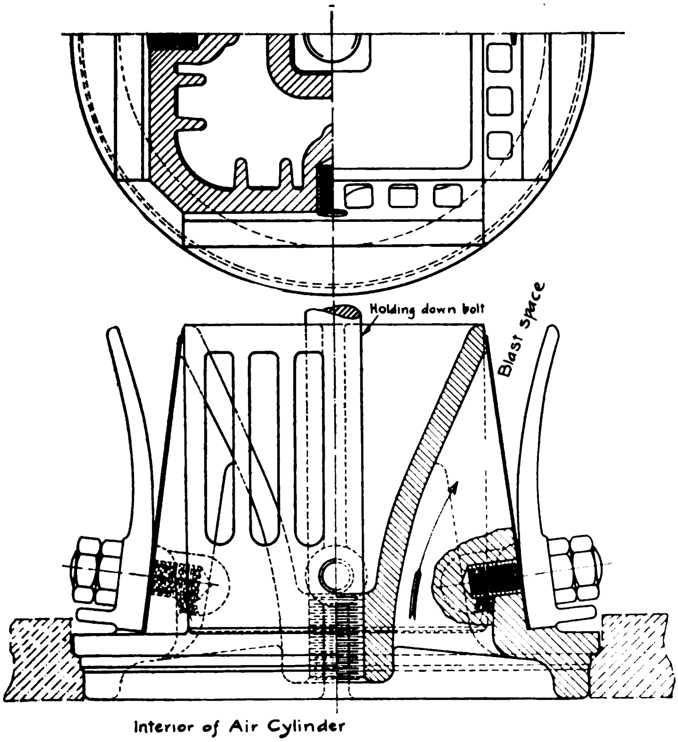



FIG. 15b SLICK AIR VALVE

32 In Europe the high-speed blowing engine is an accomplished fact. There the problem has been attacked along altogether different lines. European engineers long since realized that the harmful kinetic energy stored up in a valve is proportional to its mass and to its travel, and that, therefore, both should be cut down. This fact in itself is not new to American engineers. The Weimer blowing

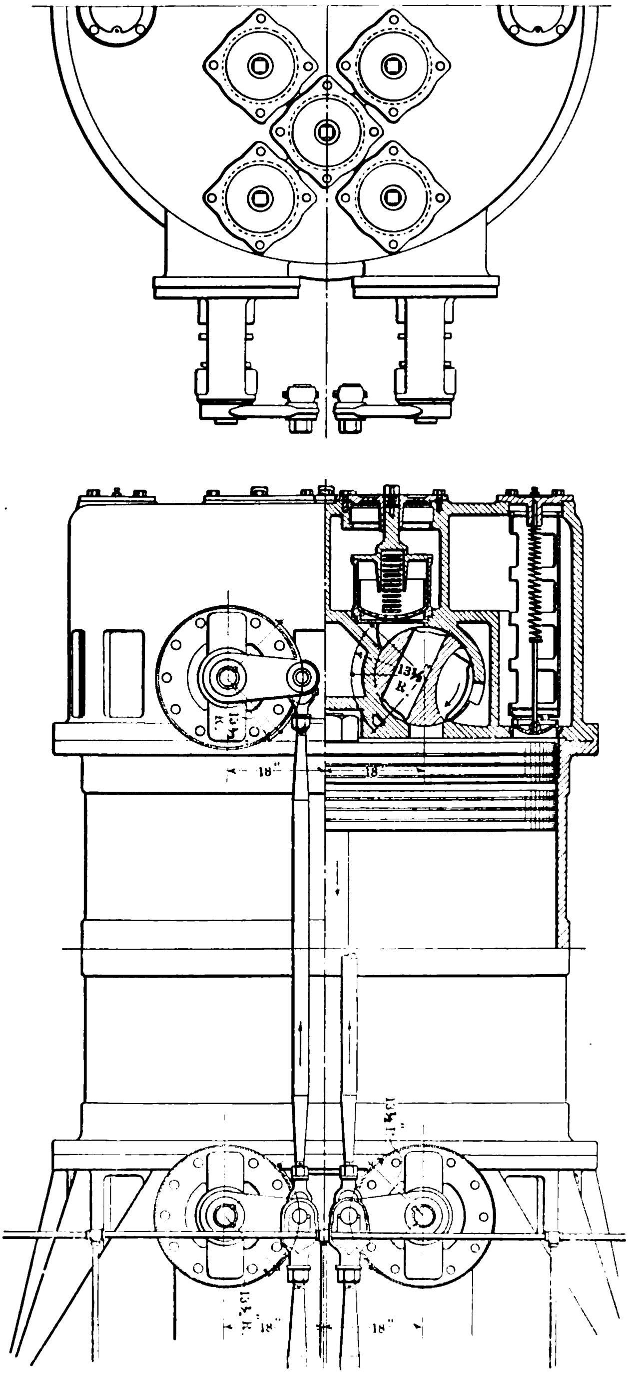
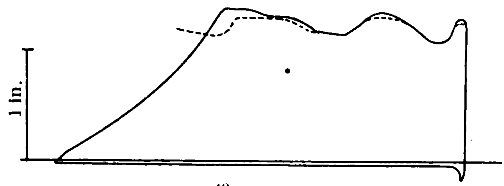



Fig. 16 Blowing Cylinder with Combination Inlet and Outlet Valve (Mesta)

engine (Fig. 18) which can look back upon a respectable number of decades, has tried hard to embody the principle of small mass and low lift. It has failed by sticking to the use of leather which is unsuited to high pressures[1]. Fifteen years ago Mr. Mansfield designed a blowing engine for Leetonia, O., in which he used a great number of light, low-lift strips. The engine failed, not on account of the valves, but because it was "weak in the knees." Mr. Slick (see Fig. 15) introduced light low-lift valves. But these attempts cannot compare with the sweeping success on the other side of the Atlantic.

33 Out of the mass of European designs, two stand out conspicuously, the Hoerbiger (Fig. 19) and the Borsig (Fig. 20). As



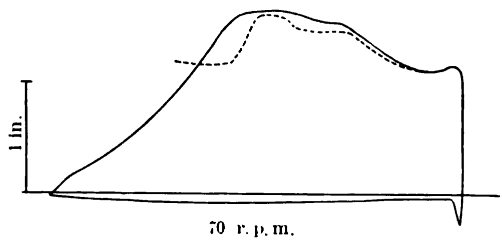




Fig. 17 Indicator Cards taken from Engine shown in Fig. 16

will be noticed, these valves are of the automatic, multi-ported, low-lift type. They are guided without friction by elastic deformation of part of the valve. To get enough valve area, the cylinder head must be extended considerably beyond the piston diameter (Fig. 21), or a valve belt must be used and the clearance correspondingly increased. It should be noted that there is no novelty in the valve belt as such. It was used 20 years ago, both in this country and abroad, and was temporarily abandoned because no satisfactory automatic valve existed.

34 European engineers do not hesitate to use large clearance

[1] Since this paper was written the author has been informed by Mr. Weimer that his company has been using low-lift aluminum valves for the outlet for about ten years and that they are quite successful for speeds up to 60 r.p.m. However, the grinding of the valves is not free from uncertain friction. This fact undoubtedly limits the rotative speed of the engine.

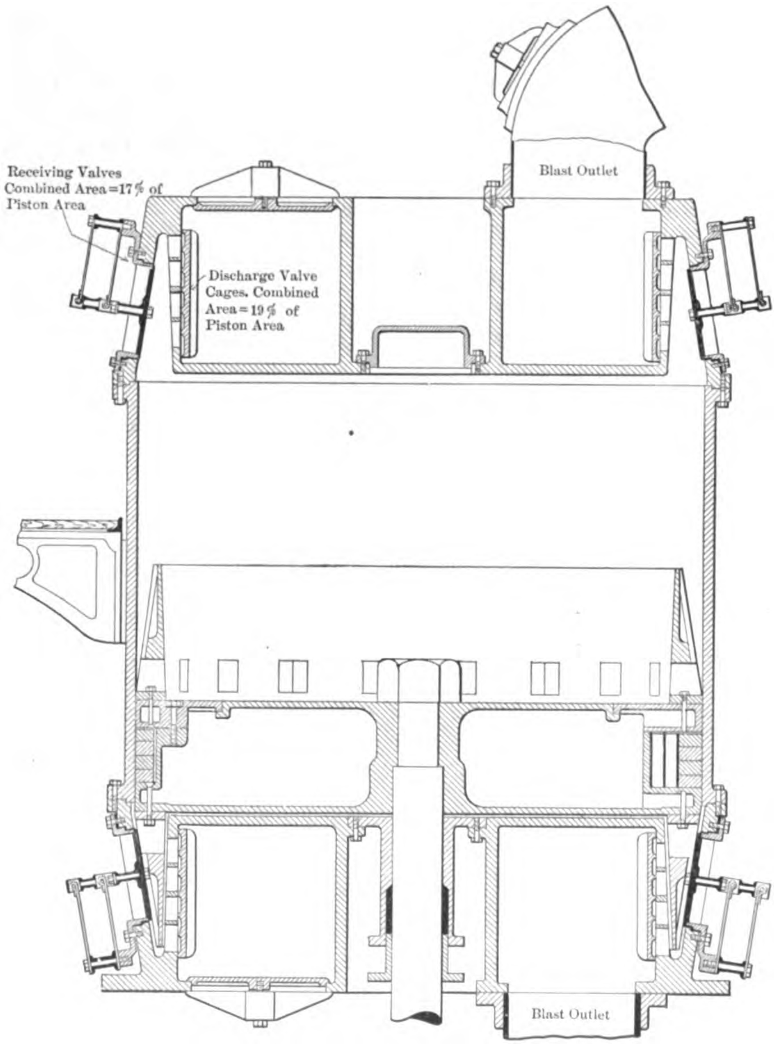



FIG. 18 ENGINE WITH AUTOMATIC INLET AND OUTLET VALVES (WEIMER)

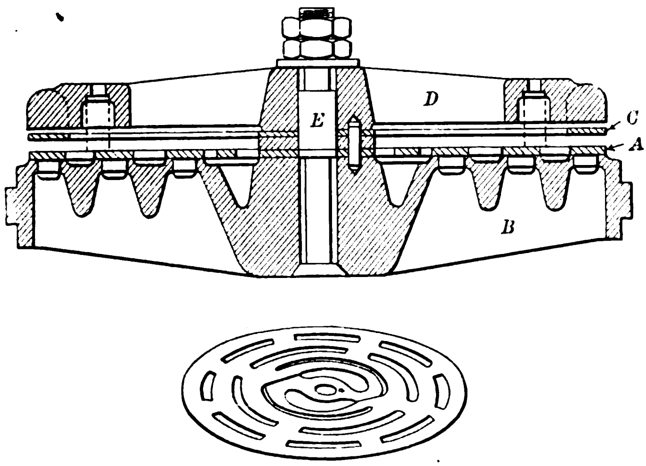



FIG. 19 MULTI-PORTED PLATE VALVE (HOERBIGER-ROGLER)

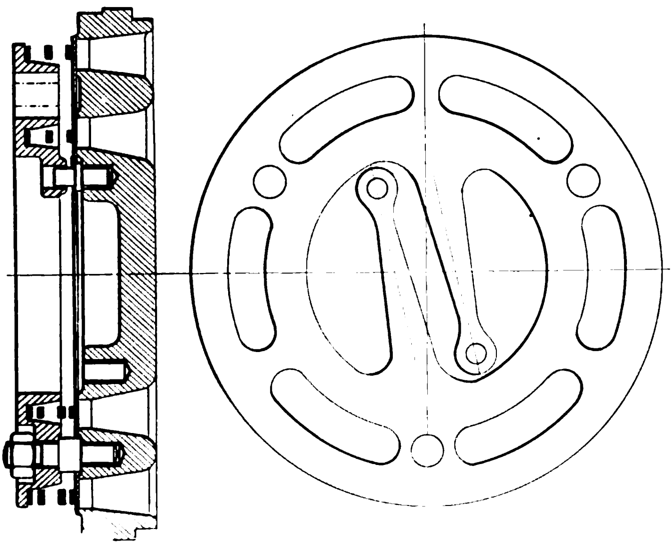


FIG. 20 MULTI-PORTED PLATE VALVE (BORSIG)

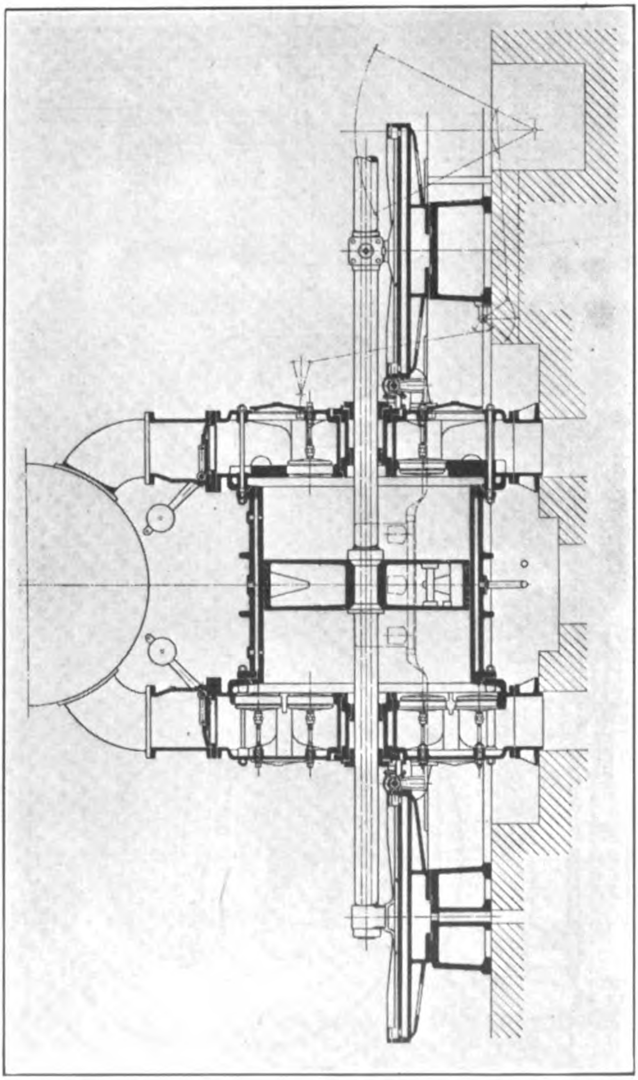


FIG. 21 BLOWER WITH MULTI-PORTED PLATE VALVES, SHOWING EXTENDED HEAD

spaces if by doing so other advantages can be gained, and they meet with success. Matters are different in this country. Clearance in a blowing engine seems to be an eyesore to the American furnace man. The influence of this much abused clearance space can be summed up in a few words.

*a* Clearance volume increases the necessary size of blowing tub for a given weight of air to be pumped per stroke.

*b* The larger size of blowing tub results in a small increase of friction work and, therefore, in a larger size of power cylinder.

*c* The influence of the increased heat-exchanging surface on the true volumetric efficiency is small.

35 On the other hand, clearance allows the use of very large valve areas, which fact decreases throttling work and causes better filling of the air cylinder and also allows higher piston speeds, or in other words, a smaller and cheaper engine. The higher piston speed makes possible the use of a more efficient prime mover, namely, the gas engine. When the truth of this is realized, recognition of the merits of the modern European high-speed blower should present no difficulties. The plate valves are so light in weight and the spring load can be made so small that for the greater part of their working time the valves rest against the guard or stop; this fact, of course, greatly reduces fluttering. Furthermore, there are no wearing parts and, therefore, no sliding surfaces nor sticking or binding from gummed and dusty oil. The low lift does not allow the valve to acquire destructive velocity in closing. If a sufficient number of valves are used the pressure loss through the valves is small and the filling of the cylinder is most perfect. The life of the valves is long, provided that they are made of the proper high-grade steel and that the spring loading is properly proportioned. If a valve should break, it can easily be replaced because the valves are light; besides the inlet and outlet valves are alike, so that only a few valves need be carried in stock.

36 To engineers who are accustomed to standard American practice some of the foregoing statements will appear too good to be true and will require proof. Fig. 22 shows an indicator card taken from a Borsig blowing engine in Differdingen. Fig. 23 shows two cards taken at 55 and 82 r.p.m. from a blower with Hoerbiger-Rogler valves in Rombach. This latter card shows the blast pressure in the main just outside the valves, and allows the computation of the valve losses. In Fig. 24 these losses have been plotted

in per cent of the ideal blowing-engine work against piston speed. In the same illustration are shown the valve losses from the Differdingen-Borsig blower computed from detail drawings, and for comparison, the valve losses of a Mesta high-speed blower using cup valves, the results of actual test, are given. The calculation of the Borsig valve losses was based upon the test of the Mesta engine,

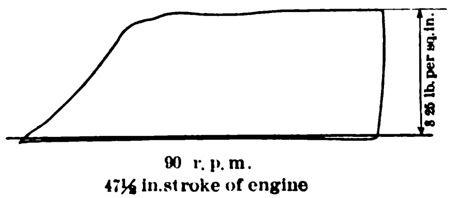



FIG. 22 INDICATOR CARD TAKEN FROM CYLINDER WITH VALVES SHOWN IN FIG. 20

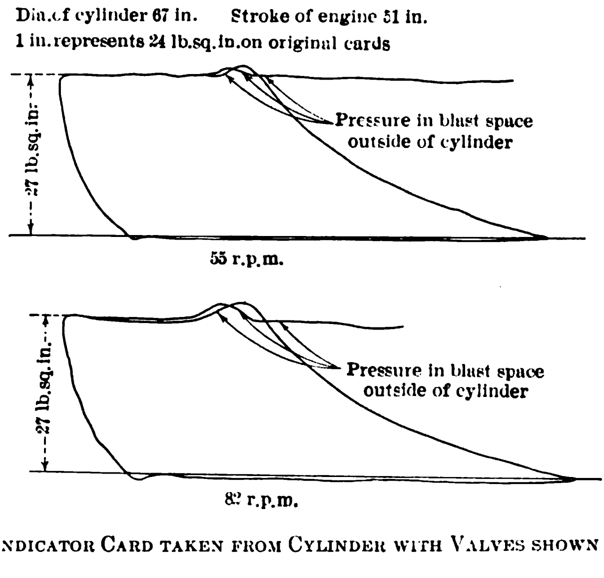



FIG. 23 INDICATOR CARD TAKEN FROM CYLINDER WITH VALVES SHOWN IN FIG 19

that is to say, the method of figuring valve lifts and losses was checked by a test and the coefficient of discharge was thereby determined. The discrepancy between inlet and outlet losses on the Hoerbiger-Rogler and Borsig valves is entirely due to the respective number

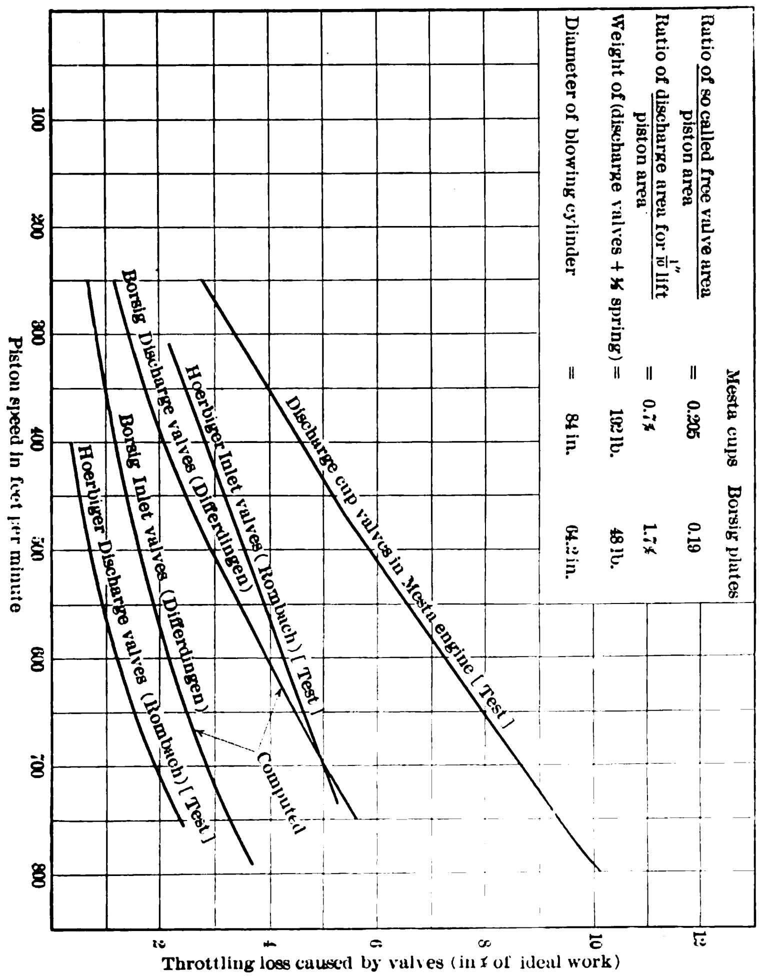



FIG. 24 THROTTLING LOSS CAUSED BY VARIOUS TYPES OF DISCHARGE VALVES

of valves employed. It will be observed that the plate valves show a very much smaller loss than the cup valves, although the cup valve area is very much larger than standard American practice. Comparison is invited between the engine (Fig. 16) whose discharge valve losses are represented by the chart, and between the engine shown in Fig. 14. The former engine has an 84-in. cylinder bore and ten cup valves of 12-in. diameter. The latter engine has an 80-in. cylinder bore and four cup valves of 18-in. diameter. Since the area exposed per unit lift, say 1-in. lift, counts in a discharge valve, it will be noticed that our American high-speed blowing engines are apparently somewhat inferior to the European type

FIG. 25 MULTI-PORTED PLATE VALVES (MESTA)

37 With regard to the life of these valves, statements of European builders are interesting. Borsig asserts that in several engines there has not been a single broken valve in spite of continuous high-speed operation, and that in places where valves have broken, this fact could invariably be traced to bad material. Haniel and Lueg, builders of blowers with Hoerbiger-Rogler valves, make exactly the same statement. Particular emphasis is placed upon the almost silent operation of these valves, both by users and builders. No separate cushioning means are employed except that in the Hoer-

biger-Rogler valve an elastic plate softens the impact of the opening stroke before the valve strikes the guard. This cushioning alone does not suffice, but another circumstance comes in helpfully. Thin films of oil coat the valve plate, cushion plate and guard. The squeezing of the air and oil between these plates provides a sufficient cushion to prevent injury to the valve.

38 The author has taken particular pains to secure data on the behavior of valves. Unfortunately, it was impossible to secure such data on the Borsig and Hoerbiger valves with the exception

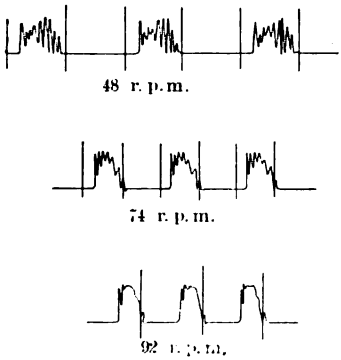



Fig. 26 Valve Motion Diagrams taken from Inlet Valve shown in Fig. 25

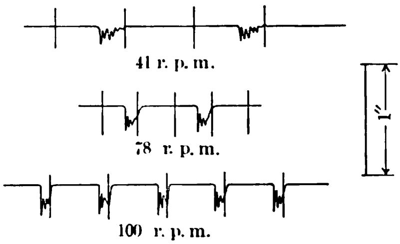



Fig. 27 Valve Motion Diagram taken from Discharge Valve shown in Fig. 25

of the indicator cards, Figs. 22 and 23, which, however, are only circumstantial evidence. The author considers himself fortunate in having secured valve behavior diagrams from an experimental engine of the Mesta Machine Company, which has lately begun a series of systematic experiments on a plate valve patterned after those of Hoerbiger and Borsig. This valve, designed by L. Iversen, is intended to equal, or if possible, even surpass the European valves. It will be noted (Fig. 25) that it is guided without friction by a volute spring, flies up against a cushioned guard and is in all respects similar to the above described European valves. Valve motion curves taken from this valve may, therefore, be regarded as indicative of the whole type.

39 In Fig. 26 the diagrams of the inlet valves are given, and

in Fig. 27 the diagrams of the discharge valve. A standard blowing-engine valve was used, which meant in this case that the valve area was larger than necessary. The result is that the inlet valve flutters somewhat at low rotative speeds and that the discharge valve lifts very little. Besides, the spring load was too great. Allowing for these departures from correct conditions, the curves present enough interesting features. Turning to Fig. 26, it will be noticed that the time of vibration of the valve is practically constant, so that at the high speed the valve has not time to perform a great number of these vibrations per engine stroke; in fact, only one small vibration during lifting and one small vibration during closing occur. At most speeds the valve is closed on the dead center, only at the very highest speeds it rebounds and closes a trifle late. This rebound appears to be caused by a sort of compression wave under the valve, or rarefaction wave above the valve so that the rebound is not necessarily caused by elastic compression of the valve seat. The velocity with which the valve strikes the seat can be determined approximately from the diagrams by the tangent method.

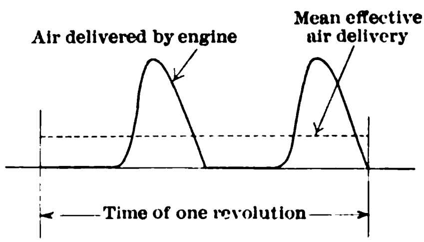



FIG. 28 AIR-WAVE PULSES CAUSED BY RECIPROCATING BLOWER

40 From the sound of closing of these valves, the author judged that their velocity of striking must be very much less than those of cup valves in the designs of Figs. 5 and 6. For this reason he was surprised to find from the diagrams (Fig. 26) that the velocity is quite high enough to call for very good material, such as alloy steel. This would be exactly in line with the experience of the German builders who state that unqualified success in these valves is not only a matter of design but just as much a matter of good material.

41 From Fig. 27 it will be observed that the outlet valve is reflected by the cushion plate and is thrown back into the air current, where it duly performs its vibration. At several speeds it closes

late. The air cards, however, show no signs of slip. In spite of the slight delay, the outlet valves close very quietly, as is proved by sound and by the rounding of the diagram at the closing point. The vibrations of this type of valve are of so short a duration that the air in blast mains does not set up synchronous vibrations. The tests on this valve have not yet been finished.

42 From a study of the various types of valves and valve gears, it appears that at the present time the low-lift, alloy steel plate valve promises to become the standard valve for high-speed blowing engines, because (*a*) there is no wear or binding or sticking;

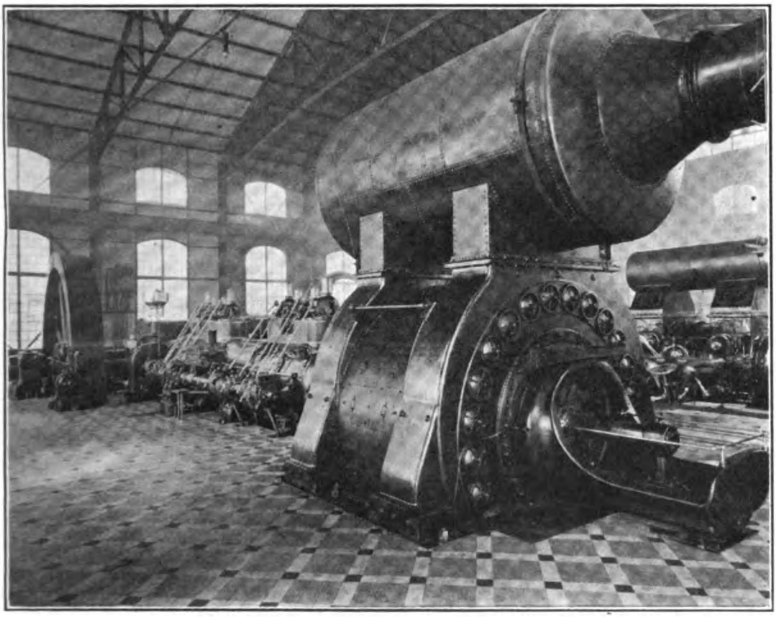


FIG. 29 BLOWING ENGINE WITH AIR TANK ON CYLINDER

(*b*) no lubrication is required; (*c*) it causes very small throttling losses; (*d*) it can be used for the highest speeds; (*e*) it is inexpensive; (*f*) it does away with mechanical gearing, oiling and adjustment.

43 No matter with what valves a reciprocating blower is equipped, its delivery remains discontinuous, that is, it delivers air impulses comparable to a constant delivery, over which is superposed a wave motion or vibration (Fig. 28). If the blower discharges directly into the blast main, then vibrations are transmitted with

undiminished strength and shake the whole line. In steam-engine practice this evil was long ago cured by placing a large steam or water separator near the engine, and so convinced are we of the necessity of this separator that we install it also on lines carrying superheated steam, ostensibly for the purpose of dropping out moisture which is not there, but really to damp the vibrations of the pipe line. If a similar request is made of a furnace man for the air line, a great deal of resistance is encountered. The author knows of only one furnace plant in this country where a large tank or equalizer was installed for each blowing engine. The pipe lines thus connected are practically free from vibration.

44 In Europe a similar resistance is probably offered by furnace men; at least it would appear so from the fact that modern high-speed reciprocating blowers are equipped by the builders with large tanks resting on the backs of the cylinders, thus permitting the furnace man to retain his long cherished ideas of pipe-line design (see Fig. 29). The results must be satisfactory, if comparison is made with the American plant in which tanks are used.

45 Summing up, we find that the reciprocating blower has in the last decade made wonderful strides towards becoming a successful high-speed machine. While the increase of piston speed was started by the gas engine as a matter of necessity, it has also benefited the steam-driven blowing engine, and isolated furnace plants can now work with two air cylinders instead of three, because one will successfully blow a furnace in case of emergency, or else three smaller units may be used.

46 The combination of the high-speed reciprocating blower with the blast-furnace gas engine makes the use of the latter profitable even in the Pittsburg district where coal is cheap. The latest group of furnaces in this region has been equipped with slow-speed reciprocating steam-driven blowers. If a high-speed gas-driven blower had been on the market, the result would probably have been different, because then the first cost of the more efficient gas engine would have been lower.

47 A gas-driven blowing engine with 800 to 900 ft. per min. piston speed and high rotative speed will be the most formidable competitor of the turbo-blower, if European experience may be taken as a guide. There are engineers in this country who have already carried into practice higher piston speed for gas engines for electric power, and interesting developments in this line of work may be expected in the next five years.

# APPENDIX No. 1

## THE INFLUENCE OF CLEARANCE (VOLUME AND SURFACE) IN BLOWING ENGINES

**48** The influence of clearance is fourfold:

(*a*) The high-pressure air imprisoned in the clearance space re-expands and prevents the entering of atmospheric air until the pressure in the clearance space has dropped down to atmosphere.

(*b*) The surface of the clearance space is heated by the compression, gives up heat to the incoming atmospheric air and thereby reduces the weight of air taken in per stroke.

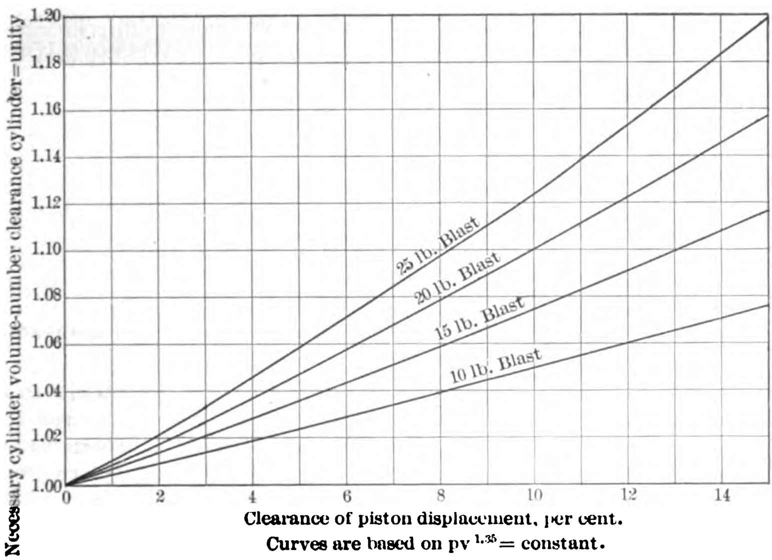



Fig. 30 Influence of Volume of Clearance Space Upon Piston Displacement of Blowing Engines

(*c*) The two foregoing actions require a larger cylinder than would be required without clearance space or surface for delivery of a given quantity of air per stroke. The larger cylinder means heavier piston and rod, larger valves; briefly, a more expensive machine for unit weight of air taken in per stroke.

(*d*) The larger parts cause a loss by friction and this fact calls for an increase in the size of the power cylinder, steam or gas.

49 The enlarging of the air cylinder due to the action described under the first heading, re-expansion, can be mathematically determined. The results of such a calculation are plotted in Fig. 30. Since 15 lb. per sq. in. represents the average blast pressure, approximately 1 per cent of increase of cylinder diameter will be necessary for every 3 per cent increase of clearance volume.

50 The influence of clearance surface on weight entering per stroke cannot be mathematically treated, at least not by any formula simple enough for practical use. It should be noted that this harmful surface is present even if the clearance volume is reduced to zero. The lack of knowledge of the influence of the heating surface offers the most assailable point to the opponents of the reciprocating blower. Tests are therefore needed, and the author believes that on an engine with tight valves a thermometer in the intake pipe, a thermometer in the outlet immediately beyond he valves and an indicator will give a very good idea. From the temperature of the outtlet and the shape of the indicator card, the temperature at the beginning of the compression can be computed. Comparison of the value thus obtained with the reading of the

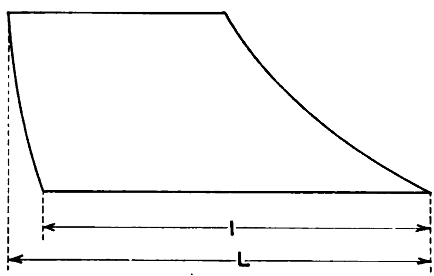



Fig. 32 Theoretical Indicator Card Showing Effect of Clearance

thermometer in the intake pipe gives the influence of the walls. From figures on the number of revolutions per pound of coke delivered to the blast furnace and from other data furnished the author by Julian Kennedy of Pittsburg, it appears that the influence of these walls on large size engines is quite small indeed, but no definite conclusions can be drawn, because the reactions in the blast furnace vary.

51 The author was particularly interested in variations of volumetric efficiency caused by variations of surface of clearance space. To obtain data on this point, a small 8-in. by 8-in. compressor at the Carnegie Technical Schools was so equipped that its clearance surface could be varied, leaving the clearance volume constant. The quantity of air passing through the compressor was measured by a positive air and water tank displacement meter. Fig. 31 proves that the influence of extra surface is indeed very small, so small as to be of no practical influence in blowing-engine practice. This is reasonable since during the suction stroke the incoming air is exposed to heating by the cylinder head, the piston and approximately one-half of the cylinder barrel in a machine without clearance, and compared to this enormous surface the extra walls of ordinary clearance spaces are small. Besides, heat transmission decreases with diminishing temperature difference, and after the air has been heated a certain amount, further temperature rise becomes sluggish.

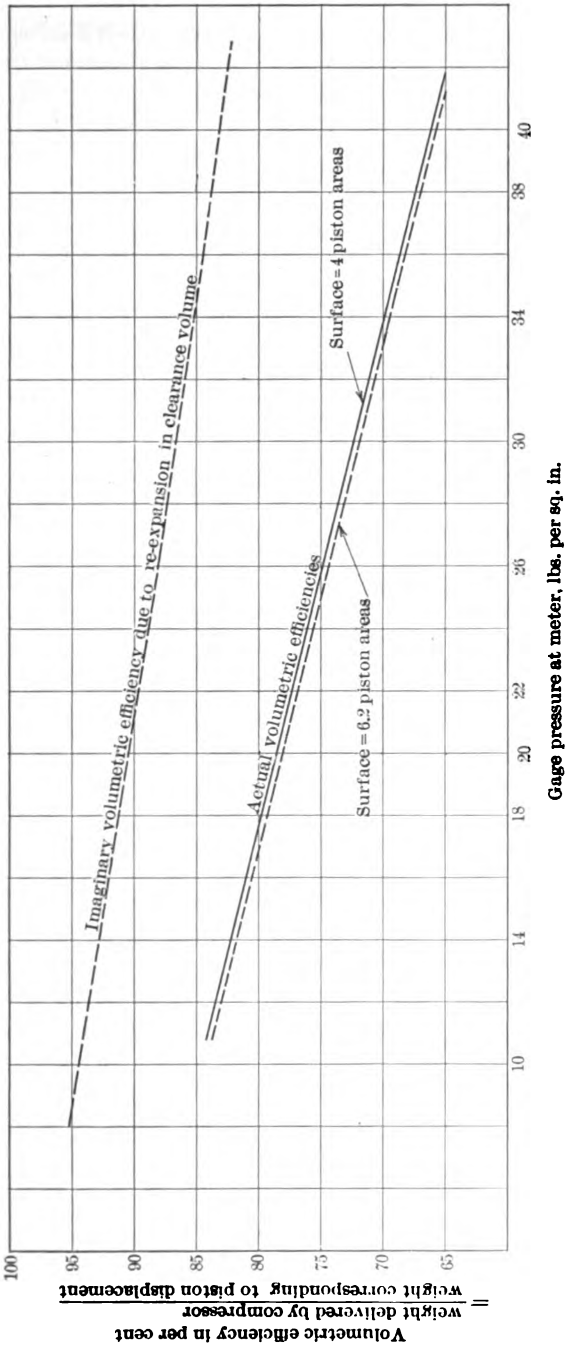



FIG. 31 INFLUENCE OF ADDITIONAL SURFACE IN CLEARANCE SPACE UPON VOLUMETRIC EFFICIENCY. CLEARANCE VOLUME =9.6% OF PISTON DISPLACEMENT

52 It should be noted that in this test conditions were purposely made unfavorable: The surface was large compared to the volume; the extra surface was arranged in the current of the air; no radiation from these surfaces to the outside air could take place, and the compression was higher than usual in blowing engines. In view of these facts the statement that the influence of the walls of extra clearance space in blowing engines is negligible will appear justifiable.

53 A brief consideration of (*c*) shows that it is not so serious as might appear at first glance. The larger cylinder is imaginary, because if clearance is enlarged for the purpose of increasing the valve area with a view to allowing higher piston speed the actual cylinder volume per unit quantity of air pumped is much reduced.

54 If, for instance, the rotative speed of an engine is doubled, the ideal cylinder volume per unit weight of air delivered is cut in two; if the clearance is increased a few per cent to accommodate larger valves, the new unit cylinder volume will probably be 52 to 54 per cent of the original one, so that in spite of the theoretical increase of volume, a practical reduction, which is very material, results.

55 The friction loss mentioned under the fourth heading exists in reality and would doom clearance space, if no compensating benefit existed. The magnitude of the friction loss might be determined by tests, but in the absence of tests that cover a sufficient range, the following reasoning is suggested: The mechanical efficiency of blowing engines varies from 85 to 92 per cent, that is to say, the indicated air work is 85 to 92 per cent of the indicated steam work. In order to cover all contingencies, the calculation should be based upon the engine with greatest friction work, that is to say, an engine with 85 per cent mechanical efficiency; the latter figure is equivalent to the statement that 17.6 per cent of the indicated air work is friction loss. Let this figure be correct for an engine without clearance. Then the friction work in an engine with clearance will be greater principally for two reasons:

(*a*) If the stroke remains the same, the forces will be greater in the ratio of $\frac{L}{l}$ (see Fig. 32). Since the diameters of crank pin and of shaft in main bearing are nearly proportional to $\sqrt{\frac{L}{l}}$, the friction path is larger in ratio $\sqrt{\frac{L}{l}}$ for the machine with clearance. The work lost by friction will therefore be proportional to $\left\{\frac{L}{l}\right\}^{1.5}$.

(*b*) Piston area grows proportional to $\frac{L}{l}$, and the piston thickness grows proportional to $\sqrt{\frac{L}{l}}$, so that the piston weight which produces friction grows with $\left\{\frac{L}{l}\right\}^{1.5}$. These figures are based on equal strokes for machines with and without clearance. Friction work from this source, therefore, is also proportional to $\left\{\frac{L}{l}\right\}^{1.5}$.

56 Other friction losses, for instance those caused by crosshead sliding, flywheel windage and others, are not proportional to $\left\{\frac{L}{l}\right\}^{1.5}$, but they certainly do not exceed that ratio.

57 As a first approximation the friction loss may, therefore, be taken as proportional to $\left\{\frac{L}{l}\right\}^{1.5}$ (see Fig. 32). On the basis of a mechanical efficiency of 85 per cent for the no-clearance machine, the additional friction work due to clearance volume has been plotted in Fig. 33. It will immediately be recognized that an increase of clearance volume from 2 per cent to 6 or 8 per cent means a very small loss, a loss that need not be considered, if other more important features can be gained. The most important feature is a smaller and cheaper engine. In steam-driven units this in itself is a gain from the standpoint of the purchaser, provided that 3 or 4 per cent in fuel consumption makes no difference. In gas-engine blowers great fuel economies are made possible, as stated in the main paper.

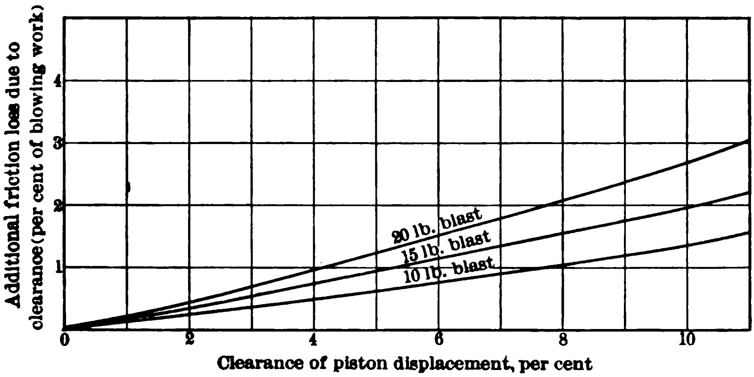



FIG. 33 ADDITIONAL FRICTION LOSS DUE TO CLEARANCE IN BLOWING ENGINES. BASED ON 85% MECHANICAL EFFICIENCY OF ENGINE WITHOUT CLEARANCE

# POWER FORGING, WITH SPECIAL REFERENCE TO STEAM-HYDRAULIC FORGING PRESSES

By BARTHOLD GERDAU and GEORGE MESTA

## ABSTRACT OF PAPER

Various methods of producing forgings by power are discussed. Comparison is made between forgings produced by hammers and by presses with regard to quality. The particular fields for power hammers and presses are outlined. The effect of the blow of a hammer and the consumption of steam per working stroke are computed. The various types of presses are discussed with a view of determining their steam consumption under equal conditions. The computation of the steam consumption is carried out. The most interesting features of various steam-hydraulic presses are illustrated.

# POWER FORGING, WITH SPECIAL REFERENCE TO STEAM-HYDRAULIC FORGING PRESSES

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This paper deals principally with the most modern methods of producing forgings, and in order to appreciate these methods it will be necessary briefly to review what has been done.

2 All are acquainted with the fact that the power of the hand hammer is not derived from its weight alone, but from weight combined with velocity imparted by muscular power during a relatively long stroke. The same is true of the sledge and of all sorts of drop hammers, whether lifted by friction, water power or steam.

3 The power of drop hammers depends solely upon the mass of the hammer and its lift; whereas, in a certain kind of hammer operated by steam or compressed air additional power is obtained by increasing the acceleration beyond that caused by gravity alone.

4 While the steam hammer is older than the present generation, this can hardly be said of the modern type of forging press, illustrated diagrammatically in Fig. 1. A plunger *a* is forced by hydraulic pressure against the forging *b*, thus exerting a steady pressure instead of a blow. All forces are self-contained and no free forces are transmitted to the foundation.

5 In the course of events the forging press began to supplant large steam hammers everywhere, whereas the small hammer, operated by steam or compressed air, has held its own for small work. In the authors' opinion, the logical reason for this fact is the following: Small pieces cool quickly and, as a rule, require a finer surface finish than is demanded in large forgings. Since the hammer strikes

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a blow, the force of the impact increases as the forging cools, so that work is done on the surface of the forging, even when it is quite cool. The press, on the other hand, would be powerless to do any work on the cold piece, unless the anvil surface was reduced very much.

6 Thus the hammer will probably always be used for small work and for making tools, because tool steel must not be heated as much as machinery steel or wrought iron.

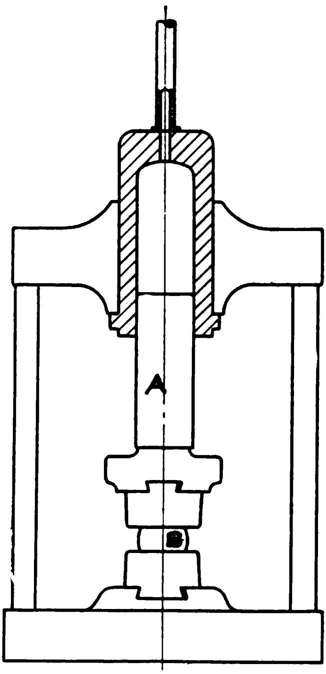


Fig. 1 Simple Type of Forging Press

7 The very features which make the hammer desirable for small work make it undesirable for large work. The hammer acts upon the surface of the material, driving the surface over the core without compressing the latter, as in Fig. 2. The press, on the other hand, exerts a continuous pressure, which forces the semi-fluid material of the forging to flow under compression, as in Fig. 3, which process tends to increase the density of the material.

8 It is thus evident that from the standpoint of improving the quality of material of forgings, the press is superior to the hammer, and it would be considered even more useful if, under equal conditions, it used less steam than a hammer would consume.

9 To investigate the comparative steam consumption, a con-

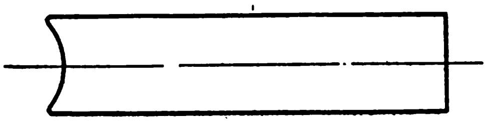

Fig. 2. Showing Effect of Hammering

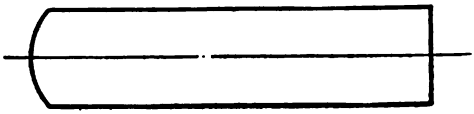

Fig. 3. Showing Effect of Forging by Pressure.

crete case will be assumed. Let the dimensions of a hammer with live steam above the piston be as follows:

Weights of falling parts $P = 5$ long tons
Diameter of steam cylinder $= 27\frac{1}{2}$ in.*
Stroke of piston $= 79$ in.
Initial steam pressure $= 107$ lb. per sq. in.
Mean effective pressure $= 71$ lb. per sq. in.
Face area of anvil $= 186$ sq. in.

Then we find:

*a* Mean effective accelerating force ($P_2$) due to steam pressure $=$

$$\frac{\pi}{4} \times 27.5^2 \times 71 = 42{,}000 \text{ lb.}$$

*b* Acceleration provided by $P$ and $P_2 =$

$$\frac{(42{,}000 + 11{,}200)\ 32.2}{11{,}000} = 155 \text{ ft. per sec.}$$

*c* Velocity ($V$) of moving parts at end of stroke $=$

$$\sqrt{2 \times \text{acceleration} \times \text{stroke}} = 45 \text{ ft. per sec.}$$

*d* Kinetic energy stored up in moving parts $=$

$$53{,}200 \text{ lb.} \times \frac{79}{12} \text{ ft.} = 350{,}000 \text{ ft-lb.}$$

* These dimensions were converted from metric dimensions, which accounts for the odd sizes.

For hammers of this size and correct temperature of forging, it may be assumed that the moving masses are brought to rest within a space of 1⅝ in.

*e* Basing the retardation of the moving parts upon this distance the average retarding force is found to be 2,580,000 lb., or approximately 1200 long tons. This figure may be termed the force of the blow and will be used below for comparison with a press. This force was based upon a retardation space of 1⅝ in. It would be wrong to assume that all of this space is utilized for compressing the forging. The elasticity of the foundations absorbs a considerable amount of the work of the blow. A correct mathematical treatise of these losses meets with insurmountable difficulties. From the experience of the authors it appears that almost one-third of the work is lost in vibrations so that only about 1 in. of useful compression or deformation of the forging results.

*f* Since it is intended to investigate the relative economy of different methods of forging, the steam consumption per working stroke of the hammer in question will now be computed. Steam is needed for the lifting and for the down-stroke. The steam for the up-stroke may be figured approximately from the equation that pressure multiplied by change of volume equals work done. Thus cubic feet of steam required for up-stroke =

$$\frac{11{,}200\times\frac{79}{12}\text{ ft-lb.}}{144\times 107\text{ lb. per sq. ft.}}=4.8\text{ cu. ft.}=1.3\text{ lb.}$$

10 For the down-stroke a cylinder full of steam at 71 lb. per sq. in. pressure may be taken, which will be sufficiently close for this purpose. Thus the volume of the steam per down-stroke =

$$\frac{\frac{\pi}{4}\times 27.5^2\times 79}{144\times 12}=27\text{ cu. ft.}=5.4\text{ lb.}$$

The steam consumption of one cycle then equals 6.7 lb.

11 This steam consumption is based upon correct operation of the hammer, which, however, is seldom realized if the operator neglects to close the throttle at the instant the hammer touches the forging, because in that case the pressure in the cylinder may rise to

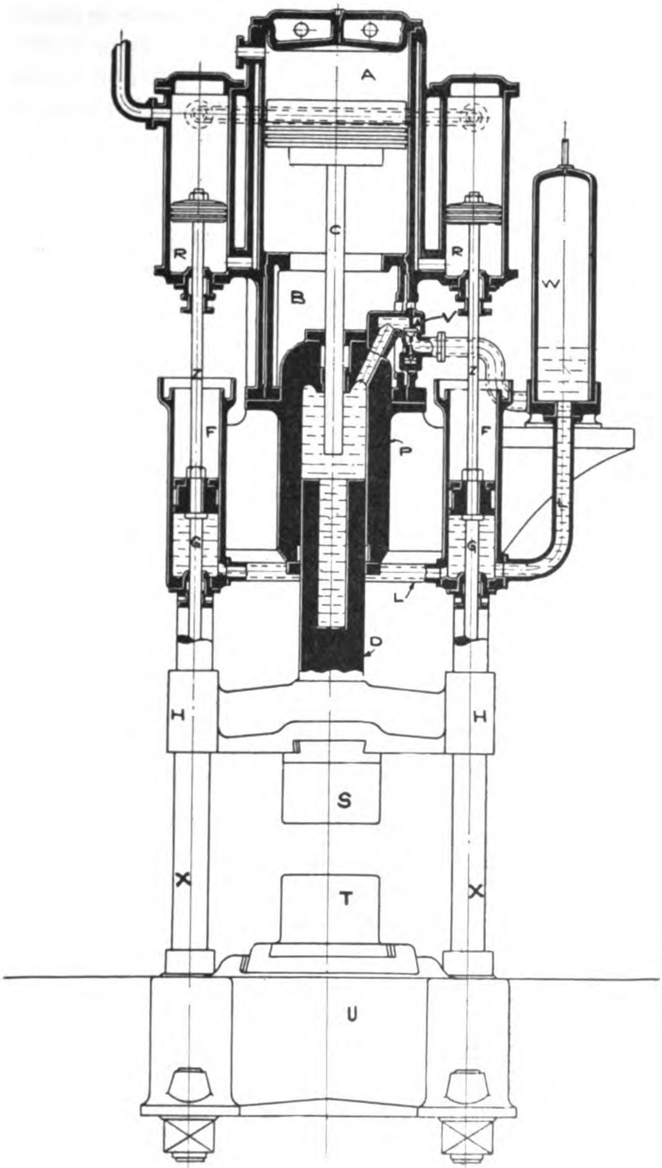


Fig. 4. Steam-Hydraulic Forging Press

boiler pressure. If the hammer is used to strike light blows, full strokes may be made, using the hammer principally as gravity drop, or short strokes may be made with live steam on top. In either case the steam consumption per unit of work done is enormously increased. The great number of combinations possible forbids giving figures.

12 Turning to the steam consumption of the press, we find that conditions are not so simple. It will be remembered from Fig. 1 that the press is operated by water under pressure. The steam consumption then depends first upon the method of producing the water pressure and second upon losses of water pressure between its production and its application to the press plunger.

13 Before the intended computation can be made, it is evidently necessary to review the various types of presses on the market. Two general types of presses exist: (*a*) The so-called purely hydraulic presses whose pressure-water is furnished by separate pumping engines; (*b*) the so-called steam-hydraulic presses in which water under pressure is generated in a steam intensifier.

14 The general type mentioned under (*a*) is best illustrated by Fig. 1; the pipe at the top of the cylinder is connected either directly or by means of a hydraulic accumulator to a high-pressure pump which may be either direct-acting or of the crank flywheel type.

15 The type mentioned under (*b*) is shown diagrammatically in Fig. 4. The press consists of a heavy base *U* and four uprights *XX*, supporting the hydraulic and steam cylinders above. *S* and *T* are the dies, the upper one being carried by the crosshead *H*. This crosshead is moved into position for forging by the use of the steam cylinders *RR*. Pressure for forging is obtained by admission of steam into the top of cylinder *A*, which moves the piston downward and forces rod *C* into the hydraulic cylinder *P*. This action again causes the plunger *D* to move downward, carrying with it the crosshead and the upper die. The effect is that of a steam-actuated intensifier.

16 Hydraulic cylinder *P*, balancing cylinders *FF* and about one-third of air chamber *W* are filled with water. Air pressure of about 100 lb. is pumped into air chamber *W*, which is sufficient to move piston rod *C* with its piston to the top of steam cylinder. The areas of plunger *D* and cylinders *FF* are equal, so that the downward force on plunger *D*, due to the air pressure on the water, is counterbalanced by cylinders *FF*. By opening check valve *V* in the connection between air chamber *W* and hydraulic cylinder *P* thus, allowing water to flow from the hydraulic cylinder to the air chamber,

and admitting steam to cylinders *RR*, the crosshead can be raised to any position and similarly it can be lowered.

17 Referring to type (*a*) it is found that the pumps commonly work against a pressure of 4300 lb. per sq. in. which is maintained by an accumulator. Unfortunately, the process of forging does not always require all of this pressure, but on the average only about 50 to 60 per cent of this amount, the remaining 40 to 50 per cent being lost in the controlling valve.

18 It might appear that it would be more economical to let the pump work directly against the press without an accumulator and even without intermediate controlling valves, but this scheme is too ideal to be practical. It has been found necessary to provide controlling valves, by-pass valves, throttling governors and other means for regulating the speed and power of the press.

19 Nevertheless, this type of press has one advantage, namely, that it can make a continuous full-pressure stroke of the maximum length for which the press was built. For this reason this type is most advantageous for drawing operations, for instance, the drawing of tubes, etc.

20 Taking up type (*b*) as illustrated by Fig. 4, it has already been mentioned that the pressure is generated by a direct-acting intensifier which is similar in its action to a direct-acting pump. While at first thought it might appear that the direct-acting intensifier, which necessarily has to maintain an almost constant steam pressure throughout the stroke, would be inferior to a high-class compound crank and flywheel pump, experience has taught that the opposite is the case, the reason being that the work is intermittent and requires a continually varying amount of power.

21 After these explanations we are ready to take up the computation of the steam consumption of a press for the same work which formed the basis for a similar calculation for the steam hammer. From what has been said it is evident that the type of pump, the conditions under which it works, the proper balancing of the accumulator pressure with regard to the work and other factors, affect the steam consumption. Therefore the following figures should be considered only as an attempt to solve the problem.

22 The effective work of the hammer was 240,000 ft-lb. per working stroke. Basing the press on the same work and taking the efficiency of the transmission pipe as 90 per cent, the pressure drop in pump ports as 10 per cent, and the efficiency of the pump as 75 per cent, the work actually to be done in the pump

cylinder is 395,000 ft-lb. Let the pump be driven by a steam engine whose steam consumption is 32 lb. per hp-hr. on account of the intermittent working; then the steam required for the equivalent work is

$$\frac{395,000 \times 32}{33,000 \times 60} = 6.3 \text{ lb.}$$

This shows that the purely hydraulic press is slightly more economical than the steam hammer.

23 Matters are a great deal simpler for the direct-acting steam-hydraulic press. Basing the calculation upon the fact that pressure, times change of volume equals work, and assuming a steam pressure of 150 lb. per sq. in. gage, we find the necessary volume of steam to be

$$\frac{240,000}{150 \times 144} = 11 \text{ cu. ft. or } 3.7 \text{ lb. of steam}$$

For the sake of simplicity friction of pistons has been neglected in all cases. This last result is reliable, whereas in the case of the purely hydraulic press and in the steam hammer, additional losses may occur which cannot very well be considered on account of their uncertainty. The excellent economy of the direct-acting steam hydraulic press presupposes that no dead volume of clearance space has to be filled before the motion of the steam piston against its full resistance begins.

24 The importance of this last sentence is so great that the authors take the liberty of repeating it in different words. The expression used actually includes three separate facts: (*a*) The steam piston of the intensifier must be in its starting position with practically no clearance; (*b*) the movable anvil must practically rest on the piece to be forged; (*c*) there must be no voids in the plunger-and-intensifier cylinder.

25 These three principles are embodied in the design shown in Fig. 4, which, in the authors' opinion, represents the most practical form which this type of press can assume. In this system the formation of voids in the water space is impossible, because the intensifier plunger floats upon the water at all times; in other words, the direction of motion of the intensifier piston and plunger is the same, which thus provides a continual force closure. If such force closure were absent, and in some types of steam hydraulic presses it actually is, there would be no guarantee of a filled water space and increase of steam consumption would be the inevitable result. Moreover, it will be seen from Fig. 4 that the pressure is generated directly

in the same cylinder in which it is used, thus avoiding the losses which must occur where the intensifier is separated from the press itself and the pressure water has to be forced through pipes and connections.

# THE MECHANICAL ENGINEER AND PREVENTION OF ACCIDENTS

By John Calder, Published in The Journal for February 1911

## ABSTRACT OF PAPER

The paper discusses the nature and incidents of industrial injury, its prevalence and high rate, in the United States in particular, and the present general desire for better conditions of safety. It analyzes the chief causes of injury as revealed from a study by the author of a large number of verified casualties and recommends practicable measures calculated to reduce the present numerous fatalities and injuries. It discusses in particular the important services which the mechanical engineer, both as an executive and as a constructor, can render in exercising his ingenuity to avoid industrial accident.

The paper contains a number of practical safeguarding illustrations from the field of machine building, equipment installation, transmission plant and especially dangerous machines and processes, and concludes with suggestions for administrative and remedial precautions.

## DISCUSSION

F. R. Hutton. The protection of working people from disaster is primarily the job of the mechanical engineer; whether the mechanical engineer is regarded as the designer of the individual tool by which specific production is carried on, or whether in a larger sense the mechanical engineer is regarded as the designer of the works in which, as a tool, production as a whole is carried on. The analysis with which Mr. Calder has underlain his discussion presents to you in the form in which it has presented itself to me, albeit a little different from his, the philosophy of the origin of accidents.

If there is no power in a plant, there will be no accident. The aphorism of the wise German philosopher, who said, "Show me a man who never made any mistakes, and I will show you a man who never did anything," has its parallel in the safety field—show me the works in which there are no industrial accidents, and I will show you

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The American Society of Mechanical Engineers, 29 West 39th Street, New York. All discussion is subject to revision.

works in which they nowhere turn a wheel. The mere presence of great dynamic power concentrated in a factory, which is so much greater than the possible resistance of the strongest human body, means that the man exposed to a blow from dynamic power goes under. If that dynamic power ever gets beyond control, there is an accident, and no thinking, no planning in advance by the mechanical engineer can prevent such accidents. It is therefore obvious that the starting point of all accidents is the power. And in preparing the scheme which is to underlie the exhibit of a well-ordered Museum of Safety,[1] the starting point, the first class, will be the power plant accidents and the prevention of such accidents; the second, the transmissive machinery accidents; the third, the accidents at the danger zone of the tool, and the fourth, the accidents which happen in the plant anywhere independent of the danger zone of the tool.

When we begin to consider the problems in the danger zone of the tool itself, the very magnitude of the field begins to appall. There is no limit to the possibility of the dangerous accidents which can happen in the danger zone of the tool, if the word tool is used in its widest sense. A mine may not be thought of as a tool, but it is. It is an apparatus destined and designed for production. Exhibits from the American Museum of Safety both emphasize what Mr. Calder has said in some directions, and amplify it in others. One of the best things Mr. Calder brought out—and he threw it off as if it were a mere trifle—was that there is no use of signs. The man who will present a sign or symbol for danger which shall be as clearly understood as the cross is in the religious world will be one of our great benefactors. What we want is something that will signify that here is a danger point, not specifically saying "Look out for death," but here is a place at which danger lurks.

The United States Steel Corporation have an emphatic sign for a death danger in the form of a skull and cross bones. For the danger of electricity, they have a closed hand, the hand of Jove, with the thunderbolts going in all directions. The difficulty met with in so many places in this country is that no sign whatever, unless given in eight languages, is of any use. The sign in English might serve for many, but you must repeat it eight times. The skull and cross bones is open further to the objection that its effect is so intense that by and by it fails to attract attention. The death's head overdoes it. No-

[1] The American Museum of Safety, 29 West 39th Street, New York, maintained by the Industrial Safety Association.

body quite likes to show the red flag, which is up to date the best suggestion that has been offered. That unfortunately now has a double significance in some parts of the country, and yet, it would be a splendid warning note for the purpose: to say "Look out for yourselves."

Among the accident-preventing devices there are two very interesting types of what may be called the interlocking system of safeguarding. The philosophy of that as applied to a punch or press is that the operator has to work two levers, one with his right hand and the other with his left. He can not operate the machine and have his fingers anywhere in the danger zone. Nothing could be better than that as an ideal design, from the mechanical engineer's point of view as a safeguard, but it is prohibitive on the economic side. You have at once removed the possibility of the operator doing as much in an hour as if he had one hand free or both hands free.

What Mr. Calder has to say about wood-working machinery is very much to the point. There is a device offered where the operator stands upon a rubber mat, making it reasonably impossible for him to fall against the saw. The tale of the man falling against a revolving circular saw told by Mr. Calder is no exaggeration.

Mr. Calder has referred with great emphasis to the difficulty of having safety recommendations carried out. The method which has been followed in the United States Steel Corporation through its various works is to create at the individual works committees of safety of the men themselves. Usually, the foreman is the chairman of the committee of safety in that department and associated with him are those in the group of workmen themselves whose business it it to see that everybody keeps his safety devices about the plant in condition and in use. It makes the men themselves responsible for the maintenance of the safety provision and responsive to suggestions as to where increased safety can be procured, and unites the employees in bringing about this point of common safety, to secure which no better method has been found.

Byron Cummings. For our purpose this subject may be considered under three heads:

- *a* Is it possible to reduce the number of industrial accidents without reducing the output?
- *b* Will it pay employers to adopt methods of operation and safeguarding necessary to produce the desired result?
- *c* What measures are best calculated to produce the desired result?

As to the possibility of preventing accidents the testimony of those who have adopted a systematic plan for that purpose warrants the opinion that a very large proportion of industrial accidents are preventable.

Mr. Calder cites one plant in which the annual number of accidents was reduced 68 per cent. He states that this experience has been repeated in many cases. The Edison Electric Company report that the result of their efforts for accident prevention has been very satisfactory, and the United States Steel Corporation state that preventive measures adopted by them have reduced the annual number of accidents by 50 per cent. Furthermore it is admitted by authorities that practically 50 per cent of the industrial accidents in this country are preventable accidents.

To the second question, Will it pay to employ the necessary preventive means, we think there can be but one answer and that is, it will, to which the testimony of all who have employed such measures subscribes.

In considering this phase of the question we desire to call attention to the attitude of the courts with reference to claims for damages on account of industrial accidents. If the claimant can show that the accident was due to unguarded machinery of any description, it is more than probable, if the injury was serious, that judgment in his favor will be rendered for an amount considerably in excess of $5000, the usual limit in a liability policy for an accident to one person. It matters little if it be contended that the appliance that caused the accident was one not usually guarded, or that it was in an out-of-the-way place, or that it was not dangerous; the fact that the accident was due to the absence of a guard is accepted as prima facie evidence that the machine, appliance belt or condition that caused the accident was dangerous and should have been guarded. Comparatively recent judgments have been rendered for $15,000 for injury that caused the loss of a leg; $25,000 for the loss of four fingers in a laundry accident; $30,000 for the loss of one hand and part of the other in a printing office; $7500 for the loss of one leg; $11,000 for the loss of five toes; $12,500 for the loss of sight; $17,500 for the loss of an arm, and $27,500 for the loss of an arm and a foot. We do not wish to be understood as claiming that as heavy judgments as these are usual, but they are becoming alarmingly frequent—their frequency being emphasized by the fact that during a period of three months, 31 personal injury cases were decided by the Minnesota Supreme Court confirming judgments of $144,926 and reversing judgments to the amount only of $6600.

We have no details as to the number of verdicts affirmed, but assuming that only 10 per cent of the verdicts were reversed, we have judgments confirmed in 90 per cent of the cases acted upon averaging over $5000 each. The State of Minnesota is not alone in this matter. The laws of many of the leading manufacturing States are very similar and the decisions of the courts in any one State generally follow closely the decisions in others. Moreover the state of public opinion is such that more stringent laws are continually being proposed, there being at the present time under consideration in the various state legislatures no less than 21 employers' liability and workmen's compensation laws, some of them being more exacting in their demands than anything heretofore proposed in this country.

When considering the advisabilty of installing safeguards the employer should not overlook the fact that the absence of a guard may entail a heavy loss similar to those above noted. He should also take note of the fact that the Supreme Court of Michigan has decided that failure of a state factory inspector to recommend a guard is not a valid defense on account of an accident due to the absence of a guard.

For the reasons given and for many others that could be cited, we believe that we are justified in the opinion that as a matter of business policy it will pay the employers to use every possible method and appliance for the prevention of industrial accidents.

At this point, we wish to call attention to what may be termed elevator hazards. The author's statement with reference to this hazard may lead some persons to think that the dangers in elevator operation have been eliminated, but such is not the fact, for 193 elevator accidents are reported in two years in hotels and apartment houses, of which 53, or more than 25 per cent, were fatal. It is true that efficient safeguards have been provided for passenger elevators but, nevertheless, entirely too many elevator accidents are happening. Careless operation is responsible for many of these accidents but carelessness or negligence on the part of passengers is also responsible in a number of cases. Probably 50 per cent of the number of accidents on passenger elevators are due to passengers attempting to enter or leave the elevator when the elevator is in motion or to some other condition in connection with the entrances to the hoistway due to improperly guarded hoistways. The use of efficient interlocking doors on all passenger elevators and the proper safeguarding of the entrances to hoistways on freight elevators would prevent a large number of accidents annually.

While on the subject of hotel accidents, we wish to call your attention to the number of dangerous machines employed in an up-to-date hotel. The laundry, usually conducted on the hotel premises, contains the dangerous mangle and the centrifugal dryer. Much of the danger in connection with these machines may be eliminated by the use of the latest improved safety device but there are far too many old types of inefficiently guarded machines still in use. Another attribute of the hotel is the dangerous steam cooker, not the original steam jacketed kettle but the cooker in which live steam is turned directly into the chamber in which the food is to be cooked. Many very serious accidents caused by escaping steam when opening the doors of these cookers have occurred. Such accidents may be prevented by the device which will make sure the passage of steam from the cooking apartment before the door can be opened.

We all know the dangers of the circular saw, but an up-to-date hotel has a machine called an ice cuber which has usually five circular saws in one machine, this being used to cut the ice into the small cubes which are placed in the glasses of the guests. Machines of quite recent manufacture have these saws guarded, but there are many in use without any guarding whatsoever. When in addition to the circular saw hazard we have a hazard due to wet floors caused by the melting ice, we have an extremely dangerous condition, which should be eliminated by the use of the latest guarding appliance and corrugated rubber covering for the floor surrounding the machine.

In considering the methods best calculated to prevent accidents, the use of caution notices should be mentioned. The author states and we agree with him that the ordinary caution notice is of doubtful efficiency. There is, however, a type of notice coming into use which we believe will assist in preventing accidents. This notice consists in the statement of the employer that he desires to prevent accidents whenever possible and requesting the coöperation of his employees and suggestions from them as to methods or appliances calculated to bring about the desired result. One of these notices in use by the Minneapolis Steel and Machinery Company is as follows:

DANGEROUS

NOTICE TO EMPLOYEES TO PREVENT ACCIDENTS

**This machine is dangerous and cannot be guarded. Unusual care is required to operate it safely; and no one should operate it without having had full instructions from the foreman.**

**This notice is posted in order to comply with the following Labor Law of the State of Missouri:**

**Extract from Section No. 6433: The belting, shafting, gearing and drums, in all manufacturing establishments when so placed as to be dangerous shall be safely and securely guarded when possible; if not possible, then notice of its danger shall be conspicuously posted in such establishments.**

Another used by a company operating a number of breweries in Ohio goes farther and promises a money reward for practical suggestions that have been adopted.

NOTICE TO EMPLOYEES

**It is hereby expressly made the duty of each employee to report at once to the foreman in this plant, and also to the president or secretary of the company at its main office, any defective or unsafe condition of the grounds, buildings, machinery, tools or appliances, lack of guards or the improper operation of any machinery in or connected with the plant, and, under no circumstances to continue to operate or use the same before the defect is remedied, and he is strictly forbidden to clean, oil, handle or repair any machinery while it is in motion.**

**This rule must be enforced, and failure to comply therewith will be sufficient grounds for suspension or discharge.**

**The company welcomes any suggestion which employees may make for guarding their safety, and will pay for such suggestions as it may adopt.**

**THE CLEVELAND AND SANDUSKY BREWING COMPANY**

**December 15, 1910.**

We believe that notices along the above lines will accomplish much good, but in our opinion the best method for the prevention of accidents of which we have any knowledge is that adopted by the United States Steel Corporation and consists in what may be termed inspection committees or committees of safety. The South Chicago Works have given careful and earnest attention to this matter and we believe that if similar plans are adopted and carried out earnestly and concientiously by mechanical engineers in charge of large operations that the result cannot help but be beneficial. Some of the rules at the plant referred to are as follows:

## FACTORIES, SHOPS AND YARDS

### General Instructions to Foremen

No. 1 Have a thorough understanding of the following rules. Until you know them all, and are living up to them, you are not doing your duty.

No. 2 You will be held responsible for accidents to your men or to the public.

No. 3 You should caution your sub-foreman regarding the prevention of accidents, but you will still be responsible for your sub-foreman.

No. 4 Watch out for men who are hurt frequently, either by carelessness or bad luck and put them where they will not get hurt.

No. 5 You must not put men to work on any job until you have inspected everything and satisfied yourself that the place is safe; you must warn men of any danger that may come up in the course of doing this work. If on returning after you have been away, you see a man violating your instructions or taking chances that place him liable to injury, deal with that man so as to make it certain he will not again disobey orders.

No. 6 Judgment should be used at all times in placing men on jobs; heavy, slow men should not be placed on jobs where a light, quick man is required. Slow thinking, unintelligent men should not be placed around machinery or in places where presence of mind is required, for by so doing the probability of accidents is increased many times.

No. 7 One or more workmen should be chosen to act in each division as an inspection committee to serve one month each. Each member of this committee to spend one day each week inspecting his division; making four inspections by each committeeman each month, and he shall report his findings and suggestions to his foreman after each inspection. After their term on the committee expires, the men who have served are urged to continue looking for dangerous places or dangerous customs or dangerous conditions in their division and to report the same to their foremen. In the course of time it is hoped that a large proportion of the employees will be actively looking for dangerous places, customs or conditions. Every man appointed on this committee should be taught that his duty is a most important one; that he is not a spy but that he is a safety inspector; that he is doing his duty when he points out dangerous places, or dangerous conditions or a dangerous custom, and by so doing he is protecting the life and limb, not only of himself, but of his fellow workmen in the plant.

The success of the United States Steel Corporation in the matter of prevention of accidents is evidence that the methods they have pursued have been effective and are worthy of the attention of every mechanical engineer interested in the matter.

L. D. Burlingame. I believe it will be of value as illustrating and emphasizing what Mr. Calder has so well outlined, to present some specific illustrations of what has been done in the line of safeguarding and sanitation by the Brown & Sharpe Manufacturing Company, who for many years have given much attention to such matters.

Taking first the feature of cleanliness and light, Fig. 53 shows a corner of the polishing department, often one of the dirtiest and most unhealthful places to be found about a shop. This view indicates the the light, airy condition of the room, in addition to which exhaust pipes are connected with every polishing stand, carrying the dust entirely out of the room. Guards are provided for the wheels and chairs for the comfort of the workmen. At the end of each line of

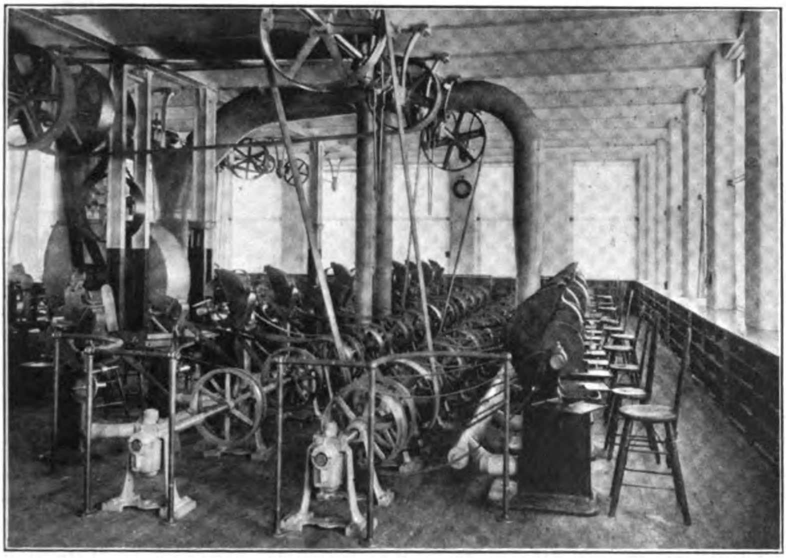

FIG. 53 POLISHING ROOM, BROWN & SHARPE MANUFACTURING COMPANY

shafting is a rail to guard against a workman's falling accidentally on the moving parts.

*The Evolution of Gear Guards.* Fig. 54 shows a design of manufacturing milling machine of an obsolete type in which the guard only partially covers the gears, leaving an element of danger which has been entirely remedied in the later design of machine shown in Fig. 55, where the gears are completely encased.

Fig. 56 shows a constant-speed drive milling machine with all gears inside, these being controlled and adjusted by levers from without.

The chain from the motor is also fully guarded. These last two views are illustrative of the present trend in machine tool design where safeguarding features are included as a part of the design of the machine.

Experience has shown that with machines where the gears are not completely encased, many accidents are prevented by the wearing of short sleeves, and their use is compulsory in these works for apprentices, as shown in Fig. 57. A case where gears are exposed on an old design of gear-cutting machine and where a temporary wooden guard is used to form a partition separating them from the passageway is shown in Fig. 58.

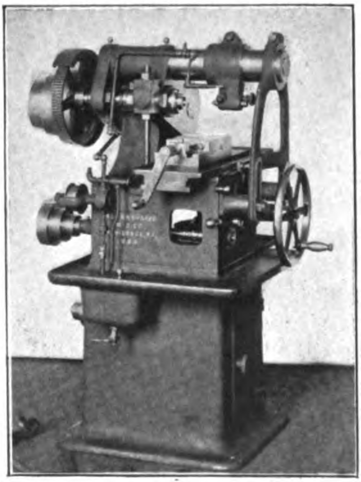

FIG. 54 OBSOLETE TYPE OF MILLING MACHINE WITH EXPOSED GEARS

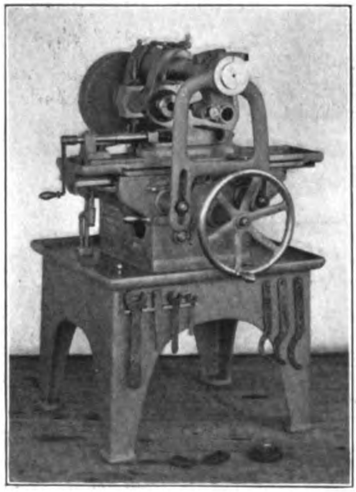

FIG. 55 MILLING MACHINE WITH GEARS COMPLETELY ENCASED

*Fast and Loose Pulleys.* Mr. Calder emphasizes the danger, where fast and loose pulleys are used, of the belts becoming wound on the shaft. A chief source of danger from this cause lies in having too little space between the pulley and the hanger, so that when belts slip off they are apt to wedge, as shown in Fig. 59. This will endanger the workmen, as the countershaft may be pulled down on him. Fig. 60 shows the proper arrangement with sufficient space allowed so that if belts slip off they cannot wedge and wind on the shaft.

*Guarding Wood-Working Machinery.* The problem of guarding circular saws, planers, jointers and other wood-working machines has proved one of the most difficult in our experience. We have found nothing on the market to meet our needs in this direction and our own efforts have been only partially successful. It is our practice to provide rubber mats in front of wood-working tools where there might otherwise be danger of the workman slipping and injuring himself on revolving saws or cutters. Fig. 61 shows our method of guarding a band saw, the guard being hinged for convenience in replacing the saws. It will be noticed that there is also a head guard covering the saw and preventing the workman's head from coming into contact with it. An exhaust is provided to carry away the sawdust.

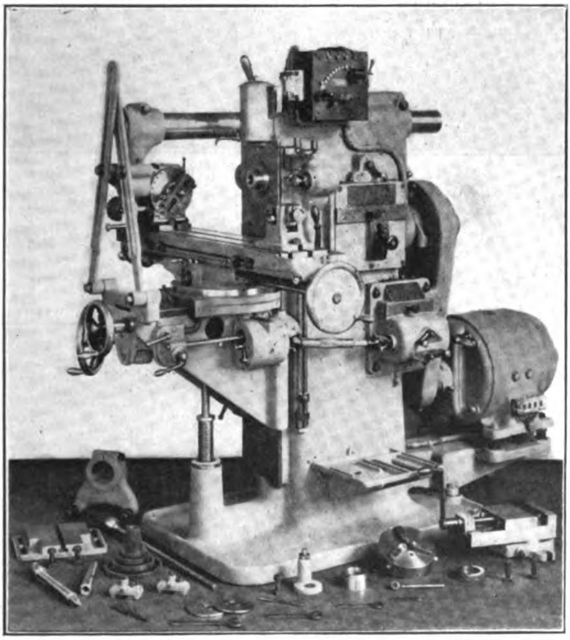

Fig. 56 Milling Machine with Gears Inside the Frame

*Foundry Safeguards.* Fig. 62 shows an interior view of the foundry with overhead tracks for moving ladles and castings about. These tracks are provided with switches and are so safeguarded that when the switches are open the truck is prevented from running off and falling on the workmen. Fig. 63 gives the view of the foundry cupola showing an elevator opening under the pouring spout so that large ladles can be filled. When small ones are being filled the

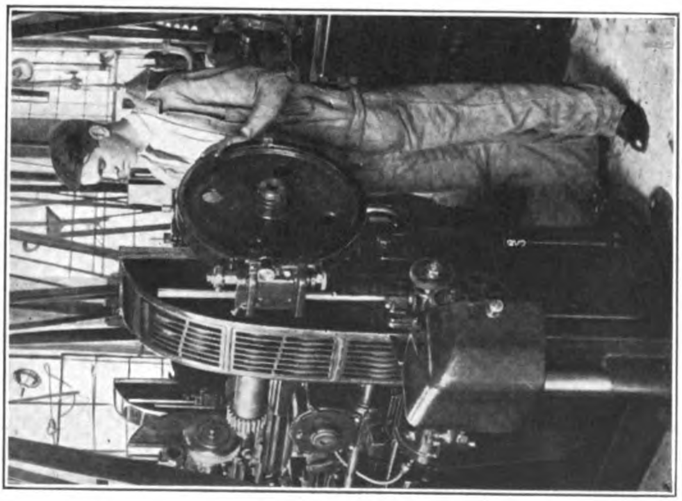

Fig. 57 All Apprentices are Required to Wear Short Sleeves

Note the swinging cover for the gears, which is closed when the machine is in operation.

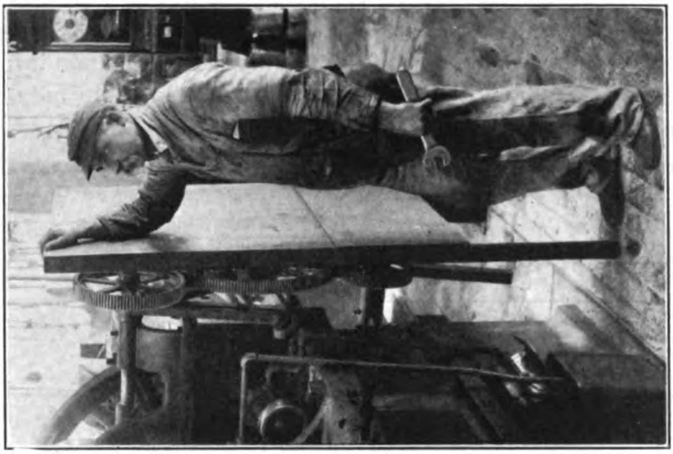

Fig. 58 Temporary Shield for Old Machine with Exposed Gears

platform of the elevator can be raised even with the level of the floor so that there will be no opening into which a workman might fall. This can remain closed when the cupola is not in use.

*Engine Stop.* Provision is made throughout the works, except where independent motors are used, to stop the engine by pushing an electric button conveniently located on each floor. The pushing of any one of these buttons sets in motion the counter weighted mechanism which shuts off the steam and stops the engine without the delay of notifying the engineer.

*Sanitary Provisions.* Fig. 58 shows one of the wash rooms. Individual streams of hot and cold water are provided for each workman. It may be seen that the coat racks are provided with steam piping underneath to assist in drying the clothing when damp. In the

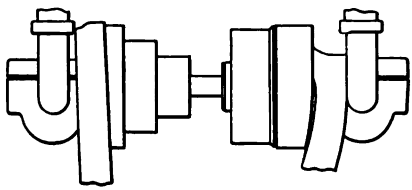

Fig. 59 Improper Design of Countershaft

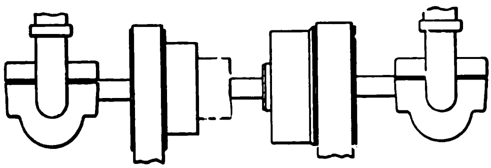

Fig. 60 Correct Design of Countershaft

nickel plating room provision is made for removing noxious fumes from the washing tanks by means of a hood and exhaust. Guards and exhausts are also provided for the buffing wheels.

*Kinks for Preventing Accidents.* The matter of safeguarding has its "kinks" and one of these which is effective in preventing accidents is that of hanging a piece of paper on the work projecting over the passageway, so that workmen will be warned in time and avoid running into it. Another "kink" is that of providing guards on the handles of a wheelbarrow so as to protect the hands and wrists of the workman when pushing it through swinging doors.

*General Features of Safeguarding.* It is the intention of the Brown and Sharpe works to give full consideration to all matters of health and safety and this policy has resulted in the adoption of many provisions working toward these ends. As an illustration, all stairways throughout the works are equipped with treads containing strips of soft metal to prevent slipping. Aside from providing especially favorable conditions as to light and air, special precautions are taken against the spreading of such diseases as tuberculosis by

FIG. 61 BAND SAW COMPLETELY GUARDED

enforcing rules against spitting on the floors or stairways and by maintaining cleanliness in all parts of the shop. Provision is also made in each department for giving first aid to the injured. The main effort, however, is to reduce the number of injuries to the minimum and the last fatal accident in the machine shop of our works, now employing over 4000 men, occurred about 25 years ago.

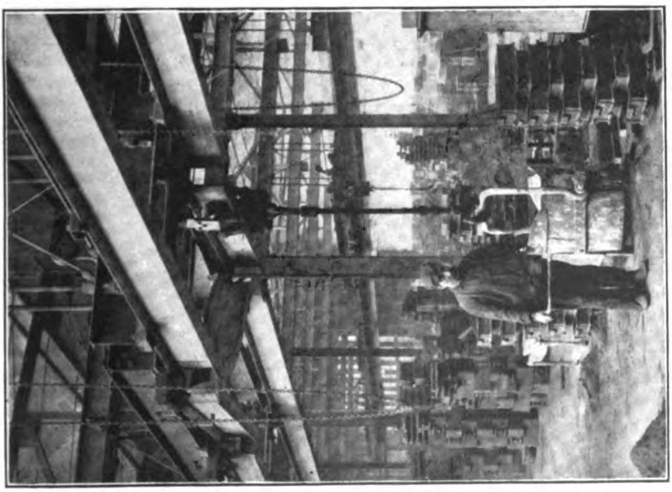

FIG. 62 SAFETY STOP AT OPEN SWITCH TO PREVENT TRUCK FROM LEAVING OVERHEAD RAIL

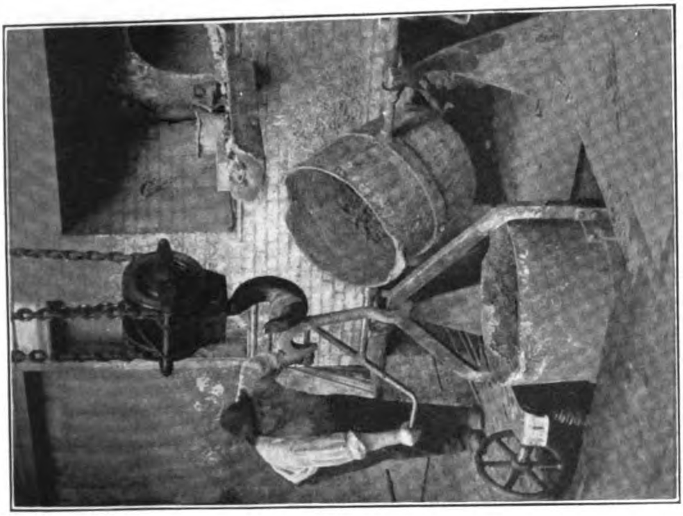

FIG. 63 ELEVATOR PIT AT FOUNDRY CUPOLA

The elevator platform covers the pit when not in use.

M. W. ALEXANDER. As a member of the Massachusetts State Commission on Compensation for Industrial Accidents, I have come in close touch with the public opinion of the State of Massachusetts, and through meetings with commissioners of other states have been able to test more or less the public opinion of the United States in regard to the problem of compensating the victims of industrial accidents. In my investigations I have found a surprising lack of appreciation both on the part of the general public and experts, of the importance of preventing accidents. The discussions

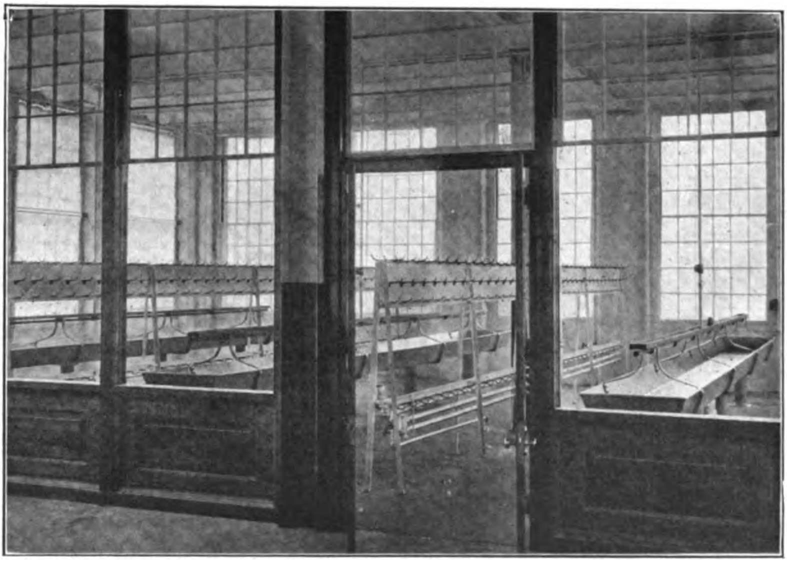

FIG. 64 WASH ROOM WITH COAT RACKS AND INDIVIDUAL STREAMS OF RUNNING WATER

have centered solely around amounts of compensation, maximum length of period of disability to be compensated for, and methods of administration; and while these discussions were going on month after month, no one seemed to take a keen interest in the preventive side of the question, so that the army of industrial victims might not meanwhile continue to increase. Sight seems to have been completely lost of the equally important, if in the long run not far more important, duty of preventing accidents, as far as they can be prevented by care and proper consideration. Accident prevention and accident compensation are, after all, only two different phases of the same problem.

It is, therefore. very fortunate that Mr. Calder has so comprehensively called the attention of The American Society of Mechanical Engineers, and through it of the whole engineering profession, to a matter of such great importance, and Mr. Calder truly deserves the thanks of the Society for his excellent paper. While I might discuss some specific parts of this paper by adding my own opinion and experience, I believe it would prove of more value to point to some general considerations that deserve close study.

In dealing with the problem of accident prevention, we must go about it scientifically and imaginatively. We must not overlook the fact that this question is not only one of safety appliances and devices, but also one of proper safety rules and regulations; and the latter feature is often the more important one for its educative effect. Many times a machine quite properly safeguarded has, nevertheless, contributed to an accident because of a ragged coat sleeve, a loose necktie, or a finger ring on the operator, which have been the cause of the accident and often invited the same. I have seen one suggestion for safeguarding large gears which were partly above and partly below the floor line. Very properly, a railing and a toe guard were placed around the pit, yet there still seems to be an easy chance for a workman with a long coat or jumper passing near by or leaning over the rail, which was placed very close to the gears, to have his coat caught in the arms of the large gear. A further step might therefore have been taken in safeguarding this particular device by covering the arms of the gear with a sheet iron disc fastened to the gear without objectionable projections.

In this case, as in many others, half-way measures of safeguarding are often worse than none at all. On the other hand, there is also the danger of going too far in the direction of protecting the limbs and lives of operatives. In their desire to do the right thing, some men have endeavored to cover up every little crack or open space about a machine into which a man might be able to put his finger while the machine is in motion. Such procedure is not only wrong from an economic standpoint, but indefensible psychologically. I cannot quite believe that we will train up a body of the right kind of workingmen and with the right kind of fibre, if we make the machines on which they have to work, and the runways and everything else that surrounds them, absolutely fool-proof, for we are then in danger of making these same workingmen fools as far as looking out for their own safety is concerned. If a man is trained to consider every machine on which he works so safe that he can sleep all over it, so to speak, without getting hurt, he is surely bound to be caught and injured sooner or later when he is called upon to work on some other machine that is not so fully safeguarded; and there are thousands of machines in daily operation now which can only be safeguarded in time, and even then perhaps not as completely as new ones built with a view to proper safeguards. I am pleading, therefore, for safe machines rather than for fool-proof machines, because a fool-proof machine, as already stated, is apt to fool its operator. The best safety device, after all, we must admit, is good common sense and due care. It should, therefore, be the duty of all employers to pay careful attention to this phase of accident prevention, and to an intelligent effort for safeguarding the working places and the machines under their own control as well; at the same time they should exert all pressure possible to the end that machine tool builders will design their new machines with full consideration to the protection of the lives and limbs of the operatives.

Many corporations and individual employers are already doing excellent work in this respect, and the general public is beginning to be aroused to the importance of the problem of accident prevention. Much more, however, needs to be done to stimulate further effort and to give it proper direction and unification. It would seem to me to be of particular value to have all machine tools of a type, already installed in the various factories, safeguarded in a more or less uniform manner, so that the workingmen emigrating from one to another might be better protected because of their greater familiarity with the nature of the safeguards. A committee of experts could to advantage design and issue for wide publication standard safeguards for lathes, planers, drill presses, punch presses and other standard tools which are already in daily use. The same committee could secure from employers all over the country photographs of safety devices and copies of safety rules and regulations covering all kinds of conditions, and after proper and careful scrutiny issue to interested persons those which deserve wide publication and imitation. If there is already in existence such a body of experts or an association created for this purpose, I should respectfully ask them for a consideration of these and similar ideas. If, on the other hand, there is not already a hopeful effort under way, I should suggest to the Society the appointment of a strong working Committee on Safety Conditions, which might take initiatory action, coöperate with other similar bodies, or do both. The fact that practically all machine tool builders and the prominent mechanical engineers in the various industries are members of the Society would give such a committee a decided advantage in securing active coöperation of manufacturers and employers. What I desire to call to the attention of the Society in particular may be summed up in these three statements:

*a* The problem of preventing accidents involves safety rules and regulations as well as safety appliances; in other words, it is a question of safety conditions.

*b* Machines should be made safe in their operation rather than fool-proof.

*c* The problem of prevention of accidents will find its complete solution only if it is based on a campaign of education, both with the operatives who are to be protected and the engineers and employers, among whom a better knowledge of the subject and a strong public opinion in favor of safety conditions must be created. This, in turn, will have a helpful effect upon the legislators of various States before whom bills for accident prevention and accident compensation are pending at the present time. These bills, when enacted, should be comprehensive and constructive in character, and as far as it can be done, more or less uniform between the various States.

L. P. ALFORD. I am disposed to emphasize the importance of the position of the mechanical engineer in connection with this subject to a greater degree than did Mr. Calder. Legislation, official requirements and recommendations can do little more than point out that something must be done. The designing and applying of safeguards, and the determining of the details of manufacturing processes are distinctly within the province of the mechanical engineer. Upon his initiative and ingenuity rest the final solution of this economic problem.

Using the word prevention in the sense indicated in the old adage, "An ounce of prevention is worth a pound of cure," the time to establish industrial safeguards is when the work of designing is being done. The place to safeguard machinery, mechanism and structures, is on the drawing board. The time to safeguard a manufacturing process is when that process is being planned.

Turning to the field of the machine shop, my experience has shown two prolific sources of accidents that are worthy of consideration. Some time ago I had occasion to analyze the accidents that had taken place during two years in a large machine shop manufacturing light and medium weight, automatic and semi-automatic machinery. The records from which the analysis was made were of the best. The plant has a well equipped emergency hospital, in charge of a registered male nurse, and keeps an accurate record of every case that is treated, no matter how trivial it may seem to be.

The average number of employees for the two years under consideration was 2590. The number of cases treated during the two years, practically all injuries, but most of them of minor importance, was 5208, or about one per employee per year. The number of serious injuries or accidents was 174, divided as follows:

| | |
|---|---|
| Lacerations and contusions of fingers, hands, wrists and forearms... | 99 |
| Lacerations and contusions of feet and legs...................... | 28 |
| Lacerations and contusions of face and head...................... | 16 |
| Miscellaneous.................................................... | 11 |
| Received in drop forging shop.................................... | 13 |
| Received in iron foundry......................................... | 7 |
| Total.......................................................... | 174 |

Disregarding the accidents received in the drop forge shop and foundry, and computing the machine shop accidents in percentage, we find that 64 per cent were in the nature of accidents to the fingers, hands, wrists and forearms, 18 per cent to the feet and legs, 10 per cent to the face and head and 8 per cent to other parts of the body.

Without taking time to present the analysis for the agent of the accident in detail, the two most prolific sources should be pointed out. One is the milling machine. Thirteen per cent of the accidents under consideration were from milling machines. In two cases amputations resulted. One of the most distressing machine shop accidents that I know of is the severing of the tendons of the wrist on a slitting saw or thin mill. I have seen several such accidents and in no case did the wound heal in a manner to leave the hand of much use thereafter. Yet the safeguarding of a milling cutter is an easy matter.

The greatest single source of accidents was from falling objects, in amount 24 per cent. Most of these were from castings and forgings that slipped from trucks while being transported, or fell from piles of material, or were dropped by the man injured or a fellow workman. This emphasizes the need of suitable transporting devices in shops and care in piling the material to prevent its falling.

Mr. Calder has not treated of the hazards around elevators and vessels under pressure, saying that of all industrial dangers they have received the most attention from engineers. While this is so, more needs to be done in certain directions.

The usual safety elevator gate constructed with a few horizontal bars, the lower one being from 8 to 12 in. from the floor, is to be condemned. Such a gate offers no safeguard to prevent objects from rolling into the elevator well. A single accident from my own experience will emphasize this point. A barrow of pig iron had been unloaded from a foundry elevator into the cupola charging floor. The elevator immediately descended. A helper in moving the barrow tipped it to one side, a half pig of iron fell off, rolled across the floor, passed underneath the bar of the so-called safety gate and fell. One man was instantly killed, a second seriously injured. Yet the gate was of a commonly approved type, hundreds of which are in use every day.

New processes often bring new hazards. The use of the oxy-hydric and oxy-acetylene fusing and cutting apparatus is our latest illustration in the machine-building field. Several fatal accidents have already occurred. On February 22 of last year an accident took place with an oxy-acetylene apparatus in this city, in which one man was instantly killed, a second seriously injured and a resulting fire caused considerable property loss. I investigated that accident and the facts as I was able to learn them are these:

The apparatus as furnished by the manufacturer consisted of two retorts for generating oxygen, gas scrubbers, an acetylene generator and the connecting piping and torches. The oxygen retorts were each a seamless cup, closed by a flanged head screwed into place. The acetylene generator was a seamless tank. To increase the capacity of this apparatus a large riveted tank was connected by the user into the oxygen system to serve as storage space. This riveted tank was apparently the one that exploded. It was ruptured nearly its entire length and was almost turned inside out. The flanged head was blown off from one of the oxygen retorts—perhaps by a flying piece from the storage tank.

This shows the ignorance that exists on the part of some users of apparatus of such serious hazard. Gases are confined under considerable pressure; one is inflammable in the air. If both are mixed together in proper proportions the mixture is violently explosive, and when in use they give some of the hottest flames used in industrial processes.

Here is a field in which some authoritative action should be taken. What is needed is a series of recommendations in regard to the design, installation, care and use of oxy-acetylene and oxy-hydric apparatus, with particular reference to safety; including tests that may be applied to new apparatus or apparatus in use to make sure that it is safe. This will be to the advantage of maker, owner and user of the appliances, alike.

Something has been done by the National Board of Fire Underwriters in recommendations seeking to reduce the fire hazard, but I believe that more is needed. Ultimately, we may look for legislative action, but we need something to bridge the interim and to form an intelligent basis for laws when they are drafted and passed.

A. Taylor. Little literature is even now available on the subject of accidents and their prevention, so that the average employer has been compelled to learn almost solely from his own experience and to endeavor to safeguard the future by his knowledge of the past instead of having the experience of others to assist him as is the case in so many other lines of work. It is fair to presume that when circumstances permit not only of a freer interchange of ideas but of the formation of some central bureau where such ideas may be properly compiled and then universally disseminated, there will be relegated to the preventable class a certain percentage of the accidents now designated as natural hazards incident to the various occupations, and any move with this desirable end in view should accordingly be facilitated in every possible way.

Every works should have its supervisor of safety appliances who should be an experienced mechanical engineeer and whose duties in whole or in part should be to see that the danger of accident from whatever cause, whether from machine tools, fire, steam, electricity, pits, translating devices, etc., is either eliminated entirely, or failing this, is minimized to the smallest degree. In any plant where work of this kind is being systematically introduced it will be advisable to consider the tools and other appliances as capable of division into three classes: first, those which should receive immediate attention as being dangerous in the extreme, and which should, therefore, be guarded without delay; second, those which are capable of producing injury but are of a minor character and the guarding of which may consequently be taken up after the more dangerous machines have been guarded; third, those in which the chance of injury is so remote as to be a negligible quantity and which accordingly need not be guarded at all.

It will also be found that the work involved is not alone one of installation but of up-keep as well, for it must be admitted that in many instances the guards employed, while performing their function, do so at the expense of production and under such circumstances are liable to be removed by the unthinking among the workmen; and for this same reason perhaps continue to be left off by the foreman under the mistaken idea that they are thus serving the best interests of all concerned. On the other hand, it will occasionally be noted that the use of properly designed safety appliances has actually increased production, as for instance, roll and inclined feed or suction and blower devices when applied to punch presses, etc., instead of the usual hand feed.

Doubtless the limits of the paper prevented the author from touching upon the guarding of traveling cranes by providing them with limit switches, thus preventing operators from over running and perhaps dropping the loads, with damage to property and risk to life. When cranes are unprovided with proper mounting platforms and are not too high up, it is sometimes advisable also to equip them with rope ladders whereby the operators are enabled to reach and leave their cages without the necessity of clambering over the cranes, thereby avoiding any possibility of falling or of shock from contact with the trolley wires. The sides of elevators should be guarded by low foot boards to prevent articles from going through to the floors below, and where this cannot be done, as on the open or approach side, the floor should, if possible, be given a slight rise. The same reason calls for similarly guarding stairs, and wide stairs should be provided with central railings. Hatchways and shafts should be lined with netting to safeguard heads, arms and feet, and elevator gates should likewise be so arranged, and moreover be sufficiently high to prevent leaning the arms on them or looking over them.

In the line of indirect safety appliances, if the term may be used, due importance, as the author of the paper points out, is not usually given to adequate lighting. A very great majority of factories, it is safe to say, are still illuminated by spot or individual lighting, a method considered obsolete, except in special cases, since the advent of incandescent and vapor lamps of medium candle power which now enable diffused lighting to be used. Unfortunately it is impossible to prove by the commonly accepted method of dollars and cents, to what extent betterment in lighting reduces the liability of accident, though it will be patent to everyone that the elimination of shadows by the use of diffused lighting in place of individual or spot lights with their sharp light and shadow effect must exert a very considerable influence, since eye-strain is wholly done away with; moreover, production is most certainly increased and the quality of the work improved.

Going perhaps a little further away from the subject, but nevertheless always a source of anxiety to the management, is the risk to life and limb when employees are boarding street cars and trains upon leaving work, the only solution to which problem is to coöperate with the railroads in the erection of suitable fences, gates or enclosures.

H. Gardner. Mr. Alexander referred to the advisability of properly instructing shop men and particularly apprentices in regard to the dangers of handling the machines they are operating. If we can bring to the men and the apprentices a proper realization of the dangers to which they are subjected and explain the exact location and nature of this danger in such a manner as to make them able to take proper precaution there will be less need for the more extravagant and elaborate types of safety devices.

The New York Central Lines with which I am employed have some 650 apprentice boys working in the several shops and we have found it profitable to inject into our educational courses carefully written suggestions relating to the care of self as well as the care of the machines. I would think that a dull boy going to the shop with a proper realization of the dangers to which he is exposed would be less liable to injury and less in need of guards around the machines than perhaps a brighter boy or even a mechanic who had not the advantage of being thus forewarned. The Brown and Sharpe Manufacturing Company have issued a hand-book for apprentice machinists containing paragraphs which ably present to the boy the need for proper care in handling machinery and undoubtedly the apprentices which Mr. Alexander has in his school at West Lynn are provided for in a similar manner.

We find that the instructor employed to train apprentices may be held largely responsible for accidents in the shop and it may be considered distinctly a part of his duty to point out the danger and stimulate individual responsibility in properly caring for machines and tools. There is no question but that proper education and instruction can help greatly in this direction.

Oberlin Smith. The paper just read is a very interesting and comprehensive one and should be followed in this and sister societies by many other papers upon this very important subject. It was of course impossible in treating such a great variety of machines to deal with each kind in detail. It is very desirable that the paper should be amplified by a treatise upon each particular kind of machine. It may be that experts in the different branches of manufacturing can be induced to write a series of papers, each one in regard to his own specialty. In this discussion, I will limit myself to that most dangerous class of implements known as presses and dies, it so happening that I am especially familiar with their doings and misdoings.

The first kind of danger incident to these machines, and one which threatens people in general moving about a shop, rather than the operator, is obviously the chance of being drawn in by belts and gearings. This can be obviated by guards arranged in any of the ordinary ways, some of which are shown by Mr. Calder.

In an experience, however, of some 40 years with these machines, I have known but few accidents of this kind. In my own practice I have not equipped presses with complete guards unless especially ordered and paid for by the customer, but a partial guard has always been placed between each pair of gears on the in-running side. This guard consists of a casting somewhat wider than the face of the gears, extending from the point of tooth contact through a considerable arc in the form of curved plates nearly touching the teeth. This has seemed to serve almost as good a purpose as guards running entirely around the gears and is not prohibitive in cost when included in the price which buyers will pay.

The next and most frequent kind of accident pertaining to a power press is the contusion or shearing off of fingers and hands by being between the dies when they come together. This often occurs through pure carelessness on the part of the operator. In cases where he lets the ram of the press run continuously, trusting to luck and to a certain acquired automatic rhythmic movement of his hands, any mental disturbance of the rhythm, as a sudden movement or noise in his vicinity, or a desire to look round for something happening in the street, may prove disastrous. Of course this cannot occur if the machine is arranged as it should be, so that his fingers cannot possibly go between the dies.

A more frequent accident occurs when the ram of the press is allowed to stop between each stroke by the action of the automatic stop-clutch generally embodied in these machines. Each operation consists in placing the work between the dies and then depressing the treadle, or in some rare cases a handle, which throws the clutch into mesh so that the continuously revolving flywheel operates the shaft through one revolution and then stops it. This performance is safe even if the fingers have been between the dies, providing they are taken out before the treadle is depressed and not put in again until the ram is surely stopped in up-position. It often happens, however, especially with piece work, that the treadle is depressed almost immediately after the ram is stopped so that again there is needed a certain rhythm common to the finger motions and the halting continuity of the ram motion. Under these conditions it is probable that most of the accidents happen because the treadle is not allowed to rise entirely to its upper position, that is, far enough to insure positively the stopping of the ram. In such a case it comes down a little sooner than is expected, and an injury to the hand is the result. A remedy for this evil has been devised by the writer and some other press makers in the shape of a device by which the clutch-lever detaches itself from the treadle action, each time the latter is depressed, by means of a cam upon the main shaft, which itself performs the stopping action of the clutch. This, if kept in order, will provide safety and is a valuable device.

A similar trouble may happen by the clutch being out of order so that the treadle and tripping device, often known as a clutch-lever, do not rise as promptly as they should, owing to the binding of some parts, or the weakening of springs which, perhaps, have not been kept in proper adjustment. An occasional trouble causing the ram to descend unexpectedly is the cutting or seizing of the flywheel, or gear upon the shaft. This, of course, is due to the lack of oil, or the presence of dirt, or both, between the wheel and the shaft. Nothing but correct automatic lubrication would seem to be a cure for it, and this is not usually applied to presses.

The cases are rare where fingers are deliberately placed between the dies and then the machine prematurely started, but even this happens sometimes. The only safe rule to follow, as a preventive of all the different kinds of accidents above referred to, is never to put fingers, hands, or arms between dies, while the flywheel or gearing of the press is in motion, even though the clutch may be fastened out of action by a clutch-lock, such as the writer has devised and always used, and further never so to place the fingers between the dies when nothing is in motion, without putting a block of some kind under the ram, or between the dies so that the ram cannot possibly descend by its own weight, or from other causes. Instead of such a block a safety-post might be made which could be swung up or forward underneath some part of the ram when not in action. In cases where hand feeding is practised, such a rule is difficult to enforce. The employers do not like it because it sometimes lessens the speed of feeding and the workmen dislike it for the same reason, when practising piece-work, or when expected to perform a given task. Even if ordered thus to protect themselves they often disobey simply from recklessness.

It would seem from the above facts that particular attention should be given to developing protective devices in and about the dies. This is done in many kinds of work, but it is difficult to make any general attachment to a press that will meet all the very numerous conditions attending the work done therein. Of course the dangers alluded to can be almost eliminated when strictly automatic feeds are used.

Considering first, primary operations, as the working of cutting, punching or shearing dies, all of which may easily be protected, the most usual feeds are:

*a* Single or double roller-feeds, where the flat sheets or bars of metal or other material are held by spring pressure between intermittently revolving rollers.

*b* Reel-feeds, where flexible metal or other material, in strips, is pulled through the dies from one reel with a brake upon it by another intermittently revolving reel upon which it is rewound.

*c* Grip-and-push or pull-feeds, generally made with a pair of stationary grippers and a pair of reciprocating sliding grippers, these latter alternately gripping the edge of the material and carrying it through the dies any desired distance at each stroke of the press.

*d* Gravity-feeds, where the press ram axis is inclined at an angle to the vertical, perhaps even to a horizontal position, and the material descends by gravity against a let-off gage, placed back of the dies, working automatically.

Concerning feeds for seconding operations the most usual kinds are:

*e* Dial feeds for redrawing, forming, curling or repunching work. A common well-known form consists of an intermittently rotating disc in the respective apertures of which the work is put by hand at the front of the press, far away from the dies, and is carried around until it reaches them, in some cases a group of dies performing successive operations upon it.

*f* Friction-disc feeds, where the articles are pushed from a table on to a flat revolving disc which carries them by friction between certain fences or guides and which delivers them under the dies. They are stopped by a let-off device to limit the motion of each one as it arrives in final position.

*g* Push-feeds, where a sliding carrier comes forward to receive the work and then carries it back between the dies again, coming forward for another piece.

*h* Tube-feeds, used especially for small articles like coins, medals, etc., which are piled upon each other in a tube and allowed to descend by gravity so as to be fed to the dies by any one of the methods, *e*, *f* and *g*, usually, however, with the last.

Feeds *f* and *h* are practically safe against hurting the fingers, while with *e* and *g* there is some little danger of getting the fingers in the feeding device itself, if they are not removed quickly enough before it starts; they cannot, however, be easily carried back to the dies. When devices of this sort are used, by stopping the press at each stroke while the work is being placed in the dial, or carrier, absolute safety is assured.

Returning to the consideration of hand-feeding: With thin metals, mere cutting operations can be made entirely safe by using a proper stripper surrounding the punch. This should fit very close to the punch and come down as close to the top of the die as possible to allow the metal to go between, and it should be quite thin so as not to obstruct the view of the work outside the limits of cutting. It should also be so high that the punch at the top of its stroke never comes entirely out of it, thus giving no chance for fingers to be put in above it. With thick metals, the stripper has obviously to be placed so high that fingers can be put in under it.

In the case of forming, repunching, etc., where small objects must be located between the dies and sometimes a considerable distance in from the front thereof, it is nothing but criminal to allow the operators' fingers ever to go between. The inserting and removing of the work should always be done with a stick of pine wood, or some other soft material, which will not damage the dies if they happen to come down at the wrong time.

In general, where hand feeding is resorted to, there is no universal panacea for the evils in question. Careful attention to all of the points above mentioned, however, will reduce the percentage of danger to a very small figure, especially if there is any such rigid discipline, backed both by altruistic and financial motives, as will absolutely prevent fingers being put between dies. It may be stated that in any ordinary press shop where thousands of different kinds of work are to be done, and perhaps only small batches of a few thousand, or a million or two, of pieces are to be made, it is very expensive to provide all of the different kinds of automatic feeds and guards that would be needed for the varying kinds of work. If, however, we should get our much desired uniform state laws providing reasonable penalties for the carelessness and parsimony that produce our present numerous accidents it is probable that the volume of them will greatly decrease.

The writer has frequently had inquiries for safety apparatus for a room full of presses but has always been obliged to reply that each press and each pair of dies must be considered separately, and that much expert designing would have to be done for special devices to suit each varying condition. Some of these would of course be simple, but others would have to be automatic in their character and, on the whole, quite expensive. Hence, not many press manufacturers have gone into this matter thoroughly, principally because they know that their competitors would not be obliged to do the same.

The Author. It is gratifying that so much practical sympathy with the movement for prevention of industrial accidents exists within the Society, as exemplified by the participators in this discussion. The subject is a large one which demands for its full consideration a treatise instead of a paper and the author, being necessarily limited in the length of the paper and the number of illustrations permissible, has chosen to dwell mostly upon causes and principles and to illustrate these from the machinery elements which are most generally created and maintained in industrial establishments by the mechanical engineer to whom the paper is specially addressed.

All dangerous apparatus not detailed in the paper is not thereby to be considered of less importance. Its protection follows as a matter of course if the general contentions of the author are admitted. It is not the writer's experience that accidents invariably or even most frequently arise out of unrestrained or unguarded applications of power, though a number of very serious ones do.

Engineers in responsible control of industrial establishments and in daily contact with their accident risks are well aware that a large number of accidents, especially of the minor kind, have nothing to do with power machinery and are not preventable by specific safety devices. Many of them may be prevented, however, by the mechanical engineer through suitable structural precautions, caution and instruction of workmen, and cultivation of a safe-working habit of mind in foremen and overseers as well.

The totally inadequate financial and technical provision made by the various States for administration of accident prevention laws is well known and no employer should be content to rely for safety upon the infrequent visits of State officials.

If the members of the Society and the staffs of professional accident investigators attached to the casualty insurance companies will pool their practical experiences in discussions such as this, the writer feels certain that much good will be accomplished.

# GAS POWER SECTION

## PRELIMINARY REPORT OF LITERATURE COMMITTEE

## (VII)

### ARTICLES IN PERIODICALS[1]

Aero and Motor Boat Exhibition at Olympia, The. *London Engineering, March 31, April 7, 1911.* 5⅓ pp., 7 figs., 4 tables. *b.*

A description of several sizes and types of English aero and marine engines.

Dieselmotoren, Thermodynamische untersuchung schnellaufender, M. Seiliger. *Zeitschrift des Vereines deutscher Ingenieure, April 15, 1911.* 5 pp., 8 figs., 3 tables, 5 curves. *b.*

An article on the thermodynamic investigation of high-speed Diesel engines. Notes great improvement in recent years.

Dieselmotoren, Uber die Verwendung von Teer in, K. Kutzbach. *Journal für Gasbeleuchtung und Wasserversorgung, April 29, 1911.* 3 pp., 1 fig., 4 curves. *A.*

Report of test of a Diesel motor using tar for fuel.

Dieselmotoren, Verwendung von Vertikalofen-Teer für, *Zeitschrift des Vereines deutscher Ingenieure, April 22, 1911.* ⅔ p., 1 table, 1 curve. *acf.*

An article on the value of tar fuel for the operation of Diesel oil engines.

Dieselmaschine für Schiffsantrieb, Eine doppelwirkendte, umsteuerbare Zweitakt. *Zeitschrift des Vereines deutscher Ingenieure, May 20, 1911.* 1/16 p.

A paragraph notice of an article in *Engineering, May 5, 1911,* on a double-acting reversible two-cycle Diesel engine for ship propulsion.

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[1]Opinions expressed are those of the reviewer not of the Society. Articles are classified as *a* comparative; *b* descriptive; *c* experimental; *d* historical; *e* mathematical; *f* practical. A rating is occasionally given by the reviewer, as *A*, *B*, *C*. The first installment was given in The Journal for May 1910.

Dieselmotoren, Die Abwärmeausnutzung bei, M. Hottinger. *Zeitschrift des Vereines deutscher Ingenieure, April 29, 1911.* 6½ pp., 8 figs., 2 tables, 3 curves. *bf.*

Engines For Sea-Going Vessels, Diesel, J. T. Milton. *The Mechanical Engineer (Manchester, England), April 14, 1911. abf.*

A serial article noting certain advantages of such motive power. Cites conditions to be met.

Engines for Sea-Going Vessels, Diesel. *The Engineer (London), April 14, 1911.* ¾ p. *Aaef.*

Criticism of J. T. Milton's paper read at a meeting of naval architects. Article sets forth the economical advantages of the internal-combustion engine over those of the steam engine, also developments that may be expected in the near future, and prophesies oil engines of 20,000 b.h.p.

Engine, Lamplough's Two-Cycle Internal-Combustion. *The Mechanical Engineer (Manchester, England), April 14, 1911.* ½ p., 3 figs. *b.*

Account of a new arrangement of such engine.

Engine, A 1000 Horsepower Marine Oil, J. Rendell Wilson. *International Marine Engineer, May 1911.* 1 fig., ½ p.

A description of large 4-cylinder engine for a Congo boat.

Engine, A 180 Horsepower Marine Oil. *The Engineer (London), May 26, 1911.* 1½ pp., 5 figs. *Abf.*

Description of the Parson's oil engine (6-cycle) with compressor plant and reversing gears.

Engines, Diesel Marine, Th. Saiuberlich. *The Engineer (London), April 7, 14, 1911.* 6 pp., 23 figs., 5 tables, 3 curves. *Abf.*

Detailed description of the 200 h.p. and 90 h.p. oil engines for the propulsion of the service boat Frerichs and lugger Ewersand. Also description of the boats, giving their dimensions, operating expenses, etc.

Gases, The Methods of the U. S. Steel Corporation for the Technical Sampling of, J. M. Camp. *Metallurgical and Chemical Engineering, June 1911.* 4½ pp., 3 figs. *be.*

Description of methods and apparatus used for sampling and analysis.

Gas Engines for Power, John H. Norris. *The Gas Engine, May 1911.* 2 pp., 1 table. *Aadf.*

Paper read before the National Commercial Gas Association, Boston, giving various purposes for which the modern gas engine is used; also the B.t.u. consumed per b.h.p., and the cost per h.p. month of 234 working hours.

Gas Engine and Producer Plant on the Yacht Progress, 100 i.h.p. *London Engineering, June 2, 1911.* 3 pp., 13 figs.

Description of plant and its operation. Details of engine construction. Engine is 2-cycle, double-acting, with three cylinders, 8½ in. diameter by 9 in. stroke. It develops 100 i.h.p. at 200 r.p.m. and is supplied with gas from a suction producer, which has been worked with anthracite, with coke and with coalite.

Gas Engines in English Steel Mill, Two-Cycle. *The Gas Engine, June 1911.* 2½ pp., 1 fig. *bf.*

Description of four single-cylinder double-acting gas-driven blowing engines, two-cycle type, 1050 b.h.p. each cylinder cycle 35½ in. by 55½ in. stroke, 70 r.p.m. These blower engines are installed in the English Frodinghar Iron & Steel Co.'s works.

Gaserzeuger Bauart Hilger, Der Drehrost, Robert Bertelt and Georg Kassel. *Stahl und Eisen, April 6, 1911.* 1½ pp.

Correspondence anent the Hilger revolving grate gas generator.

Gaserzeuger, Der Drehrost und Dremantel, Bauart Küppers, Dr. Mardus. *Stahl und Eisen, April 20, 1911.* 4 pp., 3 figs., 1 table. *b.*

An article on the Küppers gas generator with revolving grate and revolving jacket.

Gasoline-Electric Car of the Buffalo, Rochester & Pittsburg Railway. *Engineering News, May 11, 1911.* ½ p., 2 figs.

Short description of car for branch line service built by the General Electric Co.

Gas Plants for Bituminous Coals, Holbeck. *The Iron Age, May 18, 1911.* 1 p., 1 fig. *bf.*

Gas producer apparatus designed to use bituminous coal and lignites and interesting in respect to a rotary washer for cleaning the gas.

Gas Power in Germany, Peat, F. E. Junge. *Power, June 6, 1911.* 2 pp., 1 fig. *abf.*

Description of the Heinz peat gas producer.

Gas Power Plant, A Municipal, T. E. Butterfield. *Power, May 2, 1911.* 3½ pp., 7 figs., 1 table. *ab.*

Description of a gas-power fire pumping station at Haddonfield, N. J. Operating features of the plant with table showing comparative cost of pumping water by steam and producer gas power.

Gas Producer, The Effect of Varying Proportions of Air and Steam on a. *The Engineer (London), May 5, 1911.* 1½ pp., 9 figs., 7 curves. *Abcef.*

Abstract of a paper read by E. A. Allcut before The Institution of Mechanical Engineers, April 28, 1911.

Gas Producers, J. E. Dowson. *London Engineering, May 5, 1911.* 4 pp., 6 figs., 15 tables. *Abcdf.* Also *The Engineer (London), May 12, 1911.* 2 pp., 6 figs., 4 tables.

Paper read before The Institution of Mechanical Engineers, London, April 28, 1911. A discussion on the different types of producers and systems of gas production with analysis of gas obtained.

Gas Producer, The Effect of Varying Proportions of Air and Steam on a, E. A. Allcut. *London Engineering, May 5, 1911.* 4 pp., 2 figs., 2 tables, 10 curves. *abc.*

Paper read before The Institution of Mechanical Engineers, London, April 28, 1911. Objects of research, record of tests. Description of plant and arrangement for trials. Analysis of gases and efficiency of producer.

Gas Producers, W. A. Tookey. *The Gas Engine, June 1911.* 9 pp., 4 figs. *ABabdf.*

Extract from paper read before the British Association of Engineers-in-Charge. Descriptive of various producers in general, including charcoal and coal dust producers, scrubbers, tar extractors, etc.

Gaspumpen und Kompressoren Humphrey, R. Dierfeld. *Journal für Gas und Wasserversorgung, April 15, 22, 1911.* 11 pp., 14 figs., 3 tables, 6 curves.

*Abcf.* Description of details of Humphrey gas pumps.

Gasreinigung, Die Entwickelung der, H. Wolfram. *Journal für Gas und Wasserversorgung, April 1, 8, 1911.* 13½ pp., 3 figs. *Abf.*

Methods of cleaning and purifying illuminating gas.

Generator Gas Locomobile. *Praktischer Maschinen Konstructeur, March 16, 1911.* ½ p., 2 figs. *Cb.*

Description of a gas engine outfit made by Capel & Co., Dalston Lane, N. E., consisting of gas producer, condenser, scrubber and engine. Gas engine cylinder diameter, 9 in., stroke, 15 in., flywheel diameter 4 ft. 8 in. Claimed to weigh by ⅓ that of a steam locomotive. Ready for service in 15 minutes. Operating cost $\frac{1}{10}$ of steam locomobile.

LIGHTING PLANT, A GAS-ENGINE. *The Gas Engine, May 1911.* 1 p., 1 fig. *Babf.*

Description of a 1000 h.p. gas engine, direct-connected to a 480-kw. generator, running on 24-hr. per day lighting service.

LIQUID-FUEL SUPPLY, Henry Hale. *Cassier's Magazine, May 1911.* 14 pp., 14 figs. *Abdf.*

Developments in the oil fields of the Western United States giving yearly output and calorific value compared with coal.

LUFTGAS, UEBER, Busch. *Journal für Gas und Wasserversorgung, April 8, 1911.* 5 pp., 4 figs., 5 tables. *A.*

Description and reports on pent air gas plants.

MOTOR-CÔTE

A new type of gasoline motor, simple in design; remarkable arrangement of pumps.

MOTEURS À GAZ. *Revue de Mécanique, April 30, 1911.* 11 pp., 40 figs., 2 tables.

Description and cuts of the following types of gas engines and gas motors: Anderson Foundry, Glasgow; Gas Power Co., Elyria, O.; Hamilton, Sandiacre, two-cycle motor; Fullagar, Head New Castle, two-cycle motor; Hopkins, Manchester, two-cycle motor; Barclay, Birkenhead, two-cycle motor; Pengemet, Billancort, two-cycle motor; Kilburn, Bolton, two-cycle motor; Badger & Whitacker, Rotherham, two-cycle motor.

MOTEURS À PETROLE SANS SOUPAPES, QUELQUES. *Le Mois Scientifique et Industriel, April 1911.* 4 pp., 12 figs.

MOTEUR ROTATIF, ROOTS. *Fer et Acièr, March 1911.* 5 pp., 1 fig.
Description of a rotating gas motor, Root System.

MOTOR SHIPS, FRENCH AUXILIARY, J. Peltier. *International Marine Engineer, May 1911.* 3 pp., 6 figs.

Description of adaptation of oil engines as auxiliaries to sailing vessels by French merchants.

POUSSIÈRES COMBUSTIBLES, ÉTUDE COMPARATIVE AU POINT DE VUE DE L'INFLAMMABILITÉ, DES, Taffanel and Durr. *Comité Central des Houilleries de France, April 1, 1911.* 6 pp., 10 figs., 1 table. *Acf.*

Comparative study of combustible gases (mines) in reference to their inflammability.

PRODUCER GAS, FORMATION OF, J. K. Clement, L. H. Adams and C. N. Haskins. *The Gas Engine, June 1911.* 2 pp. *Bcf.*

Extract from Bulletin No. 7, Bureau of Mines.

PRODUCER-GAS POWER PLANT, A 1000 H.P. OIL FUEL. *Engineering News, May 18, 1911.* 1 p., 2 figs.

Descriptive of gas electric power station being built for the Holton Power Co. of El Centro, Cal., from information furnished by International-Amet Gas Power Co. and Allis-Chalmers Co.

PRODUCER-GAS PLANT, A BITUMINOUS. *Power, April 25, 1911.* 2 pp., 3 figs.

Description of plant and details of operation.

PRODUCER GAS FROM CRUDE OIL, E. C. Jones. *The Gas Engine, June 1911.* 1½ pp., 3 tables. *Abcdef.* Also *Power, May 23, 1911.* 1 p., 3 tables.

A paper presented at the San Francisco meeting of The American Society of Mechanical Engineers treating of the production of gas from crude petroleum.

PRODUCER GAS YACHT, A. *The Gas Engine, May 1911.* ½ p. *Cbcf.*

Description of 54 ft. yacht being built by McLaren Bros., Scotland, equipped with 45 h.p. gas engine, producer, electric generator and motor for propulsion.

PUMP, INTERNAL COMBUSTION, THE BABCOCK TWO-CYCLE. *London Engineering, May 5, 1911.* 1¾ pp., 5 figs. *bc.*

A self-contained water pumping unit.

TRACTOR, OIL RAILWAY. *The Engineer (London), May 12, 1911.* 1 p., 3 figs., 1 table. *Cbf.*

Thirty h.p. tractor on a railway in India. Speed 25 miles on level, capacity 18-20 tons up incline of 1 in 150. Fuel, paraffin.

TRUNK PISTONS FOR GAS ENGINES, FITTING, O. Olafsen. *Power, April 18, 1911.* 2 pp., 2 figs., 3 tables. *f.*

# GENERAL NOTES

## AMERICAN INSTITUTE OF CHEMICAL ENGINEERS

The third semi-annual meeting of the American Institute of Chemical Engineers was held on June 21-24 at the Congress Hotel, Chicago, Ill. Papers were presented on the Four-Year Chemical Engineering Course, J. H. James; Industrial Chemical Calculations, J. W. Richards; A New System of Lead and Silver Lining for Chemical Apparatus, C. L. Campbell; The Practical Value of Calorific Tests on Anthracite Coal, S. F. Peckham; and other subjects. Excursions were made in conjunction with the meeting, to the plant of Swift and Company, and that of the Corn Products Refining Company at Argo, the laboratories of the Dearborn Drug & Chemical Works, and the works of the By-Products Coke Corporation at South Deering, the Carter White Lead Company, West Pullman, and the Indiana Steel Company at Gary. A dinner was held on June 22 at the Congress Hotel.

## SOCIETY OF AUTOMOBILE ENGINEERS

The summer meeting of the Society of Automobile Engineers was held at the Algonquin Hotel, Dayton, Ohio, on June 15-17, 1911. The meeting was opened on Thursday at 8.30 a.m., by the president, Henry Souther, Mem. Am. Soc. M. E., who made an address. Reports were received from the Standards Committee, iron and steel division, given by Henry Souther, Mem. Am. Soc. M. E., aluminum and copper alloys division, by W. H. Barr, seamless tubes division, by H. W. Allen, Mem. Am. Soc. M. E., and nomenclature division, by P. M. Heidt. Papers were presented on the Question of Long vs. Short-Stroke Gasoline Motors, by J. B. Entz, and Long Addendum Gears, by E. W. Weaver. At the professional session on Thursday evening, Commercial Vehicles was the topic for discussion, with a paper on the Influence of the Engineer on the Sales Department, by W. P. Kennedy. The professional session of Friday morning included papers on the Elements of Ball and Roller Bearing Design, by A. C. Koenig, and Worm Gears and Wheels, by E. R. Whitney, with reports from the Standards Committee, among others, the ball-bearings division, by David Fergusson, and the breaches division, by Charles E. Davis, Mem. Am. Soc. M. E. The final professional session, held Saturday morning, included papers on Rotary Valve Gasoline Motors, by C. E. Mead, Some Points on the Design of Aluminum Castings, H. W. Gillett, Oversize Standards for Pistons and Rings, James N. Heald, and reports of Standards Committee, lock washer division, J. E. Wilson, Mem. Am. Soc. M. E., sheet metals division, J. H. Foster, and others. On the afternoons of Thursday and Friday, aeroplane flights on the Wright brothers' grounds were viewed, and excursions were made to factories, while on Saturday a banquet was held at the Automobile Country Club, with an address by Arthur Ludlow Clayden, editor of the Automobile Engineer (London).

## NATIONAL GAS AND GASOLINE ENGINE TRADES ASSOCIATION

The meeting of the National Gas and Gasoline Engine Trades Association was held on June 20-23, 1911, at the Hotel Pontchartrain, Detroit, Mich. Papers were presented at the professional sessions on the Relation of Ignition to the Sales Department, R. H. Combs; on the Development of Farm Power, J. E. Waggoner; the Work of the Colleges in connection with Agricultural Power, J. B. Davidson, Mem. Am. Soc. M. E.; the Commercial Side of the Agricultural Power Question, P. E. Edwards; Aeronautic Motors, E. W. Roberts; and others. Trips were made to a number of the automobile and engine factories in Detroit and an excursion taken on the lake.

## AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS

The 28th annual convention of the American Institute of Electrical Engineers was held on June 26-30, 1911, at the Hotel Sherman, Chicago. Sessions were held on Power Stations, Electric Lighting, Railways, Industrial Power, Telegraphy and Telephony, Education, and High Tension, at which a large number of papers were presented and discussed, including the Development of the Modern Central Station, C. P. Steinmetz, Mem. Am. Soc. M. E.; Tests of Oil Circuit Breakers, E. B. Merriam; Important Features entering into Making of Appraisals, H. M. Byllesby, Mem. Am. Soc. M. E.; Some Data from the Operation of the Electrified Portion of the West Jersey and Seashore Railroad, B. F. Wood, Mem. Am. Soc. M. E.; Analysis of Electrification, W. S. Murray; Induction Machines for Heavy Single-Phase Motor Service, E. F. W. Alexanderson; Automatic Motor Control for Direct-Current Motors, A. C. Eastwood; Control of High Speed Electric Elevators, T. E. Barnum; Multiplex Telephony and Telegraphy by Means of Electric Waves guided by Wires, George O. Squier; Transmission System of Southern Power Company, W. S. Lee, Mem. Am. Soc. M. E.; and Tentative Scheme of Organization and Administration of a State University, R. D. Mershon, Mem. Am. Soc. M. E. A number of trips were made to plants in the vicinity and social features for both members and ladies provided.

## AMERICAN WATER WORKS ASSOCIATION

The 31st annual convention of the American Water Works Association was formally opened at Rochester, N. Y., on June 6, by John W. Alvord, president. A number of committee reports were presented and the following officers elected: President, Alex. Milne; Vice-Presidents, D. R. Gwinn, R. J. Thomas, J. A. Affleck, G. C. Earl, Thos. Leisen; Secretary-Treasurer, J. M. Diven. It was decided to hold the next convention in Louisville, Ky. The following papers, among others, were presented at the professional sessions: Fire Line Meters, George Houston; Pumping Station Equipment and Management at Milwaukee, Thos. McMillan; Some Fundamental Considerations in the Determination of a Reasonable Return for Public Hydrant Service, Leonard Metcalf, Mem. Am. Soc. M. E., Emil Kuechling and W. C. Hawley; Wood-Stave Pipe, C. T. Hatton; Water Purification, J. L. Leal. A talk on the Panama Canal, illustrated by lantern slides, was given by D. H. Maury, Mem. Am. Soc. M. E.

## NATIONAL ELECTRIC LIGHT ASSOCIATION

The National Electric Light Association held what is considered to be the largest technical convention ever held in this country in the Engineering Societies Building, New York, during the week of May 28, 1911, with a registration of 5149. The convention opened with a reception at the Hotel Astor on May 29, and many other social events added to the pleasure of the visitors, including trips up the Hudson River and to Coney Island, as well as excursions to places of technical interest. Owing to the large number of sessions, it was necessary to hold simultaneous meetings. Many valuable reports on subjects of interest to the association were presented, representing extended research and experimental work on the part of the committee. The meeting at which was given the report of the Public Policy Committee, consisting of C. L. Edgar, Mem. Am. Soc. M. E., N. F. Brady, E. W. Burdett, H. M. Byllesby, Mem. Am. Soc. M. E., H. L. Doherty, Mem. Am. Soc. M. E., W. W. Freeman, G. H. Harries, Saml. Insull, J. B. McCall, Saml. Scovill, C. A. Stone, Mem. Am. Soc. M. E., and Arthur Williams, was held at the New Theatre, where an address was made by the Hon. Charles Nagel, Secretary of Commerce and Labor. A session on rate-making was held during the convention, at which a number of papers were presented, including Breadth of Vision in Public Utility Appraisals, H. M. Byllesby, Mem. Am. Soc. M. E.; Elements Affecting the Fair Valuation of Plant and Property, W. F. Wells; Standardizing Electric Sales, Douglas Burnett; Possibilities of Economy in the Operation of Light and Power Companies offered by Scientific Time Study, L. B. Webster, Mem. Am. Soc. M. E. Among the papers presented at other technical sessions were those on Grounding Low-Tension Circuits as a Protective Measure, P. M. Spencer; Recent Improvements in the Single-Phase Motors, M. A. Layman; Ventilation of Turbo-Generators, R. B. Williamson; Increasing the Flexibility and Reducing the Cost of Operation of Steam Boiler Plants by the Use of Fuel Oil, H. A. Wagner; and a Topical Discussion on the Operation of Transmission Systems, opened by D. B. Rushmore, Mem. Am. Soc. M. E.

The following officers were elected: J. F. Gilchrist, President; F. M. Tait, A. S. Huey, Vice-Presidents; and T. C. Martin and G. H. Harries were recommended for appointment as Secretary and Treasurer, respectively.

## AMERICAN INSTITUTE OF MINING ENGINEERS

At the meeting of the American Institute of Mining Engineers held at Wilkes-Barre on June 6–10, 1911, a number of technical excursions were made to points of interest to the membership, including the mineral spring breaker of the Lehigh Valley Coal Company, at Parsons, Pa., the Hazard Manufacturing Company, Wilkes-Barre, Pa., Hauto storage yard and the Lansford briquetting plant of the Lehigh Coal and Navigation Company, Lansford, the Summit Hill mine fire, the Mauch Chunk, Summit Hill and Switch-Back Railroad, both at Mauch Chunk and the Saucon and Lehigh plants of the Bethlehem Steel Company. Papers were presented on Geology of the Cobalt District, R. E. Hore; Lead-Smelting on the Ore-Hearth, J. J. Brown, Jr.; Use of Electricity in Anthracite Mining, D. B. Rushmore, Mem. Am. Soc. M. E.; Mine Rescue Work in Illinois, J. A. Holmes, Mem. Am. Soc. M. E.; Apparatus for Metallography, C. H. Hayward; and many others.

# PERSONALS

William M. Armstrong, formerly vice-president of the F. A. Goodrich Co., St. Louis, Mo., has been appointed treasurer of the Corrugated Bar Co. of the same city.

Earle J. Banta has been appointed general sales manager of the Davenport Locomotive Works, Davenport, Ia. He was until recently associated with the Vulcan Steam Shovel Co., Toledo, O., in the capacity of chief engineer.

Edward P. Bates will attend the fiftieth congress of the Institution of Naval Architects, which will be held in London on July 4. He is a delegate from the sister society in the United States.

Paul P. Bird, until recently smoke inspector for the city of Chicago, has taken a position with the contract department of the Commonwealth Edison Co., Chicago, Ill.

Frank G. Bolles has become associated with the Advance Sales Corporation, New York. He was formerly connected with the Reliance Engineering and Equipment Co., Milwaukee, Wis.

The degree of Doctor of Science was conferred upon John A. Brashear by Princeton University at its annual commencement on June 13th.

Willard C. Brinton, formerly with the Westinghouse Electric and Manufacturing Co., East Pittsburg, Pa., is now assistant vice-president of the U. S. Motor Co., New York.

A. H. Case has accepted the position of assistant manager of the Tennessee Copper Co., Copperhill, Tenn. Mr. Case was until recently identified with the Santa Fé Gold and Copper Mining Co., San Pedro, New Mexico, in the capacity of superintendent.

J. J. Chisholm, formerly chief engineer of power house of the Westinghouse Electric and Manufacturing Co., East Pittsburg, Pa., has assumed the duties of superintendent of power for the Tennessee Coal, Iron and Railroad Co., Ensley, Ala.

Farley G. Clark has been appointed superintendent of the Westinghouse Electric and Manufacturing Co., East Pittsburg, Pa. He was formerly connected with the P. T. & T. R. R. Co., Pennsylvania Station, New York.

Charles J. Davidson has resigned as chief engineer of power plants of the Milwaukee Electric Railway and Light Co., and as general superintendent of the Milwaukee Central Heating Co., to engage in private practice of engineering as a member of the firm of Woodmansee, Davidson & Sessions.

G. H. Gleason has become vice-president of The Dexter Engineering Co., Inc., Providence, R. I. He was formerly engineering salesman of the Dodge Manufacturing Co., Boston, Mass.

Charles Guckel has accepted a position with the Swan Falls Power Co., Nampa, Idaho, in the capacity of general manager. He was formerly secretary, treasurer and general manager of the Dover Electric Light Co., Dover, N. J., and the Rockaway Electric Light and Improvement Co.

Walter S. Hanson, formerly president of the El Reno Alfalfa Milling Co., El Reno, Okla., has been appointed manager of the Hollis Cotton Oil, Ice and Light Co., Hollis, Okla.

Parker H. Kemble, district manager of the Edison Electric Illuminating Co. of Brooklyn, N. Y., has been appointed sales manager of the Toronto Electric Light Co., Toronto, Canada.

H. B. Lange, formerly located in New York, has become associated with the American Optical Co., Southbridge, Mass., along lines of scientific management.

D. J. Lewis, Jr., has retired as manager of the Bundy department of the American Radiator Co., New York, and is now sales manager of the Lytton Manufacturing Corporation, New York.

J. R. McColl, of the firm of Ammerman, McColl & Anderson, has been appointed Dean of the newly organized engineering department of the University of Detroit, hitherto known as Detroit College.

Walter M. McFarland will represent the Society of Naval Architects at the fiftieth congress of the Institution of Naval Architects, to be held in London on July 4.

Cornelius T. Myers, formerly associated with the Wisconsin Engine Co., Corliss, Wis., as assistant secretary and assistant treasurer, has become identified with the General Motors Co., Detroit, Mich.

Horace Field Parshall has been appointed chairman of the Central London Railway, London, England.

Louis E. Polhemus has accepted a position with the Cubo Mining & Milling Co., Guanajuato, Mexico. He was until recently connected with the Mexican Light and Power Co., Necaxa, Mexico, as assistant master mechanic.

W. L. Saunders, president of the Ingersoll-Rand Co., New York, has been elected a director of the International Harvester Co.

Rupert K. Stockwell has accepted a position with the Tennessee Copper Co., Copperhill, Tenn. He was until recently associated with the Alpha Portland Cement Co., Easton, Pa., in the capacity of assistant general superintendent.

Charles E. Sweet has been appointed general superintendent of the Northway Motor and Manufacturing Co., Detroit, Mich.

C. N. Thorn has resigned his position of purchasing agent of Hugh Kelly & Co., New York, to become affiliated with the Allied Machinery Co. of America, New York, in the capacity of assistant general manager.

Paul C. Van Zandt has become district manager of Stephens-Adamson Manufacturing Co., Chicago, Ill. He was formerly connected with the cement department of the Allis-Chalmers Co., Chicago, Ill.

W. M. White, formerly hydraulic engineer with the I. P. Morris Co., Philadelphia, Pa., has assumed the duties of manager and chief engineer of the hydraulic turbine department of Allis-Chalmers Co., Milwaukee, Wis.

# ACCESSIONS TO THE LIBRARY

## WITH COMMENTS BY THE LIBRARIAN

**This list includes only accessions to the library of this Society. Lists of accessions to the libraries of the A. I. E. E. and A. I. M. E. can be secured on request from Calvin W. Rice, Secretary, Am.Soc.M.E.**

AMERICAN TELEPHONE AND TELEGRAPH COMPANY. Annual Report of the Directors to the Stockholders. 1910. *New York, 1911.* Gift of the company.

ASSOCIATION OF AMERICAN PORTLAND CEMENT MANUFACTURERS. Bulletin Nos. 1, 12, 18, 19, 20. *Philadelphia.* Gift of the association.

BUILDING FOR PROFIT. By R. P. Bolton. *New York, 1911.* Gift of author.

CHILTON AERO DIRECTORY. Vol. 1, No. 1, 1911. *Philadelphia, 1911.* Gift of Chilton Company.

COAL WASHING. By G. H. Williams. *Chicago.* Gift of Foust Concentrator Company.

COMPOSITION AND HEAT TREATMENT OF STEEL. By E. F. Lake. *New York, McGraw Hill Book Co., 1911.*

The author has condensed in this work much information as to the composition, properties and treatment of modern compound steels, which would otherwise be found in scattered articles in periodicals. There are special chapters on annealing, tempering and hardening, and a timely description of the electric furnace. This summary of modern methods of steel manufacture is a welcome addition to the literature of the subject. The work is profusely illustrated.

CONGRESO CIENTIFICO (PAN AMERICANO) CIENCIAS JURIDICAS. VI Seccion. Vol. 7. *Santiago de Chile, 1910.*

——Ciencias Economicas y Sociales. VII Seccion. Vol. 8. *Santiago de Chile, 1911.* Gift of Scientific Congress.

CONSTRUCTION AND WORKING OF INTERNAL COMBUSTION ENGINES. By R. E. Mathot. *New York, D. Van Nostrand Co., 1911.*

The author is a member of The American Society of Mechanical Engineers, a consulting engineer at Brussels, and this edition is a translation made by an English engineer. The work is of interest especially for its description of the construction of Continental and British engines of the larger powers; the details of construction of the various parts are fully treated, and a table of tests is given. There is also a short bibliography and a list of engine builders.

DAMPFKESSEL-FEUERUNGEN ZUR ERZIELUNG EINER MÖGLICHST RAUCHFREIEN VERBRENNUNG. Ed. 2. By F. Haier. *Berlin, 1910.*

EVAPORATING CONDENSING AND COOLING APPARATUS. By E. Hausbrand. Translated from the second revised edition by A. C. Wright. *London, 1908.*

FORTSCHRITTE DER TECHNIK. Vols. 1–2, 1909. *Berlin, 1909.*

GREAT BRITAIN STATISTICAL DEPARTMENT. Statistical Abstract for the Principal and Other Foreign Countries and Each Year from 1898–1908, 1909. No. 36. *London, 1911.*

HANDBOOK OF MODERN STEAM FIRE-ENGINES. Ed. 2. By S. Roper. *Philadelphia, 1889.*

HISTORY OF MECHANICS. By D. H. Ray. *Lancaster, 1911.* Gift of author.

HOLLAND AND COLONIES PATENT LAW OF Nov. 7, 1910. Translated by A. E. Doyer. *1911.* Gift of A. E. Doyer.

HUDSON FULTON CELEBRATION. Vols. 1–2, 1909. *Albany, 1910.* Gift of Hudson Fulton Celebration Commission.

ILLINOIS SOCIETY OF ENGINEERS AND SURVEYORS. 26th Annual Report, 1911. *Chicago, 1911.* Gift of the society.

INTERNATIONAL NIAGARA COMMISSION. [1]Projects of Cuenod, Sautter and others; Levy and Vigreux, Vigreux and Féray; Popp and Riedler, Lupton and Sturgeon, Pelton and Norwalk. *1890.*

——Report on Utilization of the Falls of Niagara by Means of Electricity. *1890.*

——Proceedings, *1890.*

——Designs of Niagara Falls Power Plant. Gift of Dr. William C. Unwin.

IOWA ENGINEERING SOCIETY. Proceedings of the 23rd Annual Meeting. *Iowa City, 1911.* Gift of the society.

LOGARITHMIC TRIGONOMETRICAL TABLES. Vol. 2. By J. Bauschinger and J. Peters. *Leipzig—New York, 1911.*

MARINE ENGINE DESIGN. By E. M. Bragg. *New York, D. Van Nostrand Co., 1911.*

MUNICIPAL ELECTRIC LIGHT INVESTIGATING COMMITTEE OF MARBLEHEAD, MASS., REPORT TO. By C. W. Whiting. *Boston.* Gift of author.

MÜNCHEN-KÖNIGLICHE TECHNISCHE HOCHSCHULE. Bericht, 1909–1910. *München, 1911.* Gift of Königliche Technische Hochschule zu München.

NEED OF EDUCATED MEN IN INDUSTRIAL AFFAIRS. By F. H. Taylor. (Lecture at Cambridge University, May 15, 1911.)

NEWCYCLE MOTOR. An Improved Type of Gas, Gasoline and Oil Engine, Description of. Gift of Newcycle Motor Company.

NEW YORK STATE AGRICULTURE DEPARTMENT. Proceedings of the 71st Annual Meeting of the New York State Agricultural Society, 1911. (Bulletin No. 23.) *Albany, 1911.* Gift of the department.

PRINCIPLES OF SCIENTIFIC MANAGEMENT. By F. W. Taylor. *New York, Harper & Bros., 1911.*

The work of Mr. Taylor, Past-President of The American Society of Mechanical Engineers, has aroused more popular interest than any other engineering discussion. No engineer in active practice can afford not to read this book; indeed, it is worthy the careful consideration of the thinkinglayman.

PRODUCTION OF MALLEABLE CASTINGS. By Richard Moldenke. *Cleveland, 1910.*

RAILWAY STATION SERVICE. By B. C. Burt. *New York, J. Wiley & Sons, 1911.*

The substance of this work was first made public in a short course of lectures delivered by invitation before the class on railway administration at Michigan University in 1909. The author has derived his knowledge from experience of a dozen or more years on two leading lines of the West. The book, although not designed as a manual explaining in a matter-of-fact way, either in complete detail or in outline, what things must be done at a railway station or how to do them, does state with some fullness the leading features of railway station service as matters of prescribed routine, and especially gives an insight into the general condition, spirit and principles of such service.

No other work has been published covering so intelligently the work of the local railroad representative and this should therefore be of great value both as a text books for students of railway matters and as a manual for station agents.

SUGAR MACHINERY. Ed. 2. By A. J. Wallis-Tayler. *London-New York.*

THEORY OF IONIZATION OF GASES BY COLLISION. By J. S. Townsend. *New York, D. Van Nostrand Co., 1910.*

UNITED STATES ORDNANCE DEPARTMENT. Report of the Tests of Metals. Vols. 1-3, 1909. *Washington, 1910.*

UNIVERSITY OF PENNSYLVANIA ENGINEERING ALUMNI SOCIETY. Annual Report, By-Laws and List of Members, April 1911. *Philadelphia, 1911.* Gift of the University.

UNIVERSITY OF TENNESSEE. Register, 1910-1911. *Knoxville, 1911.* Gift of the University.

WOOD PRESERVERS' ASSOCIATION. Report of Proceedings of 2d, 3d, 5th-7th Annual Meetings. *1906-1907, 1909-1911.* Gift of the association.

## EXCHANGES

AMERICAN SOCIETY OF AUTOMOBILE ENGINEERS. Transactions. Vol. 5, 1910. *New York, 1910.*

CANADIAN SOCIETY OF CIVIL ENGINEERS. Charter, By-Laws and List of Members, 1911. *Montreal, 1911.*

——Report of Annual Meeting. Vol. 25, 1911. *Montreal, 1911.*

ELECTRIFICATION OF RAILWAYS (except minutes of Proceedings of the Joint Meeting of The Institution of Mechanical Engineers and The American Society of Mechanical Engineers, July 29, 1910). *London, 1910.*

INSTITUTION OF CIVIL ENGINEERS. List of Members, 1910. *London, 1910.*

INSTITUTION OF MECHANICAL ENGINEERS. List of Members, 1911. *London, 1911.*

SOCIETY OF AUTOMOBILE ENGINEERS. Transactions. Vol. 4, 1909. *New York, 1909.*

## TRADE CATALOGUES

ASSOCIATION OF LICENSED AUTOMOBILE ENGINEERS, *New York.* Handbook of gasoline automobiles, 1911. 274 pp.

BRISTOL CO., *Waterbury, Conn.* Bull. 146A, long-distance recording tachometer, 2 pp.; Bull. 147A, radii averaging instrument for circular chart records, 7 pp.

BRUCE-MACBETH ENGINE CO., *Cleveland, O.* Vertical multi-cylinder gas engines, 31 pp.

A. D. GRANGER CO., *Philadelphia, Pa.* Bull. 1, steel tanks, 15 pp.

HESS-BRIGHT MFG. Co., *Philadelphia, Pa.* Cranehook thrust ball bearing mounting, 2 pp.; Typical mounting for high-speed spingle with pulley, 1 p.; Mounting ball bearing for radial load, 4 pp.

INDUSTRIAL INSTRUMENT Co., *Foxboro, Mass.* Foxboro Recorder, vol. 3, no. 1, containing papers on the manufacture of instruments, 15 pp.

KEUFFEL & ESSER Co., *New York.* Slide rules, 14 pp.

CHAS. T. MAIN, *Boston, Mass.* Industrial plants designed and built, 61 pp.

MISSISSIPPI WIRE GLASS Co., *New York.* Wire glass in modern construction, 8 pp.

H. MUELLER MFG. Co., *Decatur, Ill.* Water, gas and plumbing, brass goods and tools, catalogue D, 1911, 600 pp.

NILES-BEMENT-POND Co., *New York.* Progress Reporter, April 1911, on reversing motor planers, 20 pp.

WM. POWELL Co., *Cincinnati, O.* Catalogue 10, plumbing and steam fitting supplies, 326 pp.

STANDARD THIRD RAIL Co., *New York.* W-S standard under-running third rail, 24 pp.

WESTINGHOUSE MACHINE Co., *East Pittsburg, Pa.* Circular W. M. 504, new model Roney mechanical stoker, 44 pp.

## UNITED ENGINEERING SOCIETY

EAGLE ALMANAC, 1911. *Brooklyn, 1911.*

INTERNATIONAL WATERWAYS COMMISSION. Report on Regulation of Lake Erie, 1910. *Buffalo, 1910.* Gift of the commission, American section.

MORTON MEMORIAL. A History of the Stevens Institute of Technology. *Hoboken, 1905.* Gift of A. C. Humphreys.

PRELIMINARY REPORT ON THE ROCK ASPHALT, ASPHALTITE, PETROLEUM, AND NATURAL GAS IN OKLAHOMA. Bulletin No. 2, Oklahoma Geological Survey. *Norman, 1911.* Gift of Oklahoma Geological Survey.

SANITARY CODE OF THE BOARD OF HEALTH, CITY OF NEW YORK, 1910. *New York, 1910.* Gift of New York Department of Health.

TRIBUNE ALMANAC, 1911. *New York, 1911.*

WORLD ALMANAC, 1911. *New York, 1911.*

# EMPLOYMENT BULLETIN

**The Society has always considered it a special obligation and pleasant duty to be the medium of securing better positions for its members. The Secretary gives this his personal attention and is most anxious to receive requests both for positions and for men available. Notices are not repeated except upon special request. Copy for notices in this Bulletin should be received before the 12th of the month. The list of men available is made up of members of the Society and these are on file, with the names of other good men not members of the Society, who are capable of filling responsible positions. Information will be sent upon application.**

## POSITIONS AVAILABLE

0102 Wanted, man to take charge of cost work of a manufacturing concern of high grade machinery. Must be capable of doing estimating work, making proper comparative records and able to make recommendations to manufacturing department for cost reductions. Location New England. Applicant should state age, experience, and salary expected.

0103 Chief Draftsman. American with technical training preferred; should have had considerable experience in designing hoisting equipment. Location Iowa.

0104 Assistant professor of mechanical engineering to teach mechanics and assist in mechanical laboratory and general design work. Prefer a man with two or three years of practical experience. Location New England.

0105 High grade machine tool salesman or selling engineer, preferably a man about 35 having had shop and some commercial experience, and technical education capable of recommending equipment. Location Middle West.

0106 Engineering superintendent in small marine engineering plant. Must be capable of designing, handling and installing small marine engines, boilers, gasolene motors and their auxiliaries and of superintending the manufacture of same. Location Massachusetts.

0107 Young engineer, college graduate, some knowledge of electricity good mechanician, with aptitude for sketching and building models, etc. salary $100 a month to start. Location Connecticut.

0108 Member, prepared to go into partnership or associate with a manufacturing concern where in lieu of portion of salary will be given interest in the business. Equipped with all-round research and manufacturing experience in electrical and mechanical work.

## MEN AVAILABLE

232 Technical graduate, four years experience in plant engineering in all phases, including cost reduction, accounting, tool systems, plant power operations, construction and maintenance, combined with extensive study of scientific management and accounting. Now employed. Thoroughly accustomed to handling men and working on own responsibility.

233 Graduate Mass. Inst. Tech., position with progressive manufacturing company or engineering firm. Experienced in power house design, supervision of construction. Last six years general manager of company employing 200 men. New England preferred.

234 Mechanical engineer extensive experience in the gasification of American fuels in gas producers, desires the association of capitalist or manufacturer in the building up of a line of gas producers from approved and well tried designs, for power, fuel and industrial applications.

235 Junior member, technical graduate, 6 years' experience in shop and drafting room. At present in charge of a small drafting room.

236 Junior member, M. E. Cornell. Five years practical experience in railroad shop and engineering work, special investigations in fuel and water economy. One year spent in Europe studying fuel economy and railroad engineering. Seeks connection with consulting engineers on power plant economy or industrial concern manufacturing railroad equipment. At present employed.

237 Member resident in Pittsburg, an experienced manufacturers' agent of standing and ability, wishes to secure the agency for steam or gas engine, steam or hydraulic specialties.

238 Mechanical engineer, technical graduate, junior member, age 29; experience covers designing and estimating costs with contracting engineer, manufacturing company in charge of work, executive with contracting company, at present employed; will consider position as branch or assistant manager, contract or sales engineer; prefers position in commercial work requiring technical training.

239 Junior member, 31, married, desires position as sales engineer, manager or similar position for power plant machinery of any kind; particularly familiar with pumping machinery, heaters and engines of all sizes and types. Designed several successful pumping plants. Good executive ability and successful salesman. At present employed but desires change. East preferred.

240 Sales engineer, college graduate, desires change; with present employer seven years, engaged in sale and installation of large power plants involving all types of prime movers. Will consider employment with banking interests,

in public utility corporations or executive position with operating company. Age 30 years.

241 Mechanical engineer, experienced in engineering and physical research, formerly in charge of design and construction of internal combustion engines, small and large, gas producers, and power stations, will undertake development or extension of product of manufacturing company.

242 Junior member, technical graduate, at present employed on the engineering staff of large corporation. Experienced in erection, testing and operation with a good knowledge of management. Desires a position where executive ability combined with mechanical knowledge is essential, in or near Philadelphia.

243 Member seeks a position as superintendent of machine shops, foundries, etc. Extensive experience in the building of heavy engines, air compressors, pumps, conveying and power transmission machinery.

244 Young engineer, 10 years practical shop and drafting experience, desires to connect with responsible engineering or contracting firm where there is opportunity for advancement.

245 Mechanical engineer, nine years experience, now in charge of six power plants, desires to connect with power or manufacturing concern, vicinity of New York, as assistant mechanical engineer or assistant superintendent.

246 Associate, mechanical engineer, technical graduate, ten years general engineering experience, at present in business as consulting engineer, wishes employment as mechanical engineer in manufacturing or engineering firm in or near New York City. Experienced in design and operation, power and manufacturing plants.

247 Member, experienced in erection and operation of turbines, both large and small units, also miscellaneous railway and power systems apparatus. Ability in organizing and training men.

248 Technical graduate, two years experience mechanical drafting and shop work, would like to connect with company manufacturing machinery, preferably gas engines, with view to working into sales or engineering department.

249 Junior member, age 27, technical education, eight years experience, at present employed by a public service holding corporation as mechanical engineer, operation, improvements, design and construction of power plants, handling of details of purchasing apparatus and closing of contracts and valuations of existing properties; desires change of position.

## CHANGES IN MEMBERSHIP

### CHANGES OF ADDRESS

ADAMS, Thomas D. (Junior, 1906), Werner & Pfleiderer, Saginaw, Mich., and *for mail,* Westport, Conn.

ALLEN, Albert Mark (1903; 1908), Cons. Engr., 1900 Euclid Ave., and 1503 E. 118th St., Cleveland, O.

ARMSTRONG, Wm. M. (Junior, 1894), Treas., Corrugated Bar Co., Bank of Commerce Bldg., and 5154 Westminster Pl., St. Louis, Mo.

ARNOLD, George, Jr. (1904), Cleveland Frog & Crossing Co., and *for mail,* 8217 Brookline Ave., Cleveland, O.

BAILEY, T. S. (1896; 1905), New London Ship & Eng. Co., Groton, Conn.

BANTA, Earle Jackson (1907), Genl. Sales Mgr., Davenport Loco. Wks., Davenport, Iowa.

BEHREND, Bernard A. (1909), Elec. and Mech. Engr., 442 John Hancock Bldg., 200 Devonshire St., Boston, Mass.

BILLINGS, A. W. K. (1909), care of Dr. F. S. Pearson, 25 Broad St., New York, N. Y.

BIRD, Paul P. (1907), Commonwealth Edison Co., 120 W. Adams St., and *for mail,* 1365 E. 48th St., Chicago, Ill.

BLAUVELT, Albert (1896), Asso. Mgr., West. Factory Ins. Asso., N. Y. Life Bldg., 39 S. La Salle St., Chicago, Ill.

BLUMGARDT, Isaac E. (Associate, 1908), 5 Woodcourt, Tarrytown, N. Y.

BOLLES, Frank G. (Associate, 1901), Advance Sales Corp., 50 Church St., New York, N. Y.

BOLTON, Reginald Pelham (1898), Cons. Expt., Pres., The R. P. Bolton Co., 55 Liberty St., and 638 W. 158th St., New York, N. Y.

BRINTON, Willard Cope (Junior, 1907), Asst. V. P., U. S. Motor Co., 61st St. and Broadway, and Harvard Club, 27 W. 44th St., New York, N. Y.

BROWN, Will H. (1909), Sales Agt., Toledo Elec. Welder Co., 706 Rose Bldg., Cleveland, and Willoughby, Lake Co., O.

BUCKLER, Albert H. (Junior, 1905), care of Inspr., Third Light House Dist., Tompkinsville, N. Y.

BURGOON, Charles Eli (1907), Burgoon-Matthews Elec. Co., 31 Luckie St., Atlanta, Ga.

BURTON, J. Harry (Junior, 1906), Lock Box 299, Portland, Ore.

CASE, Albert H. (Junior, 1903), Asst. Mgr., Tenn. Copper Co., Copperhill, Tenn.

CHISHOLM, John James (Associate, 1904), Supt. of Power, Tenn. Coal, Iron & R. R. Co., Ensley, Ala.

CLAPP, Geo. H. (1891), cor. 7th and Bedford Aves., Pittsburg, and Edgeworth, Pa.

CLARK, Farley Granger (1907), Supt., Westinghouse Elec. & Mfg. Co., East Pittsburg, and *for mail*, 6706 Penn Ave., Pittsburg, Pa.

CLARKE, Chas. L. (1882), Pat. Expt., Elec. and Mech. Engr., 30 Church St., New York, N. Y., and Plainfield, N. J.

DARBY, John Henry (1901), Howard Chambers, 155 Norfolk St., Sheffield, England.

DAVIDSON, Charles Jackson (1904), Member of Firm, Woodmansee, Davidson & Session, Inc., 1048 First Natl. Bank Bldg., Chicago, Ill.

DEARBORN, Wm. Langdon (Junior, 1892), Calle Enna No. 1, Apartado 1289, Havana, Cuba.

DILLARD, Capt. James B. (1907; Associate, 1909), Inspr. of Ordnance, U. S. A., care of Newport News Shipbuilding & Dry Dock Co., Newport News, Va.

DOUGLAS, Courtney Carlos (1904; Associate, 1908), Commer. Engr., Steam Turbine Dept., Genl. Elec. Co., Monadnock Bldg., Chicago, Ill.

EILERS, Karl Emrich (1890; 1904), Am. Smelting & Refining Co., 165 Broadway, New York, and *for mail*, Sea Cliff, L. I., N. Y.

FAILE, E. H. (Junior, 1907), Mech. Engr., 50 Church St., and *for mail*, 21 Claremont Ave., New York, N. Y.

FRANK, Edwin (Junior, 1909), Bergdrisch 21[1], Aachen, Germany.

GERNANDT, Waldo George (Junior, 1910), Ch. Draftsman, Carriage Chassis Dept., Packard Motor Car Co., and *for mail*, 940 Cass Ave., Detroit, Mich.

GLEASON, Gilbert Howe (Junior, 1906), V. P., The Dexter Engr. Co., Inc., Providence, R. I.

GUCKEL, Charles Henry (Junior, 1901), Nampa, Idaho.

GUMP, Walter B. (Junior, 1902), Mech. and Elec. Engr., 408 Union League Bldg., and 2510 Juliet St., Los Angeles, Cal.

GUCKEL, Charles Henry (Junior, 1901), Genl. Mgr., The Swan Falls Power Co., Nampa, Idaho.

HANSON, Walter S. (Associate, 1902), Mgr., Hollis Cotton Oil, Ice & Light Co., Hollis, Okla.

HARRISON, Edwin S. (Junior, 1905), P. O. Box 201, Evansville, Ind.

HILLYER, George, Jr. (1898; Associate 1904), Broad River Granite Co., Candler Bldg., and *for mail*, 568 W. Peachtree St., Atlanta, Ga.

JALONICK, Hartwell (Junior, 1909), Designing and Cons. Engr., Mills Bldg., El Paso, Texas.

KELMAN, John H. (1904), 194 Lefferts Pl., Brooklyn, N. Y.

KEMBLE, Parker H. (1908), Genl. Sales Mgr., Toronto Elec. Light Co., Toronto, Canada.

KING, George I. (1901), Ch. Engr., Stand. Steel Car Co., and *for mail*, 200 Brady St., Butler, Pa.

KOLLBERG, Gustaf Leonard (1910), Engr., Pumping Eng. Dept., Allis-Chalmers Co., and *for mail*, 280 31st St., Milwaukee, Wis.

LANGE, Heinrich Bartels (Junior, 1910), Am. Optical Co., and *for mail*, 37 Everett St., Southbridge, Mass.

LAVERY, George L. (1886), Lavery-Taylor Realty Co., 1122 Bryn Mawr Ave., and 5453 Kenmore Ave., Chicago, Ill.

LEWIS, David J., Jr. (1892), Sales Mgr., Lytton Mfg. Corp., 1159 Hudson Terminal Bldg., 50 Church St., New York, N. Y.

LYON, J. Lawrence (Junior, 1906), 767 Lincoln Pl., Brooklyn, N. Y.

McCOLL, J. R. (1903), Member of Firm, Ammerman, McColl & Anderson, 1330-1332 Penobscot Bldg., and Dean Engrg. Dept., Univ. of Detroit; also 9 Gladstone Ave., Detroit, Mich.

McDEWELL, Horatio S. (Junior, 1908), Allis-Chalmers Co., 71 Broadway, New York, and *for mail*, Cementon, N. Y.

McMULLIN, Frank V. (1903), 2313 Farmers Bank Bldg., Pittsburg, Pa.

MATTSSON, A. Geo. (1892), Ch. Engr., Great Lakes Engrg. Wks., and *for mail*, 199 Palmer Ave., E., Detroit, Mich.

MAYSILLES, John Henry (1901; 1910), Supt., Davenport Loco. Wks., and *for mail*, 1719 Brady St., Davenport, Iowa.

MILLER, John S. (1900; 1907), Sales Engr., Yuba Constr. Co., and *for mail*, 625 H St., Marysville, Cal.

MILLHOLLAND, William Knox (1907), Pres., W. K. Millholland Mch. Co., Industrial Bldg., 10th and Canal Sts., and *for mail*, 2857 N. Capitol Ave., Indianapolis, Ind.

MONTAGUE, Chas. Dwight (1905), 2563 Bedford Ave., Brooklyn, N. Y.

MURRIE, John L. (Junior, 1905), Ford, Bacon & Davis, 115 Broadway, New York, N. Y.

MYERS, Cornelius T. (Associate, 1908), Mech. Engr., Genl. Motors Co., and *for mail*, 127 Woodward Ave., Detroit, Mich.

NICHOLL, John Seymour (Junior, 1909), with Walter B. Snow, 170 Summer St., Boston, Mass.

NORTON, Fred Elmer (1907), Genl. Elec. Co., West Lynn, and *for mail*, 22 Atlantic St., Lynn, Mass.

O'NEIL, Frederick Wm. (1901; 1908), Mgr. of Sales, Nordberg Mfg. Co., Milwaukee, Wis.

PARK, Walter E. (1903), Box 1562, Cape Town, S. A.

PENNINGTON, James H. (1902), Supt. Constr. and Power, Am. Smelting & Refining Co., and *for mail*, 734 Roland Ave., Baltimore, Md.

POLHEMUS, Louis Edward (Junior, 1909), Mech. and Elec. Engr., Cubo Min. & Milling Co., Apartado 49, Guanajuato, Mex.

REED, William E. (1898), 71 Broadway, and *for mail*, The Van Dyck, 175 W. 72d St., New York, N. Y.

REPATH, Charles H. (1891), P. O. Box 841, Douglas, Ariz.

RIDDLE, Howard Sterling (1905), V. P., Weinman Pump Mfg. Co., Columbus, and *for mail*, Route 2, Shepard, O.

RIDGELY, Wm. Barret (1880; 1895), 1908 Q St., N. W., Washington, D. C.

RIGGS, John D. (Junior, 1892), Draftsman, O. C. P. W., and *for mail*, 422 N. Main St., South Bend, Ind.

RILEY, Robert Sanford (1906), 381 Wayland Ave., Providence, R. I.

SCHAEFFLER, Joseph C. (1900; 1904; 1907), Joseph C. Schaeffler & Co., 73 Tremont St., Boston, Mass., and 38-40 W. 32d St., also 151 W. 91st St., New York, N. Y.

SHAW, Charles H. (Associate, 1906), West. Sales Mgr., Potter & Johnston Mch. Co., 967 National Ave., Milwaukee, Wis.

SHEPPARD, John Leefe, Jr. (Associate, 1906), N. E. Engrg. Co., 50 Church St., New York, N. Y.

SICKLES, Eugene Charles (1896; 1904), Supt. Power Plants, B. & O. R. R., Central Bldg., and 844 N. Carey St., Baltimore, Md.

SMITH, Jesse M. (1883), Manager, 1891-1894; Vice-President, 1894-1896; 1899-1901; President, 1909; Life Member; Mech. and Elec. Engr. and Expt. in Pat. Causes, Rm. M-14, 220 Broadway, and 120 Riverside Drive, New York, N. Y.

SMITH, Roy B. (Junior, 1905), Asst. M. P. Inspr., Pa. Lines West, and *for mail*, 218 King Ave., Columbus, O.

STEVENS, Wm. N. (Junior, 1886), V. P., Conveying Mchy. Co., 120 Liberty St., New York, and 243 Brooklyn Ave., Brooklyn, N. Y.

SWAN, John Joseph (1899; 1909), Chicago Pneu. Tool Co., 50 Church St., New York, N. Y., and Plainfield, N. J.

SWEET, Charles E. (1907), Genl. Supt., Northway Motor & Mfg. Co., Detroit, Mich.

SYMINGTON, E. Harrison (Associate, 1903), Mech. Expt., T. H. Symington Co., Md. Trust Bldg., Baltimore, Md.

SYMONDS, Nathaniel Gardiner (Junior, 1905), Sales Engr., Westinghouse Mch. Co., 407 Traction Terminal Bldg., Indianapolis, Ind.

THORN, Charles Norman (Associate, 1910, Asst. Genl. Mgr., Charge of N. Y. Office, Allied Mchy. Co. of Am., 55 Wall St., New York, N. Y.

VAN ZANDT, Paul C. (1900; 1907; 1909), Dist. Mgr., Stephens-Adamson Mfg. Co., 1055 First Natl. Bank Bldg., Chicago, Ill.

WADLEIGH, George R. (1907), Engr., Bemis Bros. Bag Co., and 4258 Shaw Ave., St. Louis, Mo., and *for mail*, Bemis, Tenn.

WARNER, Worcester R. (1880), Manager, 1890-1893; President, 1897; Pres., Warner & Swasey Co., Cleveland, O., and *for mail*, Wilson Park, Tarrytown, N. Y.

WEGG, David S., Jr. (Junior, 1909), Telluride House, Ithaca, N. Y., and *for mail*, 16 E. Ontario St., Chicago, Ill.

WETMORE, Charles P. (1901), 518 Astor St., Milwaukee, Wis.

WHITE, Wm. M. (1907), Mgr. and Ch. Engr., Hyd. Dept., Allis-Chalmers Co., and *for mail*, A 375 Lake Drive, Milwaukee, Wis.

WILKINSON, Cecil Tom (Junior, 1908), 8 Culmington Rd., Ealing, London, W., England.

WILKINSON, Thomas L. (1894; 1905), Cons. Mech. Engr., 406 Boston Bldg., and 5833 Montview Blvd., Denver, Colo.

WILLIAMS, Alan Gillespie (Junior, 1909), 672 Eagle St., Terre Haute, Ind.

WINTERROWD, William H. (Junior, 1907), Asst. Engr., Mech. Dept., Lake Shore & Mich. So. Ry. Co., Genl. Offices, and *for mail*, 156 Carlyon Rd., Cleveland, O.

## NEW MEMBERS

ARNOLD, Anthony Brown (1911), Asst. Engr., Am. Agri. Chem. Co., 92 State St., Boston, Mass.

ARTER, Wilbur D. (Junior, 1911), Asst. Engr., N. Y. C. & H. R. R. R. Co., and *for mail*, 332 W. 58th St., New York, N. Y.

BAQUET, Camille, Jr. (1911), Supt., Valley Iron Wks., Box 34, Williamsport, Pa.

BAUSCH, Carl L. (Junior, 1911), Industrial Engr., Bausch & Lomb Optical Co., Rochester, N. Y.

BAYNE, George Henry (1911), Mech. Engr., Pa. Coal & Coke Co., 17 Battery Pl., New York, N. Y.

BERRESFORD, Arthur W. (1911), V. P. and Genl. Mgr., The Cutler-Hammer Mfg. Co., Milwaukee, Wis.

BOBLETT, Kinderman M. (Associate, 1911), Radiator Expt., The Kinsey Mfg. Co., Toledo, O.

BONNETT, L. B. (1911), Civ. Service Examiner, Mech. Engr., Municipal Civil Service Com., 299 Broadway, New York, N. Y., and *for mail*, 310 W. Jersey St., Elizabeth, N. J.

BUCK, Lucien (Junior, 1911), Engr., The Champion Fibre Co., and *for mail*, Box 428, Canton, N. C.

BURROUGHS, Joseph Howell, Jr. (Junior, 1911), 226 W. 140th St., New York, N. Y.

CARISS, Carington Carysfort (Junior, 1911), Ch. Draftsman, E. Leonard & Sons, and *for mail*, 396 Glebe St., London, Ont., Canada.

COLE, Fred Baker (1911), Prin. Asst. Engr., Chas. T. Main, 201 Devonshire St., Boston, Mass.

DAVIS, Leon Keith (1911), Engr., Mfrs. Mut. Fire Ins. Co., 815 Banigan Bldg., Providence, R. I.

D'OLIER, William Livingston (1911), Pres., D'Olier Engrg. Co., 1304 Morris Bldg., Philadelphia, Pa.

FABENS, Andrew Lawrie (Junior, 1911), Apprentice Sales Dept., Aluminum Co. of Am., Pittsburg, and *for mail*, 501 Sixth Ave., New Kensington, Pa.

FINCH, Ellis Jerome (Junior, 1911), Asst. to Supt., Pittsburg Plate Glass Co., Crystal City Plant, and *for mail*, Box 736, Crystal City, Mo.

FORD, William Lucas (1911), N. E. Sales Mgr., Murphy Iron Wks. of Detroit, Mich., Rm. 520, 35 Federal St., Boston, Mass.

GILBERT, E. E. (1911), Sales Mgr., Turbine Dept., Genl. Elec. Co., Schenectady, N. Y.

GOING, Charles Buxton (1911), Managing Editor, The Engineering Magazine, 140 Nassau St., New York, N. Y.

GREENWALL, Walter L. (1911), Asst. Ch. Draftsman, Nordberg Mfg. Co., and *for mail*, 534 Logan Ave., Milwaukee, Wis.

HALL, Harris Forster (1911), Member of Firm, Wright-Hall Engrg. Co., Fisher Bldg., Chicago, Ill.

HAMMOND, Myram Hance (1911), Genl. Supt., Knickerbocker Portland Cement Co., Hudson, N. Y.

HARTWELL, Arthur Edward (Junior, 1911), Dir. Mech. Engr. and Asst. Mgr., Hartwell Iron Wks., and *for mail*, 1209 Webster Ave., Houston, Tex.

HOBBS, Franklin Warren (1911), Treas. and Exec. Officer, Arlington Mills, 78 Chauncey St., Boston, Mass.

HONYWILL, Albert William (Junior, 1911), 171 Ellsworth Ave., New Haven, Conn.

HOWELL, Sylvester S. (1911), Cons. Engr., Chamberlain & Howell, 1522 Marquette Bldg., Chicago, Ill.

HUBBARD, Carleton Waterbury (Junior, 1911), Engr., Mianus Motor Wks., Stamford, and *for mail*, Greenwich, Conn.

HUMES, W. Sharon (1911), Sales Engr., Genl. Ry. Supply Co., 531 Marquette Bldg., Chicago, Ill.

JOHNSTON, William Atkinson (1911), Assoc. Prof. of Mech. Engrg., Mass. Inst. of Tech., Boston, Mass.

KNOX, Clarence M. (Junior, 1911), Mech. Engr., 281 Wethersfield Ave., Hartford, Conn.

KOESTER, Herman (Junior, 1911), Mech. Supt., The Bristol Co., and *for mail*, 66 Holmes Ave., Waterbury, Conn.

KRAEMER, Milton (Junior, 1910), Mech. Engr., A. & F. Brown Co., 172 Fulton St., and *for mail*, 318 W. 51st St., New York, N. Y.

LAMAR, Philip Rucker (1911), Asst. to V. P., The So. Cotton Oil Co., Augusta, Ga.

LEISEN, Theodore Alfred (1911), Ch. Engr. and Supt., Louisville Water Co., and *for mail*, 435 Third St., Louisville, Ky.

LEWIS, Frederick Humphreville (1911), Cons. Engr., 732 Brown-Marx Bldg., Birmingham, Ala.

LOEB, Leo (Junior, 1911), Asst. in Mech. Engrg., Rensselaer Poly. Inst., and *for mail*, 4 Locust Ave., Troy, N. Y.

LYDECKER, Kenneth (Junior, 1911), Field Engr., Natl. Bd. of Fire Underwriters, 135 William St., New York, N. Y.

MAGUIRE, Jeremiah De Smet (1911), 30 Church St., New York, N. Y.

MEYER, Erwin Charles (Junior, 1911), Draftsman, E. W. Bliss Co., Brooklyn, and *for mail*, 563 W. 183d St., New York, N. Y.

MILNER, Bert Branson (Junior, 1911), Pa. R. R. Co., Wilmington, Del.

MULLHAUPT, Alfred, Jr. (Junior, 1911), Engrg. Dept., Buffalo Forge Co., and *for mail*, Y. M. C. A., Buffalo, N. Y.

MORSE, Arthur Holmes (1911), Mech. Engr., The Baldwin Co., and *for mail*, 2305 Nelson Ave., Cincinnati, O.

NAILLER, Raymond Frederick (1911), Pres. and Gen. Mgr., The Enameled Pipe & Engrg. Co., Elyria, O.

NEWMAN, Martin Freeze (1911), Asst. Mgr. Water Purifying Dept., Wm. B. Scaife & Sons Co., 221 First Ave., and *for mail*, 754 Sheridan Ave., Pittsburg, Pa.

NICKERSON, John Winslow (Junior, 1911), Asst. Mech. Engr., Saylesville Bleacheries, Saylesville, R. I.

NORTON, Arthur Edwin (1911), Asst. Prof. Mech. Drawing, Harvard Univ., and *for mail*, 303 Pierce Hall, Cambridge, Mass.

OLIVENBAUM, John Emmanuel (1911), Instr. Steam Eng., Case Sch. of Applied Science, Cleveland, O.

PACKARD, Horace Nelson (Junior, 1911), Instr. Mech. Engrg., Univ. of Wis. Extension Div., and *for mail*, 451 Woodstock Pl., Milwaukee, Wis.

PERKINS, Julius A. (1911), Mech. Dir., Universal Roller Bearing Co., 25 Broad St., New York, N. Y.

PROUT, Henry Byrd (Junior, 1911), Secy., Turbine Equip. Co., 30 Church St., New York, N. Y.

REA, James Childs (Junior, 1911), Asst. to Genl. Supt., Oliver Iron & Steel Co., Pittsburg, Pa.

REID, Joseph Snively (1911), Secy., Ch. Engr. and Mech. Supt., Clark Bros. Co., Belmont, N. Y.

RICHARDSON, George Edward (Associate, 1910), Mill Power Engr., Genl. Elec. Co., 84 State St., Boston, Mass.

ROLLINS, William Benjamin (1911), Cons. Engr., Rollins & Westover, 535 Beals Bldg., Kansas City, Mo.

ROWE, Don Ray (Junior, 1911), Ch. Draftsman, Charge of Engrg. Wk., The Noyes Mfg. Co., Dayton, O.

ROWELL, Henry K. (1911), Industrial Engr., Prin. Asst. Charge Organization Dept., Chas. T. Main, Boston, and *for mail*, 135 Dale St., Waltham, Mass.

RUDDY, William (Junior, 1911), Asst. to Supt., W. A. Wood Mowing & Reaping Mch. Co., Hoosick Falls, N. Y.

SCOTT, Charles Felton (1911), Cons. Engr., Westinghouse Elec. & Mfg. Co., Pittsburg, Pa.

SESSIONS, Edson O. (1911), Member of Firm, Woodmansee, Davidson & Sessions, 1048 First Natl. Bank Bldg., and *for mail*, 5648 Winthrop Ave., Chicago, Ill.

SMITH, Albert Samuel (1911), Ch. Engr., Mass. Inst. of Tech., Boston, and *for mail*, 32 Oakland St., Winthrop, Mass.

STIX, Lawrence Cullman (Junior, 1911), Supt. of Erection, Internatl. Steam Pump Co., Cudahy, Wis.

STODDARD, Elgin (1911), Mgr., Chas. C. Moore & Co., 99 First St., San Francisco, Cal.

SULZER, George H. (1911), Ch. Designer and Mgr., Centrifugal Pump Dept., Henry R. Worthington, Harrison, and *for mail*, 492 Devon St., Arlington, N. J.

SWEET, Ernest E. (1911), Cons. Mech. Engr., and Ch. Engr., Cadillac Motor Car Co., and *for mail*, 195 Chandler Ave., Detroit, Mich.

TALLMADGE, Webster (Junior, 1911), Erecting Engr., Steam Turbines, Westinghouse Mch. Co., New York, and *for mail*, 1312 54th St., Brooklyn, N. Y.

THIEMER, William H. (1911), M. M., The Winton Motor Carriage Co., and *for mail*, 9517 Willard Ave., Cleveland, O.

THORKELSON, Halsten Joseph (1911), Assoc. Prof. Steam Engrg., Univ. of Wis., and *for mail*, 1526 W. Washington Ave., Madison, Wis.

TRUETTE, Arthur Pierce (Junior, 1911), Asst. in Mech. Engrg., Mass. Inst. of Tech., Boston, and *for mail*, 130 Dean Rd., Brookline, Mass.

WENTWORTH, Reginald Andrew (Junior, 1911), Industrial Engr., Dodge, Day & Zimmermann, and *for mail*, 2045 N. 63d St., Philadelphia, Pa.

WHITNEY, Clarence Edgar (1911), Pres. and Genl. Mgr., The Whitney Mfg. Co., Hartford, Conn.

WOODMAN, George A. (1911), Mech. Engr., Kirby Equip. Co., Peoples Gas Bldg., and *for mail*, 6752 Perry Ave., Chicago, Ill.

ZIMMERMANN, William Frederick (Junior, 1911), Ch. Draftsman and Designer, Gould & Eberhardt, and *for mail*, 42 Treacy Ave., Newark, N. J.

## PROMOTIONS

ALEXANDER, Ludwell Brooke (1905; 1911), Asst. Genl. Sales Mgr., Bosch Magneto Co., 223 W. 46th St., and Cliffwood Court, 179th St. and Ft. Washington Ave., New York, N. Y.

BARSTOW, Francis Loring (1905; 1911), Ch. Engr., Mittineague Paper Co.' Mittineague, and Woronoco Paper Co., Woronoco, Mass.

BROOKS, J. Ansel (1907; 1911), Assoc. Prof. Mech. and Mech. Drawing, Brown Univ., Providence, R. I.

CLUETT, Sanford L. (1903; 1911), V. P. and Secy., Walter A. Wood Mowing & Reaping Mch. Co., Hoosick Falls, N. Y.

DIXON, Charles Francis (1903; 1911), Asst. Engr., N. E. Engrg. Co., 50 Church St., and 609 W. 178th St., New York, N. Y.

GAY, Harry (1907; 1911), Stone & Webster Engrg. Corp., 147 Milk St., Boston, Mass.

KENNEY, Lewis H. (1904; 1911), Draftsman-in-Charge Mchy. Div., Navy Yard, Philadelphia, Pa.

KLEIN, Arthur W. (1903; 1911), Assoc. Prof. Mech. Engrg., Lehigh Univ., Williams Hall, South Bethlehem, and *for mail*, 158 S. New St., Bethlehem, Pa.

LINDBERG, Fritz A. (1908; 1911), Prin. Asst. Engr., Brill & Gardner, 1135 Marquette Bldg., and *for mail*, 514 E. 62d St., Chicago, Ill.

RAUTENSTRAUCH, Walter (1904; 1911), Prof. Mech. Engrg., Columbia Univ., New York, N. Y.

RAY, David H. (1904; 1911), Life Member; Ch. Engr., Bureau of Bldgs., Borough of Manhattan, 220 Fourth Ave., New York, N. Y.

RUCKES, Joseph J. Jr. (1902; 1911), Engr., Barrett Mfg. Co., Chicago, Ill., and *for mail*, 1336 Bristow St., New York, N. Y.

RUTHERFORD, Eugene W. (1904; 1911), Mech. Engr. and Asst. to Genl. Mgr., U. S. Rubber Co., 42 Broadway, New York, and *for mail*, 231 Jefferson Ave., Brooklyn, N. Y.

SHEPERDSON, John Wm. (1908; 1911), Asst. Supt. Gautier Dept., Cambria Steel Co., Johnstown, and *for mail*, 126 Tioga St., Westmont, Johnstown, Pa.

VAN VALKENBURGH, Ralph D. (1901; 1905; 1911), Dist. Mgr., Colonial Steel Co., 213 W. Lake St., and *for mail*, Hotel Ontario, 620 N. State St., Chicago, Ill.

WAITE, John Culbertson (1906; 1911), Cons. Steam and Ch. Operating Engr., Capitol Power Plant, and *for mail*, 622 E. Main St., Madison, Wis.

WYER, Samuel S. (1904; 1911), Cons. Mech. Engr., Harrison Bldg., Columbus, Ohio.

YARNALL, D. Robert (1903; 1911), Mech. Engr., 316 Preston St., Philadelphia, Pa.

YORK, Robert (1901; 1908; 1911), V. P. and Treas., York Lumber & Mfg. Co., Memphis, Tenn.

## DEATHS

ABRAHAMS, Morris Landa, May 28, 1911.

BROWN, Alexander E., May 3, 1911.

HEWLINGS, Andrew J., January 18, 1911.

LARSON, Charles J., April 6, 1911.

# COMING MEETINGS

### July–August

**Advance notices of annual and semi-annual meetings of engineering societies are regularly published under this heading and secretaries or members of societies whose meetings are of interest to engineers are invited to send such notices for publication. They should be in the editor's hands by the 15th of the month preceding the meeting. When the titles of papers read at monthly meetings are furnished they will also be published.**

AMERICAN CHEMICAL SOCIETY

June 28–July 1, annual convention, Indianapolis, Ind. Secy., Chas. L. Parsons, Durham, N. H.

AMERICAN SOCIETY OF HEATING AND VENTILATING ENGINEERS

July 6, 7 and 8, semi-annual meeting, Chicago, Ill. Secy., W. W. Macon, 29 W. 39th St., New York.

AMERICAN SOCIETY FOR TESTING MATERIALS

June 27 to July 1, annual meeting, Atlantic City, N. J. Secy., Prof. Edgar Marburg, University of Pennsylvania, Philadelphia, Pa.

INDIANA ELECTRIC LIGHT ASSOCIATION

August 23-24, annual meeting. Secy., J. V. Zartman, Indianapolis, Ind.

THE INSTITUTION OF MECHANICAL ENGINEERS

July 24, summer meeting, Zürich and Northern Switzerland. Secy., Edgar Worthington, Storey's Gate, St. James's Park, Westminster, S. W., London, England.

INTERNATIONAL RAILROAD MASTER BLACKSMITHS' ASSOCIATION

August 15, annual meeting, Toledo, O. Secy., A. L. Woodworth, Lima.

INTERNATIONAL RAILWAY GENERAL FOREMEN'S ASSOCIATION

July 25-27, annual meeting, Chicago, Ill. Secy., L. H. Bryan, D. & I. R. Ry., Two Harbors, Minn.

NATIONAL ELECTRIC CONTRACTORS' ASSOCIATION OF THE UNITED STATES

July 19, Niagara Falls, N. Y. Secy., W. H. Morton, 41 Martin Bldg., Utica, N. Y.

OHIO ELECTRIC LIGHT ASSOCIATION

July 25-28, annual meeting, Cedar Point, O. Secy., D. L. Gaskell, Greenville, O.

TRAVELING ENGINEERS' ASSOCIATION

August 29–September 2, annual convention, Hotel Sherman, Chicago, Ill. Secy., W. O. Thompson, care of N. Y. C. Car Shops, East Buffalo, N. Y.

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| Cornell University | Dec. 4, 1908 | R. C. Carpenter | F. E. Yoakem | D. S. Wegg, Jr. |
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| Washington University | Mar. 10, 1911 | | | F. E. Glasgow |
| Lehigh University | June 2, 1911 | | | |

# THE JOURNAL

OF

# THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS

VOL. 33 AUGUST 1911 NUMBER 8


## OCTOBER MEETING IN NEW YORK

The New York meeting of the Society to be held in October will have the following general program, subject to minor modifications. A paper will be presented by L. P. Alford, Engineering Editor of the American Machinist, and H. C. Farrell, Mechanical Engineer of the United Shoe Machinery Company, on Factory Construction and Arrangement with special reference to the construction, development and arrangement of the United Shoe Machinery Company's plant at Beverly, Mass.

Owing to the limited time, it has been decided to confine the discussion to three subjects, as follows:

*a* Machinery Arrangement, covering the different methods of arranging machinery for manufacturing.

*b* Artificial Shop Lighting, dealing with the advantages and disadvantages of diffused illumination, and the best type of lamps versus the advantage of individual lights at each machine.

*c* Factory Floors, giving the relative advantages and disadvantages of concrete floors, composition floors and wood floors.

It is expected to limit the various discussions to ten minutes, making them brief and to the point, and so far as possible illustrating them with lantern slides. These are all live subjects and the Committee on Meetings of the Society in New York hopes to have a large attendance and a lively discussion.

## MEMORIAL TO CHARLES WALLACE HUNT

The specially bound copies of the memorial resolutions adopted by the Council of the Society upon the death of its Past-President, Charles Wallace Hunt, on March 27, 1911, were presented to Mrs. Hunt in the name of the Society on July 16, by Past-President Jesse M. Smith, Mrs. Smith, and the Secretary.

A fund to be known as the Charles Wallace Hunt Fund, the income of which shall be devoted to the Engineering Societies Library, in which Mr. Hunt took so deep an interest, is being created by a number of his friends in the Society, as a tribute to his memory.

# NECROLOGY

## DOUGLASS G. MOORE

Douglass G. Moore was born at Corning, N. Y., February 26, 1846, and died at Norfolk, Va., March 7, 1911. He was educated in the public schools of Elizabeth, N. J., and in Dr. Foote's Academy, and served his apprenticeship under his father, Samuel L. Moore, of Samuel L. Moore and Company. From 1866 to 1870 he engaged in marine practice, returning in the following year to work with his father in the large machine shop and foundry of the company at Elizabethport, N. J. He sold his interest in this concern, however, to the American Shipbuilding Company when the latter firm was formed, and purchased a controlling interest in the Port Johnston Towing Company and the Poughkeepsie Brass Company, with both of which he retained active connection until his death. Mr. Moore was greatly interested in public affairs and was ever eager to adopt useful improvements.

## FRANCIS SCHUMANN

Francis Schumann was born in Thuringia, Saxony, in 1844, and came with his family to America during the disturbances in 1848. Here he became interested in engineering and served throughout the Civil War as a topographical engineer on General Meade's staff, becoming engineer to the Treasury Department at Washington at its close. Eventually he resigned to become president of the Phoenix Iron Works of Trenton, N. J., leaving there in 1887 to found the Tacony Iron and Metal Company at Tacony, Pa. During his association with the company, as its president and general manager, the tower of the Philadelphia City Hall, including the William Penn statue and the smaller bronze groups, many of the United States coastwise lights, and the ornamental bronze work of the Congressional Library at Washington, were constructed. He later became president of the Pennsylvania Iron Works Company.

Mr. Schumann was a past-president of the Engineers Club of Philadelphia, the first president of the American Foundrymen's

Association, and a member of the Franklin Institute and of the American Institute of Architects. He was instrumental in founding the Tacony and the Pelham Trust companies and was vice-president of each. He died on June 29, 1911, at his home in Germantown, after a prolonged illness.

## D. HOWARD HAYWOOD

D. Howard Haywood was born in London, England, March 26, 1869. He received a technical training in the Crystal Palace School of Practical Engineering during which time he spent several months in a wood-making pattern shop, machine shop and foundry. From June 1888 to May 1890 he was employed in the drafting office of Brewer and Company, engineers and contractors of New York City, and until January 1893 he was with Brown and Seward, patent attorneys. For the next seven years he conducted a business of his own in general engineering, mechanical and expert drafting work, in soliciting patents and in giving testimony as an expert in patent suits. At the time of his death, July 5, 1911, he was a member of the firm of Chapin and Haywood, New York City.

Mr. Haywood was a member of the New York Bar, NewYork County Lawyers' Association and foreign member of the Chartered Institute of Patent Agents.

## ANDREW J. HEWLINGS

Andrew J. Hewlings was born in Philadelphia. Pa., July 27, 1857, and received his early education in the public schools and Franklin Institute. In 1874 he entered the shops of L. Schutte and Company, where he served an apprenticeship of ten years. His later work included the erection of condensers, injectors, steam, water and air apparatus. He was president of the A. J. Hewlings Company, Chicago, Ill., until 1902, when he became manager of the catalogue department of the Crane Company, also of Chicago. This position he held at the time of his death on January 18, 1911.

# TOPICAL DISCUSSION ON FUEL OIL

(Published in Condensed Form)

## THE PRODUCTION OF PETROLEUM ON THE PACIFIC COAST

By Arthur F. L. Bell, San Francisco, Cal.[1]

Non-Member

Attention was first drawn in the early 60's to the presence of petroleum in California by the discovery of numerous oil seepages in Los Angeles, Ventura, Santa Barbara and adjacent counties. Most of the early drilling was confined to Ventura County and until the discovery of the Los Angeles City field no other area exceeded about 40 acres. In 1882 the Los Angeles field came in with an approximate area of 400 acres. The oil territory traversed a narrow strip in the northwestern portion of the city, crossing hundreds of city lots, so that in consequence all lot owners became oil operators or leased their lots to others. The formation was so easily drilled that portable rigs were used and in many instances wells about 800 ft. in depth were completed in a week. As late as the year 1900, a well 2000 ft. in depth was considered exceptional and there were but a few in the State, whereas today we have wells of about one mile or over in depth.

2 Such conditions resulted in an immediate over-production with a corresponding drop in price of oil from about $1.50 per bbl. previous to the discovery of the Los Angeles field, to from 15 to 30 cents per bbl. in Los Angeles in 1896. This low price caused every Southern California industry that required fuel in its operations to adopt oil on account of its cheapness and resultant saving. The real opening of California's oil industry may be said to date from the discovery of the Los Angeles field. In 1898 this field was on the wane and the price of oil rose to the dollar mark. The universal adoption of oil

[1] The Associated Oil Co.

Presented at San Francisco meetings, December 1910 and March 1911, of The American Society of Mechanical Engineers. All discussion is subject to revision.

in Southern California had interested so many men in the industry, however, that new fields were sought with the result that the Fullerton, Coalinga, Kern River, McKittrick, and Sunset fields were immediately exploited in the order named and by 1902 the price of oil again fell to 15 and 20 cents per bbl. in the Kern field. The production of the cheap Kern River oil forced its use over the entire Pacific Coast States as well as the Hawaiian Islands.

3 It should be understood that in the early development of the oil industry the discovery of oil was greatly a matter of chance. All of the early fields, including the Los Angeles City field, Kern River, Coalinga, Sunset, etc., were discovered by drilling close to oil seepages. The Summerland field was discovered by chance through digging a water well. The Kern field was discovered by a wood chopper who having seen a small seepage on the bank of the Kern River, dug a well and with the proverbial good luck of the novice struck oil at about 75 ft.

4 Today the industry has become so well understood that, to extend the field, instead of the operator hugging the outcrop, he confidently locates his well far out in the valley or in the outlying ranges within the possible oil belt, in many cases miles from the nearest production. Where he has used fair judgment, based on the knowledge which we now have of the geological conditions of the oil measures, the chances of failure are greatly reduced. The present development of the oil industry is due, first, to the improvement in the art of drilling wells which has enabled us to reach successfully and economically depths of from 4000 to 5000 ft.; and, second, to knowledge of the oil-bearing formation, for which we are to a great extent indebted to the United States Geological Survey, which has for the last few years had a corps of geologists in the field mapping and cross-sectioning proven and possible oil territory. It is satisfactory to note that during the last year successful discoveries have been made in far outlying districts, reported as possible oil territory by the United States Geological Survey.

5 California oils are found in the territory formation in loose sandy beds. In many cases these sand strata are from 400 to 500 ft. thick, which allows for enormous storage of oil, whereas in the Eastern fields the older rocks have become so cemented and are so close-grained that there is no room for storing the oil, a difference which accounts for the small production of the Eastern wells compared with those of California.

6 In 1908, the United States Geological Survey reported 8450 sq. mi. (5,408,000 acres) of possible oil territory in the United States,

giving California 850 sq. mi. (544,000 acres), or about one-tenth of the total area, and also credit for one-half of the probable minimum oil production of the United States, or one-third of the probable maximum production. The contents of the probable oil lands of the United States in barrels of 42 gal. have also been estimated as follows:

| | Minimum | Maximum | | Minimum | Maximum |
|---|---|---|---|---|---|
| Appalachian.. | 2,000,000,000 | 5,000,000,000 | Gulf..... | 250,000,000 | 1,000,000,000 |
| Lima-Indiana | 1,000,000,000 | 3,000,000,000 | California | 5,000,000,000 | 8,500,000,000 |
| Illinois....... | 350,000,000 | 1,000,000,000 | Minor.... | 1,000,000,000 | 5,000,000,000 |
| Mid-continent | 400,000,000 | 1,000,000,000 | Total..... | 10,000,000,000 | 24,500,000,000 |

The following shows the average daily production per well in the various fields of the United States:

| | bbl. | | bbl. |
|---|---|---|---|
| Appalachian.............. | 1.73 | Illinois.................. | 8.73 |
| Lima-Indiana......... .... | 2.74 | Mid-continent.......... | 5.29 |
| Colorado & Wyoming .... | 8.35 | Guld.................. | 14.08 |
| California .............. | 42.56 | | |

7 These were conservative estimates when made two years ago, but the development in the industry has been so rapid that they will not answer for today. I have therefore made an estimate of what I consider the proven and prospective areas of today which shows a total area of practically proven oil territory of 94,200 acres, with an estimated production of 4,319,000,000 bbl., and a probable extension of oil territory of 338,320 acres, with an estimated production of 13,-258,000,000 bbl., making a grand total of proven territory of 432,520 acres and 17,577,000,000 bbl. The total consumption to date has been about 383,000,000 bbl., leaving an estimated future possible production of 17,194,000,000 bbl. Table 1 gives an itemized statement of the production by counties.

8 In submitting the above estimate of extractable oil, which is about double the estimate of the United States Geological Survey, I can only say that it is impossible for any one to state definitely what our actual production will be. I have included as possible territory only what I consider, with our present knowledge, probable territory, amounting to about 700 sq. mi., but it is quite possible that a greater acreage will be developed which will bring the total up to or over the estimate of the United States Geological Survey of 850 sq. mi., which should again increase the quantity of prospective extractable oil.

9 In the computation I have made, I have assumed the interstices in the sand to be three-tenths of its bulk and that it is filled with oil of which one-tenth would be held by capillary attraction to the

TABLE 1 CALIFORNIA'S ESTIMATED FUTURE OIL SUPPLY

| County | Proven Acreage | Thickness of Sand (Ft.) | Estimated Production (Bbl.) | Possible Acreage | Thickness of Sand (Ft.) | Estimated Production (Bbl.) | Totals By Counties: Acreage | Totals By Counties: Production (Bbl.) |
|---|---|---|---|---|---|---|---|---|
| Fresno, Coalinga | 29,000 | 50 | 1,128,000,000 | 21,440 | 50 | 834,000,000 | | |
| Kettleman Hills | | | | 20,080 | 50 | 778,000,000 | | |
| **Total** | 29,000 | | 1,128,000,000 | 41,520 | | 1,612,000,000 | 70,520 | 2,740,000,000 |
| **Kings**, Kettleman Hills | | | | 53,120 | 50 | 2,064,000,000 | | |
| Total | | | | 53,120 | | 2,064,000,000 | 53,120 | 2,064,000,000 |
| **Kern**, Lost Hills | | | | 46,080 | 50 | 1,800,000,000 | | |
| Devils Den | | | | 14,720 | 50 | 596,000,000 | | |
| Antelope Hills | | | | 16,000 | 50 | 622,000,000 | | |
| McKittrick Front | 2,000 | 50 | 85,000,000 | 6,400 | 50 | 250,000,000 | | |
| McKittrick Front | 400 | 150 | 45,000,000 | | | | | |
| Midway Sunset | 40,000 | 50 | 1,700,000,000 | 100,480 | 50 | 4 000,000,000 | | |
| San Emidio | | | | 12,000 | 50 | 466,000,000 | | |
| Kern River | 6,000 | 150 | 590,000,000 | | | | | |
| Total | 48,400 | | 2,420,000,000 | 195,680 | | 7,734,000 000 | 244,080 | 10,154,000,000 |
| **Santa Barbara**, Santa Maria | 3,600 | 25 | 70,000,000 | | | | | |
| Lompoc | 1,280 | 25 | 25,000,000 | 2,000 | 50 | 26,000,000 | | |
| Cat Cañon | 1,920 | 50 | 76,000,000 | 16,000 | 50 | 622,000,000 | | |
| Total | 6,800 | | 171,000,000 | 18,000 | | 648 000,000 | 24,800 | 819,000,000 |
| **Southern California Fields** | 5,000 | 100 | 400,000,000 | 5,000 | 50 | 200,000,000 | 10,000 | 600,000,000 |
| Miscellaneous | 5,000 | 50 | 200,000,000 | 25,000 | 50 | 1,000,000,000 | 30,000 | 1,200,000,000 |
| Total Proven Acreage | 94,200 | | | | | | | |
| Total Possible Acreage | | | | 338,320 | | | | |
| Estimated Production Proven Acreage | | | 4,319,000,000 | | | | | |
| Estimated Production Possible Acreage | | | | | | 13,258,000,000 | | |
| Final Grand Totals | | | | | | | 432,520 | 17,577,000,000 |
| Less Oil Produced to 1911 | | | | | | | | 383,000,000 |
| California's Estimated Future Supply | | | | | | | | 17,194,000,000 |

sand, one-tenth as readily extractable oil, and the remaining one-tenth as oil which can not be obtained. This would admit of producing about ¾ gal. per cu. ft. of oil sand, or 750 bbl. per acre foot. To substantiate these figures, I will state that prior to 1900, the Alcatraz Asphalt Company in Santa Barbara County, mechanically extracted from the bituminous sands at its Carpenteria and Sisquoc refineries, 27 per cent and 25 per cent respectively of bitumen. These sands were exposed oil sands from which the bitumen or dried-out oil was being extracted.

10 In 1901, Bernard Bienenfeld, William Mulholland, and the writer, as commissioners for the purpose of appraising the value of the different properties in the Kern field that were to form the Associated Oil Company, determined that the Kern field oil sand did contain 32 per cent of void in the sand and when filled with oil, amounted to 2.4 gal. per cu. ft. It will therefore be seen that an estimate based on an extraction of ¾ gal. per cu. ft., or 750 bbl. per acre ft., should not be considered as unreasonable if only the correct thickness of productive sands is figured.

11 To determine the life of our field, taking as a basis the figures quoted in a paper by M. L. Requa read before the California Mining Students, we would have, if we assumed the present production of 75,000,000 bbl. as the maximum consumption, 52½ years' supply for the proven territory, and for the proven and prospective territory, less consumption to date, about 230 years' supply. If our consumption is increased, as it naturally will be, the life of our fields must be reduced proportionally. Our consumption for 1910 will amount to about 63,000,000 bbl., as about 12,000,000 bbl. will have gone into storage this year, and at the end of 1910 we will have in storage about 30,000,000 bbl., or about five months' supply. The following is a list of the recorded production of California from 1875 to 1910, inclusive, and the average daily production per well:

| | Bbl. produced | Average bbl. per well per day |
|---|---|---|
| 1875 | 3,000 | 4.11 |
| 1880 | 40,552 | 15.83 |
| 1885 | 325,000 | 38.70 |
| 1890 | 307,360 | 15.88 |
| 1895 | 1,208,482 | 13.19 |
| 1900 | 4,324,484 | 9.15 |
| 1905 | 33,427,473 | 33.49 |
| 1910 (estimated) | 75,000,000 | 42.10 |
| Total | 382,821,212 | |

# COMPARATIVE EVAPORATIVE VALUES OF COAL AND OIL

By C. F. Wieland, San Francisco, Cal.

Member of the Society

12 In comparing the evaporative values of the two fuels, coal and oil, it is only fair to select a coal that is considered standard and that is largely used in evaporative tests. It would not be just to select a coal of the inferior value of our Western coals, and Pocahontas coal and Kern crude oil are therefore selected as a basis of comparison, having analyses as follows:

| | Pocahontas Coal, Per Cent | Kern Crude Oil, 14.5 Gravity, Per Cent |
|---|---|---|
| Proximate Analysis | | |
| Fixed carbon | 73.30 | ...... |
| Volatile matter | 17.61 | ...... |
| Moisture | 0.49 | 0.15 |
| Ash | 8.60 | ...... |
| | 100.00 | |
| Ultimate Analysis | | |
| Carbon | 82.26 | 87.64 |
| Hydrogen | 3.89 | 10.48 |
| Sulphur | 0.49 | 1.02 |
| Oxygen | 4.12 | 0.08 |
| Nitrogen | 0.64 | 0.78 |
| Ash | 8.60 | ...... |
| Sludge | ...... | ...... |
| | 100.00 | 100.00 |

Calorific B.t.u., 14,067.
Coal data from Naval Liquid Fuel Board report, p. 10.

13 Assuming the complete combustion of the heat values in the two fuels as analyzed and knowing that 1 lb. of C requires 11.6 lb. air, 1 lb. of H requires 34.8 lb. air, and 1 lb. of S requires 4.3 lb. air, we have as the volume of air chemically required for the combustion of the coal and the oil the results shown in Table 2.

14 For our comparison we will make the following assumptions:

*a* Flue gas temperature is the same in both cases, viz., 500 deg.

*b* Moisture in the two fuels is the same.

*c* Air intake temperature (temperature of fireroom), 70 deg.

The flue temperature as placed at 500 deg. is probably the mean which obtains in practice; lower results have been obtained, but numerical value makes little difference in our comparison.

15 Moisture as shown in the selected coal is low and that in the selected oil is also low. In most oils it is more nearly an average of 5 per cent and for this reason we will consider that the moisture content is the same in each case.

TABLE 2 VOLUME OF CHEMICALLY REQUIRED AIR FOR COMBUSTION OF COAL AND OIL

| | Weight of Air Required | |
|---|---|---|
| | Coal | Oil |
| Carbon | | |
| Coal, 11.6 lb. air × 0.8226 lb. C. | 9.54 | .... |
| Oil, 11.6 lb. air × 0.8760 lb. C. | .... | 10.16 |
| Hydrogen | | |
| Coal, 34.8 lb. air × 0.0389 lb. H. | 1.35 | .... |
| Oil, 34.8 lb. air × 0.104 lb. H. | .... | 3.62 |
| Sulphur | | |
| Coal, 4.3 lb. air × 0.0049 lb. S. | 0.02 | .... |
| Oil, 4.3 lb. air × 0.010 lb. S. | .... | 0.04 |
| Lb. of air required | 10.91 | 13.82 |
| Weight of the combustibles (after deducting ash from coal) | 0.91 | 1.00 |
| Total weight which will be considered as dry chimney gas | 11.82 | 14.82 |

16 The sensible heat carried away in the flue gases in the case of the coal is

$$0.24\ (500-70) \times 11.82 = 1219.8 \text{ B.t.u.}$$

In the oil

$$0.24\ (500-70) \times 14.82 = 1529.4 \text{ B.t.u.}$$

0.24 being the specific heat of the chimney gases.

17 In the combustion of hydrogen to water each pound of H results in 9 lb. of water, or in our coal the water formed will be

$$0.038 \times 9 = 0.34 \text{ lb.}$$

18 The heat loss both latent and sensible in the evaporation of this water is

$$0.34\ (142 + 966 + 288 \times 0.47) = 422.6 \text{ B.t.u.}$$

wherein 212 deg. − 70 deg. = 142, assuming the temperature of the water in the coal to be that of the fireroom; 966 being the latent heat of the formation of steam at 212 deg. and of expansion against the atmosphere; 500 deg. − 212 deg. = 288 being difference between steam at 212 deg. and flue temperature as assumed; and 0.47 being the specific heat of superheated steam at atmospheric pressure.[1]

19 In case of oil we have

$$0.104 \times 9 = 0.936 \text{ lb.}$$

Heat loss is

$$0.936\ (62 + 966 + 288 \times 0.47) = 1088.5 \text{ B.t.u.}$$

The loss in coal due to ash is 8.6 per cent of total = 1209.7 B.t.u. A further loss in oil combustion is the heat absorbed by the steam used in atomizing, being in superheating the steam from 212 deg. to 500 deg. fahr. This is

$$288 \times 0.47 = 135 \text{ B.t.u.}$$

Tabulating these losses, which for convenience we will call fixed losses, we have:

| | Coal | Oil |
|---|---|---|
| Gases | 1219.8 B.t.u. | 1529.4 B.t.u. |
| Combustion of H | 422.6 B.t.u. | 1088.5 B.t.u. |
| Ash | 1209.7 B.t.u. | Burner 135.0 B.t.u. |
| | 2852.1 B.t.u. | 2752.9 B.t.u. |

While this calculation is not intended to convey any idea of the actual value of losses in the two fuels, it may however afford a comparison of what we may term fixed losses, within certain limits.

20 It is seen that the amount of air required for the combustion of coal is very much less than for oil. This is due principally to the very much greater hydrogen content in the oil, the carbon content being, roughly speaking, the same. Furthermore the combustion of the hydrogen requires a proportionately larger weight of air.

21 On the other hand the greatest loss in the coal is in the ash, as in the comparison of the fuels we must consider them as received. In the oil the loss due to non-combustible is practically negligible. The loss due to superheating the burner steam is also small.

22 In examining our figures a remarkable equality of the total losses is immediately apparent. To what extent this relation would hold for coals of different composition would have to be determined. Subtracting these losses from the calorific value of each fuel we have:

$$18{,}619 - 2752.9 = 15{,}866.1 \text{ B.t.u.}$$

$$14{,}067 - 2852.1 = 11{,}214.9 \text{ B.t.u.}$$

These last quantities represent the available heat left in fuel for evap-

[1] R. C. H. Heck. Thermal Properties of Superheated Steam, Trans. Am. Soc. M. E., vol. 30, p. 227.

oration. From this it would appear that the two fuels under examination had an evaporative value which is in the ratio of 11.2 for coal to 15.8 for oil. For coals equal in quality to that selected, the writer believes that this ratio will generally be correct, lower grade coals having correspondingly lower values. This ratio is also amply borne out in numerous actual tests.

23 It is shown in the foregoing that the theoretically required air supply is greater for oil than for coal. This means a greater volume of flue gases, hence a greater loss of heat. If we consider, however, those coals having a large amount of volatile matter, it is safe to say that the air supply for their complete combustion would be very much in excess of that for oil. Not knowing the composition of the volatile matter, we must necessarily figure with a certain indefinite quantity of excess air. In the combustion of oil we are able to supply more nearly that amount of air which is actually chemically required.

24 From the manner in which the oil is burned it is evident that a more perfect mixture of air with the gases is obtained. Not only is the air supply easily regulated by hand, but apparatus has been devised to effect the control mechanically and automatically to suit the momentary load requirements. Although it does not necessarily follow that a smokeless chimney signifies complete or most economical combustion, it does mean much to our neighbors and one can safely say that such a chimney is more often obtained in connection with an oil-burning furnace than with one burning coal.

25 Evaporative tests have shown that for good coal an equivalent evaporation of 11 lb. represents about the highest average, although there are cases of higher results on record. For oil the highest average yet attained is probably an equivalent evaporation of 16 lb.

26 In the report of the Naval Liquid Fuel Board the best evaporation with coal is given as 10.2 lb., while with oil the best is 14.4 lb. In some forcing tests made some time ago by F. W. Dean,[1] which are remarkable for the good results obtained at that time, an evaporation for coal of 11.32 lb. was had. In a water-tube boiler under ordinary conditions, using good coal, an average equivalent evaporation of 10 lb. can be considered good practice, although 11 lb. and slightly over is often obtained. Such results as these, it must be borne in mind,

[1] F. W. Dean. The Forcing Capacity of Fire Tube Boilers, Trans. Am. Soc. M. E., vol. 26, p. 92.

can be obtained only with the best grades of steam coal, similar or superior to the grade selected by the writer for comparison.

27 With oil fuel, in connection with water-tube boilers, records show an equivalent evaporation of 14 to 16 lb. Test records in the writer's possession range from 13.6 to 15.4 lb. The latter is the record of the performance of a 150-h.p. Heine boiler in San Francisco. The oil used had a calorific value of 18,629 B.t.u., gage pressure 119 lb., feed temperature 69 deg., flue gas temperature 480 deg., percentage of steam used for burner 2.8 of total water evaporated or 0.36 lb. of steam per lb. of oil; 15.4 is the value after correction for steam to burner. Incidentally the efficiency of the unit is 79.8 per cent. The figures given in the foregoing for oil can hardly be said to be due to any extraordinary construction or arrangement of furnace although care may have been shown in the selection of the burner.

28 In a series of eight tests made with two 66 in. by 16 ft. horizontal return tubular boilers, having one hundred and seventy-six 2-in. tubes each, and using Coalinga oil of 22 gravity, 18,900 B.t.u. per lb. of oil, the average evaporation of water from and at 212 deg. was 15.32 lb. The average total horsepower developed at rate of 34.5 lb. of water per hour was 262.5 for the battery. The theoretical evaporation of the Coalinga 22 gravity oil, 18,900 B.t.u. per lb., being 19.56 lb. of water per lb. of oil and the actual results having been an average evaporation of 15.32 lb., the fuel efficiency for this particular battery was 78.5 per cent.

29 It is the writer's opinion that with a few more years' experience and a more refined and perfected fireroom and furnace arrangement, we will be able to reach evaporations closely approximating the theoretical limits. The ease of manipulation of the fire and the possibility of practically exact regulation of air supply for complete combustion, lend to the fuel oil evaporative qualities that can be found in no other raw fuels.

## THE RELATIVE VALUE OF LIGHT OIL AS COMPARED WITH FUEL OIL

By Joseph Nisbet LeConte, Berkeley, Cal.

Member of the Society

30 Crude petroleum consists principally of various combinations of hydrogen and carbon together with comparatively small amounts of nitrogen, oxygen and sulphur. The nitrogen and oxygen and any

incombustible residue or ash may be classed as inert impurities. The sulphur, though combustible, has a low grade of heating value and is otherwise injurious.

31 Taking hydrogen and carbon as the principal constituents, it is found that those oils which are rich in the former element are of light specific gravity as compared with those rich in carbon. The range in specific gravity of California oils may be taken as from unity to 0.84, or from 10 deg. to 36 deg. of the Baumé scale. The majority of the fuel oils will range from unity to 0.9, or from 10 deg. to 23 deg. Baumé. It is also evident that, other things being equal, oils rich in hydrogen will contain more heat units per pound than those rich in carbon. Pure hydrogen contains 62,000 B.t.u. per lb., as compared with 14,500 B.t.u. per lb. for carbon. If petroleum were composed wholly of these two elements, a very consistent law might be expressed between the heat units per pound, and the specific gravity. As a matter of fact the other substances occurring in varying amounts destroy any exact relation.

32 Water in emulsion in crude oil not only acts as an inert impurity in a sample under test, but must be converted into steam in the furnace and thus still further reduces the heat value of the fuel per pound. It occurs in such variable and often in such large amounts, that no relation whatever between specific gravity and B.t.u. per pound can be discerned unless it is eliminated. In the following tables and diagrams, therefore, the oil is assumed to be anhydrous, the water having either been removed before testing, or else its amount determined and corrections made.

33 Nitrogen and oxygen are also inert impurities, but since their amounts are small, their effects are averaged in with the plotted results. Sulphur is a substance which causes considerable variation in the heating value of fuel oil. Sulphur contains 3900 B.t.u. per lb. Oils rich in sulphur, therefore, have a lower heating value per pound, other things being equal.

34 Many determinations of heating values and specific gravities of California oils have been made, but those upon which Table 3 is based were made in the chemical laboratories of the University of California and furnished through the kindness of Prof. Edmond O'Neill and his assistants. The calorific values were determined by means of an Atwater bomb calorimeter, and the specific gravity by means of a Westphal balance or a pycnometer flask at about 63 deg. fahr. Water was determined by distillation.

35 The resulting values for the heavier fuel oils the writer has

collected and plotted, as shown in Fig. 1. The ordinates in this case are degrees of the Baumé scale, which is related to the true specific gravity by the relation

$$\text{Specific Gravity} = \frac{140}{130 + B}$$

or

$$B = \frac{140}{\text{specific gravity}} - 130$$

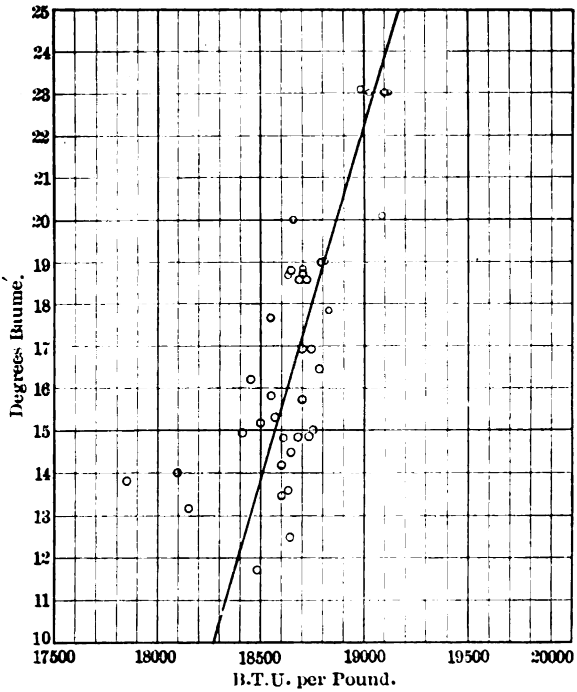



FIG. 1 RELATION BETWEEN SPECIFIC GRAVITY AND B.T.U. FOR HEAVIER FUEL OILS (ANHYDROUS)

at 63 deg. fahr. The abscissae are British thermal units per pound of the anhydrous oil. The points, as might be expected, are rather scattered, but can be approximated roughly by a straight line. In drawing the average line through these points the writer has been guided for its position wholly by the points themselves, and for its inclination, by the points and by a table of average specific gravities and calorific values furnished by R. W. Fenn of the Union Oil Company, covering a wider range of specific gravities than do the determinations gathered by the writer. The average line gives the relation

$$\text{B.t.u. per lb.} = 17{,}680 + 60\,B$$

over the range of these measurements.

TABLE 3 SPECIFIC GRAVITY, WEIGHT AND HEAT VALUE OF OIL
(UNION OIL COMPANY)

| Deg. Baumé | Specific Gravity | Weight per Bbl. | B.t.u. per Lb. | B.t.u. per Bbl. | Deg. Baumé |
|---|---|---|---|---|---|
| 10 | 1.0000 | 350.035 | 18,280 | 6,398,600 | 10 |
| 11 | 0.9929 | 347.55 | 18,340 | 6,374,100 | 11 |
| 12 | 0.9859 | 345.10 | 18,400 | 6,349,800 | 12 |
| 13 | 0.9790 | 342.68 | 18,460 | 6,325,900 | 13 |
| 14 | 0.9722 | 340.30 | 18,520 | 6,302,400 | 14 |
| 15 | 0.9655 | 337.96 | 18,580 | 6,279,300 | 15 |
| 16 | 0.9589 | 335.65 | 18,640 | 6,256,500 | 16 |
| 17 | 0.9524 | 333.37 | 18,700 | 6,234,000 | 17 |
| 18 | 0.9459 | 331.10 | 18,760 | 6,211,400 | 18 |
| 19 | 0.9396 | 328.89 | 18,820 | 6,189,700 | 19 |
| 20 | 0.9333 | 326.69 | 18,880 | 6,167,900 | 20 |
| 21 | 0.9272 | 324.55 | 18,940 | 6,147,000 | 21 |
| 22 | 0.9211 | 322.42 | 19,000 | 6,126,000 | 22 |
| 23 | 0.9150 | 320.28 | 19,060 | 6,104,500 | 23 |
| 24 | 0.9091 | 318.22 | 19,120 | 6,084,400 | 24 |
| 25 | 0.9032 | 316.15 | 19,180 | 6,063,800 | 25 |

36 Table 3 gives the computed values of B.t.u. per pound, and specific gravity, as well as the weight per barrel, and B.t.u. per barrel, as determined from this average line. From these it is seen that although the average heating value per pound of crude oil increases as the specific gravity diminishes, it does not increase so rapidly as the weight per unit of volume diminishes. The heating value per barrel of the heavier oils is therefore greater than that of the light ones.

## FURNACE ARRANGEMENT FOR FUEL OIL

By C. R. Weymouth, San Francisco, Cal.
Member of the Society

37 In a paper[1] presented at the New York meeting of this Society, December 1908, the writer gave various data regarding California

[1] Trans., Am. Soc. M. E., vol. 30, p. 797.

fuel oil, air required for combustion, the various losses in oil firing, and a description of an automatic system for the regulation of boilers fired with crude oil. Although the present subject properly includes the question of air supply for combustion, the writer, by reason of his former paper, will devote himself mainly to the question of furnace design, and this only for stationary water-tube boilers.

38 About twelve years ago the low cost and certainty of supply of crude oil led to its general use in California boiler plants. At that time with a few notable exceptions, there were none but the crudest methods for burning oil, the owner usually employing one of the numerous improvisors of oil burners to convert his plant, the operation generally consisting in introducing a burner through the fire doors, and covering the grates with fire brick. This plan was occasionally modified by the introduction of different forms of fire-brick arches, target walls, checker walls, etc. Many of these converted coal-burning furnaces caused frequent burning out of boiler tubes, due to the localization of heat; gave a very limited overload capacity; and by reason of various defects of furnace design, coupled with a general ignorance of the question of oil burning, produced in most instances mediocre results.

39 During the early period, E. H. Peabody, then testing engineer of the Babcock & Wilcox Company, began the first extensive engineering investigation of the merits of various types of furnaces, burners, etc., and after an extensive series of tests, lasting nearly two years, developed an oil furnace bearing his name, now in general use with certain types of water-tube boilers.

40 Mr. Peabody's tests indicated the following conclusions:

*a* That while there are differences in various types of burners, these are relatively unimportant.

*b* The proper design of furnace is of supreme importance as determining efficiency and capacity of boilers and immunity from shutdown, owing to tube burn-outs, etc.

*c* Fire-brick arches and target walls are not only needless in securing high furnace efficiency, but a menace to continuity of operation, owing to the impossibility of even the best grades of fire brick withstanding the intense heat of an oil furnace.

*d* Furnace depth and furnace volume are determining factors affecting furnace efficiency and capacity, and affording protection to the boiler heating surface, particularly when the character of boiler feed water gives rise to an accumulation of scale inside boiler tubes.

*e* The shape of furnace and path of flame must be such as to provide a nearly uniform distribution of furnace heat over the largest possible portion of boiler heating surface, as distinguished from an arrangement causing the direct impingement of flame on a few inches of the tube length.

*f* A large surface of heated fire brick is essential to the maintenance of a high furnace temperature and complete combustion of oil.

*g* The air for combustion should be admitted through carefully planned openings in the floor of furnace in such manner as to provide the most intimate contact of oil flame and incoming air, and thus reduce the air supply to a minimum.

*h* The flat flame or fishtail burner provides for the most economical use of air for combustion.

*i* When all these requirements for highest economy are observed, the furnace flame has not the bright incandescence sought by the pioneers in oil burning, but borders surprisingly on an orange red.

41 In the Peabody furnace the bridge wall is set back from the boiler front to give a depth of from 8 to 10 ft., depending on the size of boilers. The burner is of the back shot type, inserted from the boiler front under the floor of the furnace and turning up at the bridge wall. It shoots the flame forward toward the front of the boiler, where there should be an extra course of fire brick set in place without fire clay, to afford added protection to the front wall. With boilers having tubes inclined downwards from the front towards the rear, there is thus provided a furnace design of such a shape as to give the necessary increased volume as the velocity of the flame decreases in flowing away from the burner. This provides a gradual distribution of the furnace heat over the tubes the full length of furnace, without a direct impingement of flame at any point.

42 Except in special boilers, the furnace should have a height at its front end of not less than 6 ft. and for large size boilers the height should be from 7 to 8 ft., depending on the character of feed water and desired overload.

43 Under ordinary firing, the flame should not extend into the tubes, but under forced firing it will extend part way through the first pass.

44 Under Babcock & Wilcox boilers, Mr. Peabody's record performance of 1903 was 83 per cent efficiency at rating, based on 10 sq. ft. of heating surface per boiler horsepower, and an overload capacity of 110 per cent above rating.

45 When admitting a large excess of air and an ordinary amount of oil, the flame length will be a minimum, and the temperature of incandescence will be reached at the surface of the envelope separating the vaporized oil and air for combustion. This bright flame is sought by the untrained fireman, but it results in a large loss of fuel, as the subsequent mixture of the products of combustion with the excess of air not in contact with the flame produces a lower mean furnace temperature. With economical firing the flame lengthens before coming in contact with sufficient air for complete combustion, and with the highest furnace efficiency this temperature varies from 2500 to 2800 deg. fahr.

46 The location of the furnace relative to the boiler heat absorbing surface is of the utmost importance, not only on account of the loss of heat and consequent radiation from furnace walls when there is excessive travel, but also by reason of the large amount of heat absorbed by direct radiation as distinguished from convection. The first pass of the boiler should be located directly over the furnace, providing the most direct transmission of the heat generated, both by convection and absorption of radiant heat.

47 Owing to the large area of incandescent fire-brick surface, the radiant heat is uniformly diffused over a large heating surface and the amount of heat thus absorbed becomes an important factor in determining the efficiency of boiler heating surface; for while no heat can ultimately be lost, the greater the heat absorbed in the first pass of boiler, the lower will be the temperature of gases on entering the second pass; and finally the later passes of the boiler are able to accomplish greater cooling of the products of combustion, resulting in the lowest possible stack temperature and hence the maximum absorption efficiency of boiler.

# ATOMIZATION OF OIL

By A. M. Hunt, San Francisco, Cal.

Member of the Society

48 In order that petroleum may be burned with complete combustion, it is necessary that it be either gasified or injected in the form of a spray into the furnace in which it is burned. If the oil is being injected into a coal furnace, that is, one not enclosed by walls of brick or other material which becomes highly heated, the oil must be injected in a spray composed of very fine particles, in order that none of the particles shall fall to the bottom unconsumed. If the walls are highly heated, the radiation from them will aid greatly in vaporizing the oil particles, and larger particles will be consumed before they drop. If the furnace is short, the oil particles will have a relatively short time period within which they must be consumed, and must, therefore, be smaller.

49 It is evident that anything which will enable the oil more easily to be atomized, or that will aid in vaporizing an oil particle after it is injected into the furnace, will help to reduce the quantity of atomizing medium required, whether it be steam or air.

50 Most of the oils used for fuel are of a heavy and viscous character, and their viscosity is rapidly reduced by rise in temperature. It is, therefore, desirable that the oil fed to the burners be preheated, and it is almost universal practice to do so. The preheating is usually accomplished by passing the oil through a heater similar in type to a closed feed-water heater, using the exhaust steam from the pumps handling the oil. The burner should be so built that the relative areas of openings for issue of oil and atomizing medium can be maintained, or if they become enlarged by scoring, that adjustment can be readily and inexpensively made.

51 Some work has been done in the direction of atomizing the oil without the use of air or steam. The oil having been preheated to temperatures of from 220 to 260 deg. fahr., is injected into the furnace through a needle nozzle, having a small sized orifice. The portion of the needle stem inside the cylindrical part of the nozzle has cut on it a screw thread, which imparts to the issuing oil a rotary motion. The release of pressure on the heated oil, and the rotary motion imparted to it, cause it to issue in the form of a spray in a state of subdivision fine enough to enable it to burn successfully.

52 I give below some data as to amounts of atomizing medium required for fuel oil, obtained from various sources:

## DATA AS TO AMOUNT OF STEAM REQUIRED FOR ATOMIZING FUEL OIL IN BOILER FURNACES

| | |
|---|---|
| **Case 1** | |
| Steam supplied to burner per lb. of oil | 0.537 |
| Actual evaporation per lb. of oil | 13.48 |
| Percentage | 4.0 |
| **Case 2** | |
| Steam supplied to burners per hour | 4373.0 |
| Actual evaporation per hour | 96881.0 |
| Percentage | 4.5 |
| Steam per lb. of oil for atomization | 0.529 |
| **Case 3** | |
| Steam supplied to burners per hour | 7087.0 |
| Actual evaporation per hour | 174820.0 |
| Percentage | 4.0 |
| Steam per lb. of oil for atomization | 0.485 |
| **Case 4** | |
| Steam supplied to burners per hour | 5746.0 |
| Actual evaporation per hour | 144079.0 |
| Percentage | 4.0 |
| Steam per lb. of oil for atomization | 0.475 |
| **Case 5** | |
| Steam used was measured by use of separate boiler. | |
| Oil used | 34½ deg. Baumé |
| Total evaporation per lb. of oil from and at 212 deg | 14.99 |
| Percentage steam evaporated, used by burner | 7.4 |
| **Case 6** | |
| Steam used was measured by calibrated nozzle. | |
| Total evaporation per lb. of oil from and at 212 deg | 14.7 |
| Percentage steam evaporated, used by burner | 2.5 |
| **Case 7** | |
| Steam used was measured by calibrated nozzle. | |
| Total evaporation per lb. of oil from and at 212 deg | 14.2 |
| Percentage steam evaporated, used by burner | 3.6 |
| **Case 8** | |
| Steam used was measured by use of separate boiler. | |
| Total evaporation per lb. of oil from and at 212 deg | 15.2 |
| Percentage steam evaporated, used by burner | 2.96 |

53 From tests made under the direction of the Bureau of Steam Engineering in 1902, the following data are taken: Four tests were made using steam as the atomizing medium. The percentage of

total evaporation used by the burners ranged from 3.98 to 5.77 per cent. A number of tests made under Stirling water-tube boilers gave results ranging from 2.1 to 3.42 per cent.

54 From the above data and general practice and experience, the following statement can be made: In designing a plant it is entirely safe to assume 5 per cent of the evaporation of the boilers for steam supply for burners. In operation, if the amount is greater than 3 per cent, it may be concluded that the condition can be bettered.

55 The use of compressed air for atomizing fuel oil may be stated to offer no opportunity for fuel saving over the use of steam direct in cases where steam is available. The use of steam direct obviates complication, and risk of interrupted service, and the use of compressed air is not justified unless there is some special reason for it. It may be that steam cannot readily be had, and that a motor-driven compressor can easily be installed, or where steam is available, the loss of water through steam supplied to the burners may be undesirable, as in the case of sea-going steamers.

56 In certain metallurgical and industrial operations, especially where high temperatures are desirable, the use of air is to be preferred. In rotary cement kilns, using oil fuel, compressed air as the atomizing agent is universally employed so far as I know. Reverberatory furnaces for metallurgical operations, using oil fuel, employ compressed air.

## DATA AS TO AMOUNT OF AIR REQUIRED FOR ATOMIZING FUEL OIL

### Case 1

Rotary cement kiln, 7 ft. 6 in. in diameter by 125 ft. in length, producing about 500 bbl. of clinker daily. Air used under pressure of approximately 80 lb. Single burner, delivering oil at the rate of about 4 gal. per min. The weight of air required for atomization is approximately 25 per cent of the weight of the oil atomized.

### Case 2

Data furnished by air compressor manufacturer as to capacity of compressor furnished for boiler installation of 2500 h.p. Assuming that the entire capacity of the compressor was necessary, this figures out a use of air amounting to approximately 55 per cent of the weight of fuel atomized.

The same manufacturer gives the following data: For marine boilers figure 1 cu. ft. of free air for each 5 boiler h.p., the air being supplied at a pressure of about 25 lb.

A 10-cu. ft. compressor at 20 lb. will supply air sufficient to atomize the fuel oil to take care of a boiler furnishing steam heat for a small apartment house.

For burning sewer pipe it takes about 5 cu. ft. per min. for each burner using about 5 gal. per hr. of oil.

He adds the following comment: We favor the use of air as hot as we can get it from the compressor, cutting out the water jackets.

CASE 3

Reverberatory copper matting furnace. Hearth 80 ft. long by 17 ft. wide. Center of roof arch is about 39 in. above the surface of bath on hearth. Fired from the end using four burners. Amount of material smelted per day, 182 tons. Oil used per day, 36,472 lb. Air for atomizing supplied by a motor-driven Connersville blower at 9 lb. pressure. Amount of air used, about 50 per cent of weight of oil burned.

## SIZE OF STACKS WITH FUEL OIL

By K. G. Dunn, San Francisco, Cal.

Member of the Society

57 The question of stack area and draft depends on the quantity of fuel burned and the draft required. In coal burning, the draft necessary to overcome the friction of the fuel bed runs anywhere from 35 to 70 per cent of the total draft head. This is done away with in oil-burning furnaces and consequently a shorter stack will answer. A height of stack of from 80 to 100 ft. is all that is necessary. In coal-burning plants stack sizes are based on 5 lb. of fuel per boiler h.p. In changing to oil we have to figure on the basis of only 2½ lb. per boiler h.p., and considering that oil can be burned with a smaller amount of excess air than coal, a stack of given area would serve for double the horsepower with fuel oil than it would with coal.

58 There are many stacks operating successfully on the basis of 50 per cent of the sizes given in Kent's table. I have in mind a record of one stack which, when forced to the limit, operated on the basis of 35.7 per cent. When this point is reached the pressure in the furnace is so great that the gases pass out through the joints in the setting and through the boiler breeching. One point in connection with this, which I believe is not given the attention that it should have, is that of breeching area. Ordinarily the effective area of the breeching is not considered, as in many plants the breechings are narrow and long, and in several instances that I know of, the effective areas are in the neighborhood of 70 to 80 per cent of what they really should be.

# LOCOMOTIVE PRACTICE IN THE USE OF FUEL OILS.

By Howard Stillman, San Francisco, Cal.

Member of the Society

59 About the first practical use to which fuel oil was applied as a means of generating steam in California was on a locomotive engine of the Central Pacific Railroad, in 1886, the tests being made between Sacramento and Davisville. The oil was comparatively thin and of a reddish color, and was, I think, a foreign product. The experiments as I remember, were quite satisfactory, but the price of this oil was high and the matter was dropped.

60 Following the subsequent oil developments in California and the promise of a sufficient supply, a continuation of the early experiment was made and tests indicated great possibilities for this fuel. The first regular conversion of a locomotive to oil burning in regular service was on the Southern Pacific Railroad in November 1900 and a number of tests made in comparison with coal fuel proved so satisfactory that, in February 1901, we were authorized to equip other engines. This was gradually done, and in about five years all locomotives were converted to oil burners on the Southern Pacific in California, and extending to El Paso, Texas, embracing what are known as the Calvin Lines. The approximate number of locomotives we now have burning oil is as follows:

| | |
|---|---|
| Passenger | 396 |
| Freight | 455 |
| Switch | 140 |
| Total | 991 |

61 On the above basis the consumption is 677,875 lb. per month, or 8,134,500 bbl. per year. These figures are for about six months ago and are slightly exceeded at this time.

62 The characteristics of the oil have been fully covered in the previous papers. There is, of course, a slight variation in specific gravity ranging from 14 deg. to 15 deg. Baumé. Its calorific value is taken at 18,500 B.t.u., which we consider to express its heat value. The following specifications for fuel oil have been adopted by the Southern Pacific system:

*General Requirements*. Liquid fuel is crude petroleum as received from the wells, or the product of crude petroleum, distilled or reduced. It must contain no sand or foreign matter in the shape of sticks, waste, stones, etc., and must be sufficiently liquid to flow readily in 4-in. pipes at a temperature of 70 deg. fahr. It must contain as little water as possible, and oil containing more than 2 per cent of water and other impurities will not be accepted.

Fuel oil will be paid for on the basis of volume at 60 deg. fahr., also deducting all water contained, according to method outlined as follows:

*Tests*. One sample will be taken from each carload or fraction thereof. The sampling of cars is to be made with car thief having valve at lower end. The thief with open valve will be lowered gradually into car and valve closed at instant of touching bottom. The thief thus filled will contain oil sample to be tested for water, sand, basic sludge, and specific gravity.

Oil received in settling or storage tanks will be sampled with Robinson or other standard thief, a sufficient number of samples being taken to secure an average of its contents.

Fuel oil will not be accepted for general use, the flash point of which is less than 110 deg. fahr. when tested by the open cup, Tagliabue method. The oil to be heated at rate of 5 deg. per min., and test flame applied every 5 deg., beginning at 90. This flashpoint being the danger point at which the oil begins to give off inflammable gas, the fire or burning point is not required.

The test for water, sand, and Baumé specific will be made as follows: 100 cu. cm. of the sample will be placed in a 250-cu. cm. graduated glass cylinder provided with stopper, and thoroughly shaken up with not less than 150 cu. cm. of gasoline. The mixture will be heated to 120 deg. fahr. for from 3 to 6 hours to facilitate the separation of impurities, the amount of which can then be read from the graduations of cylinder. All proportion of water and other impurities contained in the sample will be deducted from the volume contained in the car and not paid for.

The temperature of shipment will be tested directly as sample is removed from sampling tube, or by immersion of thermometer in the receptacle itself for not less than one minute. A deduction in volume for expansion at temperature of over 60 deg. fahr. will be made at rate of 0.0004 for each degree. At 90 deg., the deduction would be 1½ per cent, etc.; Kansas and Oklahoma fuel oil furnished from Sugar Creek or Kansas City, Mo., at 90 deg., should have a deduction of 1¼ per cent.

Gravity of fuel oil should range between 13 and 29 deg. Baumé at 60 deg. fahr.

*Conditions*. If any portion of an accepted shipment is subsequently found to be damaged, or otherwise inferior to the original sample, that portion will be returned to the shipper at his expense. Any sample failing to meet all the requirements of this specification will be condemned, and the shipment represented by it will be returned to the manufacturers, they paying freight both ways.

63 In the evolution of oil burning in locomotives, the matter unfortunately resolves itself to one of local conditions. The modern locomotive boiler is not an ideal form of oil furnace. Railroads must

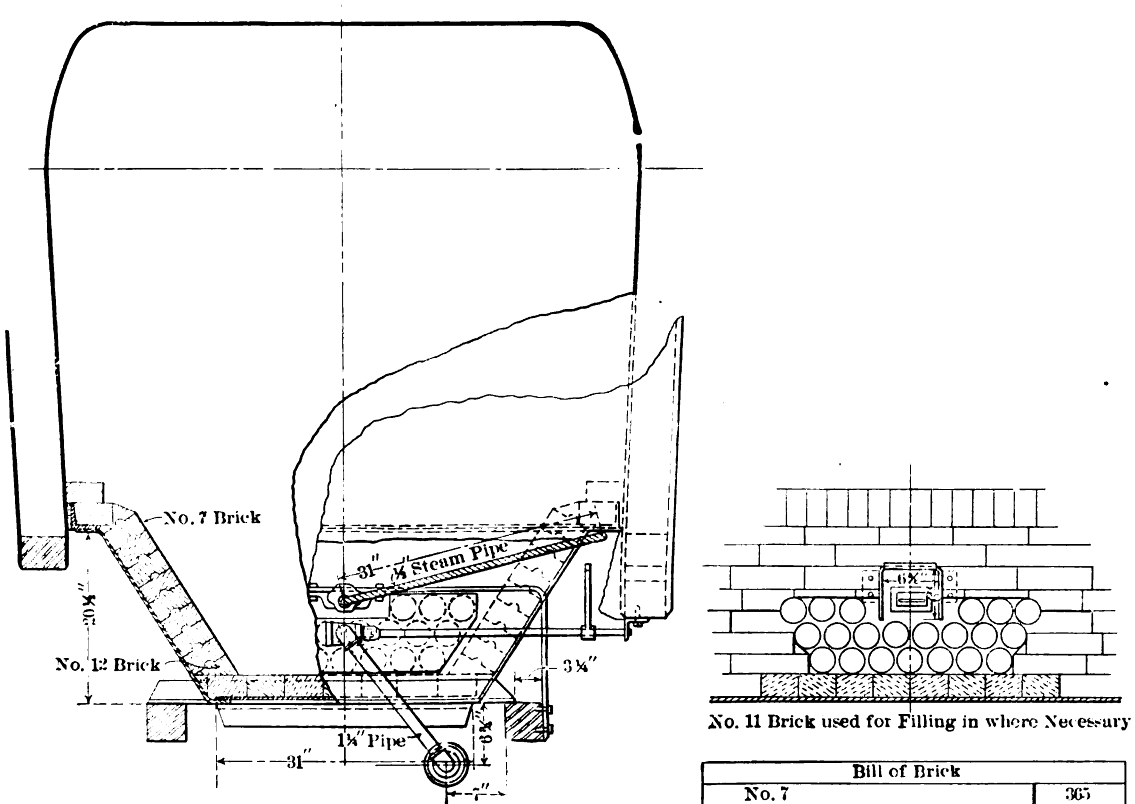
burn whatever fuel is cheapest and most available, and the matter continues to be one largely of expediency.

64 Locomotive boilers are designed for coal fuel and it was formerly boasted that should emergency arise the oil burners could be converted over night in the roundhouse back to coal again. From the figures given us by Mr. Bell it does not seem at all likely that the contingency will soon arise.

65 Locomotive fuel oil is carried in tanks built to fit the coal space in the tender. Additional flat tanks when required are placed over the coal space or back of it. Gravity supply is depended upon through flexible pipes to the locomotive. Each system of oil tanks on the tender is provided with a gage board or scale from which the fuel records are kept.

66 The burner used is of the flat jet type consisting of a flat casting divided longitudinally by a partition over which the oil flows as it is admitted to the upper cavity. The lower cavity receives the steam for the jet which strikes the oil flowing over the partition, spraying it into the furnace. We aim completely to atomize the oil near the burner tip in order that it may be immediately vaporized. The form of burner is of little importance provided it is simple, easy to clean, and without complication from carbonizing. It has in truth been said that those who try to improve the efficiency of fuel oil by alteration of the burner are on a plane with those who try to improve the steaming quality of a boiler by altering the injector. High efficiency from fuel oil is due mainly to the arrangement of the furnace.

67 The steam for atomizing is obtained from the dome and is available at full boiler pressure of 200 lb. through a suitable regulating valve. We have used compressed air experimentally and for some time used a form of burner that delivered air inductively to the burner itself. Other than by a localization of heat at the point of the burner, no benefit could be found by tests with air mingled with the steam in this way. Atomization with compressed air is undoubtedly of value under certain conditions but is liable to produce locally in the furnace a more intense heat than is desirable. With the steam jet the oil is sprayed and broken up so as to allow the air admitted through proper dampers to mix and the oil to be consumed completely without damage to the sheets. Tests on our locomotives by Professor Grey, formerly of the University of California, show that temperatures ranging from 2500 to 2750 deg. fahr. are obtained, the latter being the highest observed.




No. 11 Brick used for Filling in where Necessary

| Bill of Brick | |
|---|---|
| No. 7 | 365 |
| No. 11 | 6 |
| No. 12 | 20 |
| Plain Brick | 58 |

FIG. 2 CROSS-SECTION OF LOCOMOTIVE FIREBOX, SHOWING METHOD OF FITTING FOR OIL BURNING

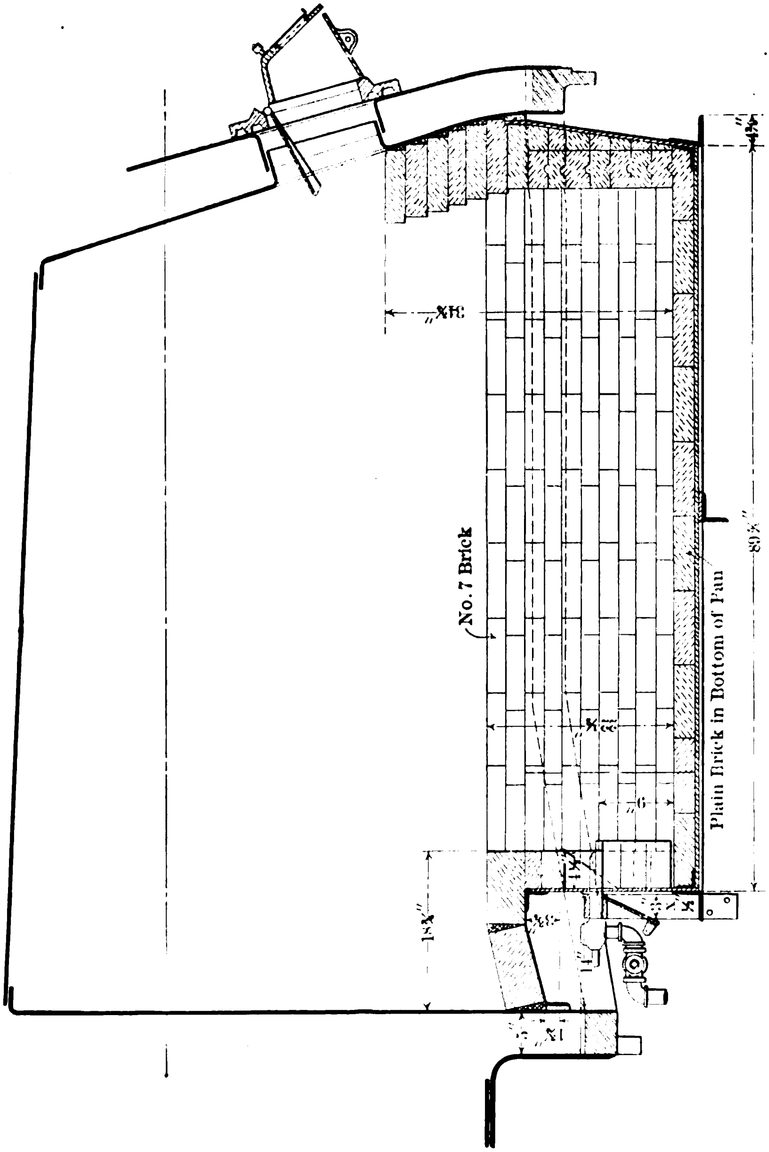



**Fig. 3 Longitudinal Section of Fire Box**

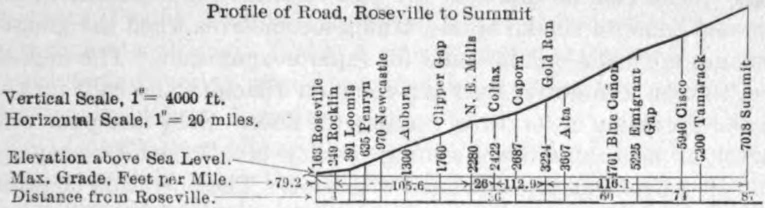
68 The method of fitting a locomotive fire box for oil burning is shown in Figs. 2 and 3, which is the present standard arrangement for our heavy freight engine of the consolidated type. Fire bricks, the most refractory obtainable, are placed at the lower side of the fire-box plates to prevent impinging of the oil blast against the sheets. No more bricks than are necessary for the purpose are used. The most refractory bricks melt out in a comparatively short time—not from an intense degree of heat but from the fluxing agents introduced with the oil, especially salt or other alkalis with which California petroleums are associated.

69 Fire-box repairs to oil-burning locomotives do not exceed those of coal-burning engines. From records kept of cost of maintenance, we know that if a furnace is properly equipped with draft adjustment and burner, an oil-burning fire box will outlast a fire box burning coal; that is, on the same class of engines in the same service. However, it cost a good many fire boxes to determine the best arrangement. In this connection I wish to emphasize the fact that the oil fireman is a large factor in successful oil burning on locomotives. The condition is very different from that of oil firing on stationary boilers. Conditions are constantly varying in the locomotive engine, depending on load and speed, regularity of service, condition of track, grade and rules of the road. The oil fireman must necessarily watch the operation of the locomotive with intelligence and every movement of the engineer demands corresponding regulation of the fire and watchfulness on the part of the fireman. He has two gages to guide him, the steam gage and top of the stack to show results, the desired steam pressure with least smoke being the objective. It is a general though not universal condition that the locomotive should give some smoke. In general a thin grey smoke is indicative of the most economic result. A careless fireman can do great damage to the fire box and flues if he neglects to attend to the dampers and regulators at the proper time.

70 It is my opinion that a greater depth of fire box is more essential for economic oil burning than for coal. If combustion is not approaching completion when the gases enter the flues, the vapors in process of combustion fall in temperature below that required for oxidation of the carbon, which is precipitated as soot or black smoke. While this is a common phenomenon of smoke production with any fuel, it is more in evidence with oil than with solid fuel where there is nothing to burn but volatile combustible. Lack of oxygen is generally supposed to be the cause of smoke, but lack of proper tempera-

TABLE 4 DATA FROM EVAPORATIVE TESTS OF LOCOMOTIVES CROSSING THE SIERRA NEVADAS, SACRAMENTO DIVISION, SOUTHERN PACIFIC COMPANY

Profile of Road, Roseville to Summit




| | | | |
|---|---|---|---|
| Class of engine | 10 wheel | Consolidation | Mallet consolidation |
| Service | Passenger | Freight | Freight |
| Date of test | May 21 and 26, 1908 | June 9 and 11, 1909 | Nov. 6 and 8, 1909 |
| Number of single trips in test | 2 | 2 | 2 |
| Total time of test | 17 hr. 39 min. | 21 hr. 23 min. | 29 hr. 2 min. |
| Actual running time | 13 hr. 55 min. | 12 hr. 59 min. | 18 hr. 11 min. |
| Miles run | 315 | 174 | 174 |
| Average steam pressure (gage), lb | 196.0 | 196.1 | 194.5 |
| Smoke box temperature, deg. fahr | 797 | 738.5 | 451.3 |
| Total gal. water evaporated | 44147 | 48103 | 91087 |
| Total lb. water evaporated | 367642 | 400858 | 759058 |
| Total gal. oil burned | 3951.6 | 4328.4 | 7692.1 |
| Total lb. oil burned | 31613 | 34627 | 61537 |
| Equivalent evaporation, lb. water per lb. oil | 14.14 | 13.95 | 15.04 |
| Lb. water evaporated per sq. ft. heating surface per hr | 8.698 | 8.809 | 6.392 |
| Lb. oil burned per sq. ft. heating surface per hr | 0.748 | 0.761 | 0.518 |
| Number of cars in train | 7 | 14.5 | 24.5 |
| Weight of train, tons | 342 | 481 | 1056 |
| Gross ton mileage | 107730 | 83694 | 183744 |
| Gal. water evaporated per 1000 ton mi. | 409.79 | 574.75 | 495.73 |
| Lb. water evaporated per 1000 ton mi. | 3413 | 4790 | 4131 |
| Gal. fuel oil burned per 1000 ton miles. | 34.90 | 48.40 | 39.51 |
| Lb. fuel oil burned per 1000 ton miles. | 279.20 | 387.20 | 316.08 |
| Boiler efficiency, per cent | 73.84 | 72.83 | 78.52 |
| Maximum i. h. p. | 1719 | 1470 | 2486 |
| Mean i. h. p. | 1368 | 1222 | 2057 |
| Dimensions of locomotive | | | |
| Engine no. | 231 | 2564 | 4001 |
| Size of cylinders, in. | 22×28 | 22×30 | 26 and 40×30 |
| Diameter of drivers, in. | 63 | 57 | 57 |
| Total weight of locomotive, lb. | 203300 | 208000 | 425900 |
| Weight on drivers, lb. | 160000 | 187000 | 394150 |
| Weight of tender, lb. | 138070 | 134745 | 169765 |
| Total heating surface, sq. ft. | 2994 | 3403 | 6394 |
| Feed water heater, heating surface, sq. ft. | | | 1221 |

NOTE.—Train weights are the average for the distance hauled and are exclusive of engine and tender. Tests made under ordinary service conditions. Engines unaided. In "water evaporated and oil burned per sq. ft. heating surface per hr.," the figures are for actual running time; the allowance of 15 gal. of oil and its equivalent in water is made per hr. while standing. In "gal. and lb. oil per 1000 ton mi.," a deduction is made of 15 gal. per hr. while standing and 3.5 per cent of oil for evaporating steam for atomizing oil. Quantity of oil burned corrected to normal temperature of 70 deg. fahr. All measuring instruments calibrated. Analysis of fuel: Kern River oil; gravity, 15.8 deg. Baumé; flash point, 230 deg. fahr.; fire point, 278 deg. fahr.; commercial weight, 8 lb. per gal.

ture required for chemical combination is as often, if not oftener, the cause. The lack of sufficient fire-box volume is, in my opinion, the common cause of smoke in oil-burning locomotives when the greater demands are made on the boiler for rapid evaporation. The deposit of soot upon locomotive flues is a common difficulty and calls for the regular operation in service of sanding the flues. Soot is a poor conductor of heat and the steaming quality of a locomotive rapidly falls off when flues become lined with soot. The operation of sanding consists in dropping a reverse lever, if possible while the engine is running, pulling the throttle wide open, while the fireman puts a few cupfuls of sand through the opening in the fire door, the draft carrying the sand through the flues and ridding them of soot, the operation being repeated if necessary. A supply of sand is carried on the foot board for this purpose.

TABLE 5 COMPARATIVE TESTS WITH OIL AND COAL

| Type of Locomotive | Number in Service | Evaporation, 2000 Lb. Coal Equivalent to Fuel Oil, Gal. |
|---|---|---|
| Eight-wheel 18-24 | 50 | 144 |
| Ten-wheel | 294 | 151 |
| Mogul | 176 | 146 |
| Twelve-wheel | 67 | 158 |
| Consolidation | 139 | 162 |
| Atlantic | 19 | 144 |
| Mallet Consolidated | 17 | No coal record |

71 In oil burning the factor of grate surface disappears. The grates are bricked over and air admission regulated through openings and proper dampers. There is no function corresponding to grate surface such as used in connection with coal burning. Only the item of heating surface remains on which to base comparisons.

72 The rate of combustion on the locomotive, like other functions, depends on the service and size of the machine. While the principles of combustion do not vary in locomotive boilers from those in stationary service, there is a wide variation in the rate of steam production, independent of the kind of fuel used. With the modern locomotive in main line service the demand for steam at full pressure per unit of heating surface far exceeds, in point of time, the product of a stationary boiler. The demand on the locomotive is intermittent and conditions vary from an enormous rate of steam production when working at a rate of maximum effort, to one of comparative rest.

73 A large number of locomotive tests have been made by the Southern Pacific Railroad, covering the use of fuel oil as well as in comparison with coal. Table 4 shows evaporative results on most recent tests covering about the heaviest oil firing which we have, crossing the Sierra Nevadas.

74 Comparisons of coal and oil from an economic standpoint are most interesting where the two fuels come in competition, and relative values must largely depend on the conditions and form of boilers under which either fuel is burned. Some engine boilers are better adapted for coal than oil, or vice versa, depending on construction.

TABLE 6 RECORD OF COAL BURNED DURING LAST SIX MONTHS OF 1901, AND OIL BURNED DURING LAST SIX MONTHS OF 1908, ON STEAMERS OF SOUTHERN PACIFIC COMPANY

| Steamer | Tons Coal Consumed Last Six Months of Coal Burning | Mileage for Corresponding Period | Miles per Ton of Coal Consumed | Barrels Oil Consumed, Six Months (42 Gal. per Bbl.) | Mileage for Corresponding Period | Miles per Bbl. of Oil Consumed | Equivalent of One Ton of Coal for Equal Mileage in Bbl. of Oil |
|---|---|---|---|---|---|---|---|
| Berkeley | 2764 | 18592 | 6.72 | 11207 | 21130 | 1.89 | 3.56 |
| Piedmont | 4223 | 19548 | 4.63 | 15414 | 20808 | 1.35 | 3.43 |
| Oakland | 3209 | 18348 | 5.72 | 13603 | 19894 | 1.46 | 3.92 |
| Bay City | 2889 | 21536 | 7.45 | 11548 | 20943 | 1.81 | 4.12 |
| Encinal | 3703 | 20284 | 5.47 | 10512 | 19678 | 1.87 | 2.93 |
| Newark | 1860 | 9372 | 5.04 | 6559 | 10631 | 1.62 | 3.11 |
| Transit | 2581 | 16715 | 6.48 | 9548 | 17922 | 1.88 | 3.45 |
| El Capitan | 1019 | 7238 | 7.10 | 3431 | 6072 | 1.77 | 4.01 |
| Solano | 4516 | 5480 | 1.21 | 17151 | 7143 | 0.42 | 2.88 |
| Apache | 1971 | 18992 | 9.64 | 7996 | 21380 | 2.67 | 3.61 |
| Modoc | 2265 | 20685 | 9.13 | 7682 | 21170 | 2.76 | 3.31 |
| Totals and Resultant Means | 31000 | 176790 | 5.70 | 114651 | 186771 | 1.63 | |

Mean Equivalent of 1 Ton of Coal in Bbl. of Oil, 3495

Comparisons therefore are to some degree a function of the boiler itself. This was gone into quite thoroughly when the locomotives were converted and a summary of the results is given in Table 5. The figures are based on evaporative tests before and after conversion. The comparisons are with ordinary bituminous coal of about 13,350 B.t.u.

75 The total number of locomotives accounted for in Table 5 is 745, and the mean equivalent is 152 gal. or 3.62 bbl. of 42 gal., equivalent in heat value to 2000 lb. of coal. The average equivalent figures in the table cover much careful work and are based on equivalent evaporative results from many service tests.

It should be borne in mind that the figures are from service tests and represent oil burned on the main line between terminals only and not losses in transfer, handling or firing up, etc. Our accounting department uses a figure of 168 gal. or 4 bbl. of oil, equivalent to one ton of coal.

76 It may be said that with fuel oil, providing engines are burning it with a fair degree of efficiency, the quality of fuel is a constant factor. Poor or bad coal as accounting for engine failures drops from the delay report—"cleaning fires" is abolished.

77 Concerning relative values of coal and fuel oil I cannot close without submitting Table 6, showing results with both fuels on the Southern Pacific Company's bay steamers, the figures comprising the last six months' record with coal for the year 1901 compared with the last six months in oil for the year 1908.

78 These figures are not from evaporative tests but cover the service of eleven steamboats, a total of 176,790 miles as coal burners, and 186,771 miles as oil burners, and are from the official accounting record.

79 The service of these bay steamers represents a consumption per year of 229,302 bbl., which, added to my former figure per year for locomotives, gives a total of 8,363,802 bbl. per year consumed by the Southern Pacific Company. In addition to this a considerable amount is used in shops and rolling mills.

80 Let us hope that the rate of production in California as shown in Mr. Bell's paper, 63,000,000 bbl. in 1910, may keep up. Approximately one-seventh is consumed by the Southern Pacific Company.

## MARINE USE OF FUEL OIL

By J. H. Hopps, San Francisco, Cal.

Member of the Society

81 As a fuel for steamships, petroleum has many advantages besides that of low cost, the most important of these being:

- *a* The saving in labor and consequent reduction in the number of firemen. The amount of money saved varies with the size of the ship and the number of firemen carried. In installations of average size, one-third the number of firemen and coal passers necessary when burning coal would be sufficient.

*b* Reduction in weight and bulk of fuel, giving increased cargo capacity and resultant greater earning power. Comparing "Wellington Screenings," a type of coal generally used for steamship work on the coast, and fuel oil at from 14 to 17 Baumé, oil for equal heating value occupies about one-half the space taken by the coal and has less than one-half the weight. Oil may be carried in parts of the ship not otherwise useful.

*c* Saving in time. The time consumed in coaling and expense of moving to bunkers is saved, as fuel oil can be pumped into the ship when at the dock and while the cargo is being taken on or discharged.

*d* Uniform steaming. The rate of steaming can be kept uniform, there being no loss due to cleaning fires, etc.

*e* Cleanliness, due to the absence of coal dust and dirt when coaling and to the absence of ashes in the fireroom.

*f* Reduced cost of maintenance. Fewer repairs on boilers due to uniform temperature in furnace and combustion chamber. No corrosion of floor plates, fire fronts, or bunkers. No grate bars to burn out, fire doors or ash-handling machinery to renew or repair.

82 That the advantages of oil as fuel are recognized is evident from the large number of steamers using this fuel. Some of these vessels are of large size and make long voyages, notably, the ships of the Hawaiian American Steamship Company, the steamers Tenyo Maru and the Chiyo Maru of the Toyo Kisen Kaisha Company, the steamers Sierra and Mariposa of the Oceanic Steamship Company and the numerous large tank steamers owned by the Standard Oil, Associated Oil and Union Oil Companies.

## RESULTS OF TESTS

83 It is not possible to give exact figures upon the saving effected by the use of oil as the prices of both coal and oil are constantly changing. Some instances, however, may be quoted.

84 In the report of the Naval Liquid Fuel Board published in 1904, figures are given upon the performance of the Steamship Nevadan of the Hawaiian American Steamship Company. The following tabulation is taken from these, voyage No. 1 with coal being from San Diego to New York and voyage No. 2 with oil from New York to San Diego.

| | Total I. H.P. | Fuel | Total Consumption of Fuel | Coal per I. H.P. | Oil per I. H.P. |
|---|---|---|---|---|---|
| Voyage No. 1..... | 1833 | coal | 2269 tons | 2 lb. | ...... |
| Voyage No.2...... | 2196 | oil | 9126 bbl. | ...... | 1.1 lb. |

85 Of the coal burned, part was Eureka and part Coronel coal. The heat value of the coal is not given. The figures for voyage No. 2 represent an exceptionally fine performance. The steamer was new, fitted with triple-expansion engines, the Howden system of forced draft, and the Lassoe-Lovekin oil-burning system.

86 When burning oil, six men were required in the fireroom as against fifteen when burning coal. Four hundred and fifty-seven tons of measured space for cargo was saved on account of the decreased bulk of the oil fuel. The financial gain to the company from all causes is given as $500 per day.

87 In the case of a small coasting steamer coming under the observation of the writer, careful records were kept of the fuel cost, both with oil and coal. The cost of fuel per hour of actual steaming, averaged for a period of six months in each case, was

| | |
|---|---|
| Coal at $5.25 per ton.................................. | $2.65 per hr. |
| Oil at $0.70 per bbl.................................... | 1.64 per hr. |

88 In 1903 a series of tests were made by T. W. Ransom on the tugs Richmond and A. H. Payson, owned by the Santa Fé Railroad Company. As these vessels ply only on San Francisco Bay and in smooth water, the installation of platform scales to weigh the feed water and fuel oil was feasible. The tests were made with great care, a number of observers being employed and all essential data recorded to show the efficiency of the entire installation and of the boilers and engines separately. The detailed data secured were destroyed in the fire of 1906, there remaining only a summary of the results.

89 The machinery of the two vessels is identical with the exception of the boilers. The Richmond is fitted with a boiler of the Scotch marine type, 13 ft. mean diameter by 11 ft. long, with three Morrison furnaces, 3 ft. 6 in. in diameter by 7 ft. 10 in. long, and 230 tubes 3½ in. in diameter by 7 ft. 10 in. long. The depth of the combustion chamber is 36 in. and the total heating surface is 2136 sq. ft. The A. H. Payson is fitted with a Babcock and Wilcox marine water-tube boiler, total heating surface 2770 sq. ft. The engines in both cases are compound engines, high-pressure cylinders 20 in. in diameter, low-pressure cylinders 42 in. in diameter, and stroke 24 in.

90 A large number of tests were made on these vessels in actual service when towing car floats to and from Point Richmond. In addition, a 5-hour test running steadily without a tow was made on each boat, with the results given in Table 7.

91 From examinations of the logs of numerous steamships, it appears that with vessels fitted with triple-expansion engines developing from 1000 h.p. up, with everything in first-class condition, the

TABLE 7 RESULTS OF FIVE-HOUR TESTS

| Time | R.p.m. | H.p. | Water used | Oil used | Water evap. actual | Water evap. from and at 212 deg. | Factor of evap. | Water per I.h.p. | Oil per I.h.p. | Speed knots |
|---|---|---|---|---|---|---|---|---|---|---|
| Five-Hour Run, Tug A. H. Payson, Aug. 2, 1903 | | | | | | | | | | |
| 11.00 | | | | | | | | | | |
| 12.00 | 95.3 | 535 | 11475 | 853 | 13.4 | 14.68 | 1.095 | 21.4 | 1.59 | |
| 1.00 | 96.0 | 523 | 11326 | 837 | 13.5 | 14.77 | 1.094 | 21.6 | 1.60 | |
| 2.00 | 94.5 | 509 | 11418 | 809 | 14.1 | 15.32 | 1.087 | 22.4 | 1.58 | 11.72 |
| 3.00 | 95.5 | 498 | 11300 | 826 | 13.6 | 14.66 | 1.078 | 22.9 | 1.65 | 10.63 |
| 4.00 | 96.4 | 537 | 12251 | 845 | 14.6 | 15.84 | 1.085 | 22.9 | 1.56 | 11.65 |
| Five-Hour Run, Tug Richmond, Aug. 24, 1903 | | | | | | | | | | |
| 12.00 | | | | | | | | | | |
| 1.00 | 91 | 418 | 9532 | 829 | 12.2 | 12.80 | 1.140 | 22.8 | 1.98 | |
| 2.00 | 92 | 424 | 10331 | 835 | 12.4 | 14.10 | 1.143 | 24.3 | 1.97 | |
| 3.00 | 91 | 418 | 8831 | 806 | 11.0 | 12.55 | 1.140 | 21.1 | 1.92 | 11.08 |
| 4.00 | 91 | 418 | 10496 | 833 | 12.2 | 13.90 | 1.140 | 25.1 | 1.99 | 10.04 |
| 5.00 | 91 | 418 | 9627 | 865 | 11.2 | 12.90 | 1.150 | 23.0 | 2.06 | 10.75 |
| Average for Five Hours Run | | | | | | | | | | |
| Payson | 95.5 | 520 | 11553 | 834 | 13.8 | 15.05 | 1.089 | 22.2 | 1.59 | 11.15 |
| Richmond | 91 | 419 | 9743 | 833 | 11.8 | 13.05 | 1.142 | 23.2 | 1.96 | 10.47 |

fuel consumption will be about $1\frac{1}{4}$ lb. of oil per i.h.p-hr. For smaller vessels fitted with compound engines, the consumption will range from 1.6 to 2 lb. per i.h.p-hr., depending on the efficiency of the plant.

## OIL STORAGE

92 In order to render a fuel oil installation safe, careful attention must be paid to the construction of the tanks in which the oil is stored. Not only should the very best workmanship, the best methods of support and the best quality of riveting be insisted on, but great care should be exercised in the design of the ventilation

system. Air pipes should be fitted to all tanks of sufficient size to lead off gases as they accumulate and to prevent any undue pressure on the tanks due to too rapid pumping when they are being filled. The ventilating pipes should be led as directly as possible to above the uppermost deck of the vessel. They should not be near the smoke stack and should be placed where it will be impossible for a naked light to be near them. The openings should in all cases be covered with wire gauze carefully secured. Further than this, the workmanship on all pipes, valves and fittings should be of the very best quality. Great care should be taken that all joints are perfectly tight, as the leakage of a very small quantity of oil may result in a formation of a large volume of gas from which a disastrous explosion or a serious fire may result.

93 In the case of wooden vessels, separate steel tanks independent of the structure of the ship are provided. The location of these tanks varies greatly, depending on the trade in which the ship is engaged and the preference of the superintending engineer. They are frequently placed in the space formerly occupied by the coal bunkers, in the fore-peak and, often, on deck.

94 In a steel vessel fitted with double bottom, the fuel oil may be stored in the compartments in the double bottom usually devoted to water ballast, or in deep tanks constructed for the purpose and usually extending entirely across the ship. Where deep tanks are used, expansion trunks should be provided.

95 The use of the double bottom for fuel oil is open to several objections. The tanks being shallow and divided into a large number of compartments by the floors, keelsons, and intercostals of the ship, it is very difficult to fill them completely owing to the air trapped in the different compartments. It is also impossible to empty them entirely and when a tank is only partly filled, trouble may be experienced in pumping out the oil when the ship is rolling. Again, if the ship has to go far North or South where the water is cold, the oil in the double bottoms congeals and difficulty is experienced in pumping. With many cargoes it is necessary to fill the compartments of the double bottom with water ballast when the oil is pumped out, and this means that at all times there will be a considerable quantity of water present in the oil. When the double bottom is used, it is necessary to provide settling tanks in or near the fireroom into which the oil is pumped from the ballast tanks before being pumped to the burners. The object of these settling tanks is to permit the removal of any water which may have found its way into the oil tanks, or

which may be in the oil when it is loaded. These settling tanks should be of sufficient size to contain from 8 to 12 hours' supply. They should be in duplicate and fitted with steam coils for heating the oil, gage glasses to show the amount of water in the bottom of the tanks, and connections for the oil pumps and for pumps to draw off the water settled out from the oil.

## OIL BURNING

96 The importance of proper furnace arrangements with means of controlling and directing the supply of air and fuel has been emphasized in previous discussions. In the case of marine installations it is not always possible to secure the best furnace arrangement. Nearly all the steamers in commission today are equipped with boilers of the internally-fired type. With the short cylindrical furnaces of comparatively small diameter used on these boilers, it is very difficult to secure the highest possible efficiency when burning oil. They are well adapted for the burning of coal.

97 For the burning of oil it is well known that an ample combustion space is needed. With a large combustion space, greater time is available and there is more opportunity for the oil particles to take up their requisite supply of air for combustion. Further, it is important, as has been pointed out, that the direction of the incoming air current should be such as to cause an intimate mixture of the air supply and oil particles. With the short cylindrical furnace these conditions are difficult of attainment. The air and fuel are admitted in sensibly parallel paths. The time during which fuel and air are in the furnace is very short. In consequence, complete combustion is difficult and is always delayed. With water-tube boilers, the furnace conditions are superior, and higher efficiencies have been shown.

98 In considering the installation of a fuel oil equipment, the subject is naturally divided into two parts, the first relating to the storage and handling of the fuel, and the second relating to arrangements for its combustion. Under the first, the safety of the ship and those on board her is the first consideration, and after this come convenience in handling fuel and accessibility of all the important parts; under the second, would be considered the system for burning oil, type of burners, and furnace arrangement.

## ATOMIZATION

99 Three systems of atomization are in use in marine installations, namely, steam, air, and mechanical atomization. Of these, by far the greater number of installations in use on the Pacific coast are of the second order.

100 The use of steam for atomization is confined to vessels plying in inland waters, or on very short runs. Steam atomization is not suitable for vessels making voyages of any length because of the large amounts of fresh water necessary for boiler feed to make up the loss due to the steam used for atomizing. This feed water must be carried in tanks, thereby reducing the cargo capacity of the ship, or else made up by the use of evaporators, a very inefficient, expensive arrangement.

101 In air atomization the air is used at pressures of from 1½ to 60 lb. per sq. in., depending on the burner. By far the larger number of oil-burning outfits utilize pressures in the neighborhood of 20 lb. per sq. in., the air being supplied by a steam-driven compressor, or in the case of low pressures, a rotary blower.

102 The third system, mechanical atomization, quite generally known as the "Koerting" or "Meyer" system, although extensively used in Europe, has not yet been adopted to any extent on the Pacific. The atomization is effected by expelling the oil through a small orifice partly closed by a plug, on which is formed a spiral thread. The edges of the orifice are sharp and the spiral thread imparts to the stream of oil a rapid, whirling motion, causing the oil to break up into fine drops which leave the nozzle in a cone of atomized oil upon which the entering air currents impinge.

103 As has been said earlier in the discussion, few data are available showing the efficiency of marine oil installations. The amount of steam required for atomization will range from 2 per cent to 8 or 9 per cent, depending on the type of burner and the intelligence with which it is operated.

104 For air atomization and with air pressures of from 20 to 30 lb. per sq. in., from 6 to 10 cu. ft. of air per minute per pound of oil burned will be required. For air atomization with low pressures, such as can be produced by a rotary blower, of which the Lassoe-Lovekin system as fitted to the steamships of the American Hawaiian Steamship Company is an example, the amount of air required for atomization is not known. The air pressure used is 1¼ lb., and all the air is heated by the Howden system. The oil is heated to 175 deg. fahr.

105 A few installations of the third, or mechanical system, have been made on the coast, but no information is available as to the efficiency obtained. In the opinion of the writer, the mechanical system has not received the attention which it deserves from our local engineers. It should be efficient and its simplicity is certainly a recommendation. I am informed by the agent for the Koerting company that the oil may be handled by the ordinary pumps installed for that purpose, with other systems, but that an additional heater is necessary as the temperature of oil at the burner should be from 240 to 260 deg. It is further stated that as long as the pressure of oil at the burner tip is maintained at more than 40 lb. per sq. in., there will be no carbonization in the heating and pipe system, nor in the burner. It is said that 100 lb. per sq. in. at the burner is the most desirable pressure for this system. The makers state that to operate the pumps and supply the heat to the oil necessary with this system takes from $\frac{3}{4}$ to 1 per cent of the steam evaporated.

106 Some large tank steamers fitted with the mechanical system are said to operate very satisfactorily. The results obtained show that a horsepower is developed for from 1.09 to 1.37 lb. of oil per i.h.p-hr. for all purposes. These vessels develop about 1900 h.p.

## PRODUCER GAS FROM CRUDE OIL

By E. C. Jones, San Francisco, Cal.

Member of the Society

107 The subject of producer gas from crude petroleum or its products is not enough crystallized to enable the economy to be determined exactly. California, with its immense deposits of petroleum, is the natural and logical field for the exploitation and industrial use of oil producer gas. It is to be deplored that such an important subject was first considered by men not conversant with the manufacture of oil gas, and in casting about for apparatus to make producer gas from oil they naturally gravitated to the old familiar methods of retorting the oil, and any improvements that grew out of these methods seem to have retained the objectionable features of the retort system. Briefly stated, these objections consist of shutdowns for the purpose of removing coke and frequently for burning out accumulated soot and lamp black. A typical analysis of gas made in this way is: $CO_2$, 4.5; CO, 7.4; $O_2$, 0.4; $CH_4$, 12.0; $H_2$, 3.1; $N_2$, 71.9; B.t.u. per cu. ft., 172; claimed thermal efficiency, 39 to 62 per cent; operating thermal efficiency, 55 per cent.

108 This gas has been applied to the operation of small gas-engine units up to and including 100 h.p. Owing to the abundance of petroleum in California, it has superseded all crude material in the manufacture of illuminating gas. To attain its present degree of perfection, elaborate experiments were performed for the purpose of changing the chemical and physical condition of the gas to best adapt it to modern domestic and industrial gas appliances.

109 The first oil gas manufactured on a large scale in California had the following analysis:

| | Per Cent |
|---|---|
| Heavy hydrocarbons | 6.2 |
| Marsh gas | 25.6 |
| Hydrogen | 62.4 |
| Carbonic oxide | 3.0 |
| Carbonic acid gas | 0.2 |
| Oxygen | 0.4 |
| Residual nitrogen | 2.2 |
| | 100.00 |
| Specific gravity | 0.303 |

110 By improvements in apparatus and refinements of operation the hydrogen content of the gas has been reduced to less than 40 per cent; the marsh gas has been increased to 34 per cent; the carbonic oxide has been increased to 9 per cent; the specific gravity to 0.485, and the B.t.u. from 624 to 680 per cu. ft. The oil-gas generators used at present for manufacturing illuminating gas are so elastic in their operation that any of them can be immediately adapted to the manufacture of producer gas from oil. The chemical composition of the gas and its heating value depend only on the manipulation of the generator.

111 The writer has carried on a series of experiments with oil producer gas, using a large generating unit and the only change in equipment was the use of compressed air at from 35 to 40 lb. pressure for the injection of oil and to assist in the partial combustion of the oil. During these experiments producer gas was made having a thermal value as low as 103 B.t.u. per cu. ft., and as high as 482 B.t.u. per cu. ft. Unfortunately no ready means was at hand for measuring the quantity of gas and the amount of oil used to produce 1000 cu. ft. A typical analysis of this gas is as follows:

| | Per Cent |
|---|---|
| Carbonic acid | 4 |
| Heavy hydrocarbon | 2 or less |
| Oxygen | 1 |
| Carbonic oxide | 10 |
| Hydrogen | 5 |
| Marsh gas | 8 |
| Nitrogen | 70 |
| | 100 |

112 This gas has a calorific value of 160 B.t.u. per cu. ft. To use this gas successfully in gas engines it is necessary that it shall be thoroughly cleansed by efficient scrubbing, and that it shall be uniform in calorific value and chemical constituents. This last can be readily accomplished in the operation of oil-gas generators, used as producers, by careful measurement of the oil used, and of the air supplied for its partial combustion, and by the maintenance of a fairly constant temperature in the generator. This can be done, as in oil-gas manufacture, by a determination of the necessary temperature by the observation of color in the checker brick and the maintenance of this temperature by frequent observations through sight cocks by the gas maker.

113 Making producer gas from oil in the ordinary oil-gas generator has many advantages over any special process. The gas can be made in very large quantities and the amount made can be easily regulated to the needs. The operation is continuous and without interruptions for cleaning. This is essential in the manufacture of producer gas for power purposes. In any other known process the interruptions are not at stated intervals, but occur when the producer refuses to work, owing to the clogging of its parts by coke or lamp black. Oil-gas generators have no easily destructible parts as the lining and checker brick are constructed with a view to resisting high temperatures and although a much higher temperature is desirable in making producer gas than that employed in making oil gas, the checker brick is not seriously affected by the high temperature. In the decomposition of oil, in the presence of air, there is a complete disposition of all the gas making constituents of the oil, so that producer gas can be made without a by-product of any kind. Any accumulation of carbon in the generator may be removed by adjusting the temperature and quantity of air supplied. This method of making gas requires a small gas holder for momentary storage, and the process

as at present understood could not be used as a suction gas producer. Producer gas made from oil and containing a small percentage of hydrogen possesses advantages over illuminating oil gas, inasmuch as it can be subjected to higher compression in gas engine cylinders, and with a gas of uniform analysis, uniform piston speed can be obtained.

114 A thought upon the possibilities of oil producer gas leads to a comparison of the modern steam turbine, having a thermal efficiency of from 12 to 15 per cent, with an internal-combustion engine having a thermal efficiency of from 24 to 30 per cent.

# DISCUSSION ON FUEL OIL

(Published in Condensed Form)

## CONTRIBUTED DISCUSSION

W. H. Frost.[1] The subject of making producer gas from oil first appealed to me commercially, as it would mean a fuel economy two to three times better than with the average steam plant, or would enable crude oil to be substituted for an equal volume of distillate or gasolene in the distillate engines.

I started out not so much to design a new method of making gas as to produce a new power system in which the relation of producer to engine and vice versa must be the first consideration. The question was how to do this. Certainly not with any of the so-called crude-oil generators then on the market, which simply provided a crude method of distillation, sending over indigestible compounds to the engine, and wasting most of the oil as a by-product. With a refined product providing a suitable vapor, it was cheaper and less troublesome to employ the distillate direct in the cylinder.

No successful method of producing a suitable power gas from crude oil was known and as a practical gas engine builder and distributor, I knew the following were necessary to accomplish this:

*a* To produce the gas continuously in the quantity required by the engine, dispensing with storage.

*b* The gas to contain the maximum of carbon monoxide and the minimum of hydrogen, to obtain highest thermal efficiency and best regulation of engine.

*c* Gas to be practically even in quality to prevent shutdowns.

*d* Gas to be clean, as very minute particles of carbon accumulate and foul engine valves, necessitating shutdowns and cleaning.

*e* Apparatus to occupy relatively small space.

[1] Los Angeles, Cal.

Presented at the San Francisco meeting, March 1911, of The American Society of Mechanical Engineers. All discussion is subject to revision.

*f* Operation to be simple, readily understood by ordinary attendant and requiring minimum of attention.

*g* To dispense with offensive fumes and by-products.

*h* To reduce the necessary elements to the minimum.

Oil carries carbon, and the oxygen of the atmosphere is free for the taking everywhere, and these two elements are the only ones necessary. Many forms of apparatus may be used, the most satisfactory seeming to be a simple open chamber into which the oil is sprayed by compressed air and open to the atmosphere through means capable of regulation. Suction is produced by the engine, or any form of suitable exhauster which keeps the interior of the producer at or below atmospheric pressure. The oxygen in the air flowing into the producer and used in spraying the oil unites with a certain portion of the oil to produce combustion and a high temperature. In this high temperature zone the unburnt oil is decomposed into its gaseous elements and free carbon. The carbon dioxide formed by the combustion evidently selects carbon from the products of the decomposition of the oil to form carbon monoxide.

An average analysis of the gas gives:

| | |
|---|---|
| Carbon dioxide | 6.0 |
| Oxygen | 1.0 |
| Illuminants | 2.2 |
| Carbon monoxide | 13.6 |
| Hydrogen | 6.2 |
| Methane | 3.3 |
| Nitrogen | 67.7 |
| | 100.0 |
| B.t.u. per cu. ft | 141.0 |

Gas can be made as lean as wanted, or to contain considerably over 200 B.t.u.

Regulation of the free air openings and of the oil controls the quality and also the volume of gas and can be automatically governed by the engine. A test flame kept burning is an indication to the attendant of the quality of the gas. Sight holes also show the internal condition of the producer.

During experiments and tests of several years' duration, it was found that engines operated most steadily and evenly and the apparatus required the least attention, when the temperature of the producer was sufficiently high to break up completely the tarry vapors into gas and carbon.

The most difficult task of all was to separate the fine, almost microscopic, particles of carbon from the gas, so that it would be perfectly clean and suited to any gas engine. Eventually, a centrifugal scrubber of simple design was devised, which absolutely cleans the gas, so much so that fine white muslin held for one or two minutes over a 1-in. outlet with gas under 2-in. water pressure, sufficient to make a very long flame, shows no stain whatever and if kept there for 2 hours shows only a slight discoloration. The scrubber doing this is about 4 ft. in diameter by 5 ft. long, and cleans about 35,000 cu. ft. of gas per hour.

The fine dry carbon, free from tar, is collected from the wash water by any convenient means. In a plant of 500 h.p. it is not sufficient in quantity to require any special separating device, but is collected in a skimming tank in the usual manner. This fine clean carbon has many valuable uses, particularly in paint for metal or wood.

The economy, of course, varies with the engine, but actual runs on plants of 100 to 500 h.p. show that a guarantee of 1⅛ lb. of oil per b.h.p. is perfectly safe.

As to sizes of producers, with a circular chamber less than 18 in. in diameter by 4 ft. long, or about 7 cu. ft. capacity, I have made the gas required to operate a 150-h.p. engine full load, but prefer larger capacity, at least for the present.

Mr. Jones in his paper on producer gas from crude oil states: "The operation is continuous, and without interruptions for cleaning. This is essential in the manufacture of producer gas for power purposes." Quoting again, "Any accumulation of carbon in the generator may be removed by adjusting the temperature and quantity of air supplied." This indicates that there is a necessity for cleaning but that a change in proportion of air, with consequent change in temperature (probably more air raises temperature), causes the accumulated deposits to be consumed. My experience has been that any change in temperature, or proportion of elements, changes the quality of the gas and causes shutdown of the engine. The change mentioned would probably make the gas leaner.

The only way to avoid serious engine troubles would be to provide sufficient storage so that the changes of gas values would be very slow and gradual and even then the load must never be greater than the leanest gas will carry, and the engine requires close attention and skilful handling. Even if the leanest gas can be kept up to 160 B.t.u., it will require 37,500 cu. ft. per hr. for a 500 h.p.

load (12,000 B.t.u. per b.h.p), making an enormous storage capacity necessary to anywhere near the average of the quality of the gas.

The statement of the necessity of changes also shows that this is not a continuous process producing a uniform gas, but one producing a continuous supply of gases of varying values, whereas a continuous supply of a practically uniform gas is absolutely essential to any engine I have operated.

Quoting again from Mr. Jones' paper, "Making producer gas from oil in the ordinary gas generator has many advantages over any special process." What are the advantages? What power plant would want such an equipment as is required for illuminating gas making? Bulky retorts, large scrubbers and filters for the great volume of gas required, and big gas holders, are necessary for all pressure systems and also to average the quality of gas.

The paper indicates that certain results have been accomplished, but lacks the statement that gas engines are successfully operating with this gas. By the process there presented there is evidently a by-product of lamp black or tar or both which must be separated by washing and filtering to fit it for the engine. Evidently the process does not produce an even and uniform gas continuously and evidently Mr. Jones relies upon the gas holder for averaging the gas, as with illuminating gas; but this is expensive, and impracticable with a power plant of average size and an impossibility within the fire limits of cities.

C. R. Weymouth. If we assume that the range of fuel oil ordinarily varies between the limits of 12 and 18 deg. Baumé, we find, in accordance with Table 2 of Professor LeConte's paper an increase of 2.18 per cent in the total heat units per barrel, in favor of the heavier oil. So long as the barrel is the unit in the purchase of oil, power plant operators cannot ignore this comparison.

Since the reading of these papers the writer has endeavored to collect data in an attempt to establish a relation between the specific gravity of California crude oil, Baumé scale, and the percentage of hydrogen shown by its ultimate analysis in order to compute a table showing the available heat per pound and per barrel of crude oil of varying gravities, correcting for loss due to latent heat of steam formed by the combustion of hydrogen. Curve No. 1 shows the hydrogen content for a number of oils of different gravities, Edmond O'Neill, professor of chemistry at the University of California, having furnished a large part of the data.

It is found that there is no exact relationship between the specific gravity of crude oil and its hydrogen content, although there is a general tendency toward an increase in hydrogen content, with the lighter oils.

Examination of the ultimate analysis and calorimeter tests of a number of California crude oils indicates the rather startling fact that it is possible in oils having practically the same total quantity of inert constituents, to have a variation in both hydrogen and carbon contents with practically no variation in the calorific value of the oil.

The inevitable conclusions that the calorific value of crude oil does not correspond to the heat of combustion of its elemental constituents, and that accepted formulae for calculating the total heat of fuels are not applicable to California crude oils, are borne out by the fact that the calculated calorific value was, in one instance, 8.7 per cent greater than obtained from a calorimeter test. This apparent anomaly is no doubt explained by the fact that crude oil is an admixture of various hydrocarbons, in the formation of which the heat required is not available in the further combustion as crude oil.

From Table 2 the writer calculated the variation in hydrogen due to variation in heat units, according to Favre and Silberman's formulae, the result being an increase of 1.263 per cent hydrogen for 10 deg. increase Baumé. From the foregoing it is evident that this relationship cannot be regarded as more than an approximation. As a matter of interest, a line has been drawn on the accompanying plate having its slope in accordance with this, and located as an average with respect to the plotted points. The writer considers that more points should be plotted to warrant even an average line. It is evident, however, from the points plotted, that the true average will have less slope than the line indicated. On the basis of the line indicated, and correcting for latent heat of steam only, the available heat per barrel of oil is 2.32 per cent greater for 12 than for 18 deg. Baumé oil. If further corrections be made for the added stack losses at a temperature of 400 deg. fahr. due to the greater air required for combustion, then 12 deg. Baumé oil has an advantage over 18 deg. Baumé oil of 2.37 per cent.

It should be evident from the wide scattering of the hydrogen points that the comparison of any two oils under consideration should be made with respect to their individual analyses, and not with respect to the average line mentioned. For example, from the plotted points a hydrogen variation of 1.6 per cent is noticeable with practically no variation on the Baumé scale, corresponding to which the stated increase of hydrogen involves a commercial loss, due to its lower available heat, and increased chimney losses of approximately 1 per cent. Taking into consideration this loss and the greater total heat units of heavy oils, the extreme variation in the commercial value of anhydrous crude oils, between the limits of 12 and 18 deg. Baumé appears to be not greater than 3 per cent.

As a result of all the tests made by Chas. C. Moore & Company, Engineers, and the Babcock & Wilcox Company, with California crude oils, it is not apparent that the above conclusions will be materially modified by a consideration of the atomizing agent, when oils are heated to the proper temperature before firing.

It should be noted that Table 1 is intended to represent a general average, the line being drawn through plotted points considerably scattered. Calorimeter determinations will still be necessary as the specific gravity of an oil is not an accurate index of its calorific value.

Mr. Dunn has fairly represented current practice in the design of chimneys for oil fired boilers at sea level, for moderate sized plants.

About eight years ago, the writer established, for Chas. C. Moore & Company, a rule for oil-burning chimneys, as set forth in Mr. Dunn's paper, and while such a basis for the selection of chimneys has kept them out of difficulties, recent investigations indicate the desirability of a radical departure from this rule in certain special instances.

For the benefit of those who contemplate using Kent's table of chimney capacities as a basis of selection of chimneys for oil-burning plants, the writer would state that Mr. Dunn's explanation of the reasons for adducing the rule stated, is hardly correct. The weight of chimney gases per boiler horsepower, when burning coal, is not twice that when burning oil. It is possible to use chimneys of smaller area for oil burning than for coal burning, by reason of the much lower draft required for the former, permitting higher velocities in the chimney, and a greater percentage of draft loss in the chimney proper. Mr. Kent probably never intended the widespread usage accorded his table of chimney capacities, and before adopting this for too general usage, engineers would do well to inquire the basis of development and the significance of the figures given.

According to Kent's table, a chimney 48 in. in diameter by 100 ft. in height, is rated at 348 commercial h.p. According to Mr. Dunn's paper, this chimney would develop double that amount, or practically 700 b.h.p. The questions arise, should this chimney be connected to boilers aggregating 700 h.p. based on the normal rating, will it merely carry boilers when operating at rating, or does it provide a margin for overload, and if so, to what extent; and were it desirable, in such a plant, to operate both boilers temporarily at 100 per cent overload, developing 1400 b.h.p., would it be necessary to install a chimney of double the sectional area? The writer no longer uses Kent's table for selecting chimneys for oil-fired boilers, and it is not possible to obtain correct ratings for oil chimneys by applying a fixed ratio to the capacity set forth in it.

With economical firing, and with properly designed furnaces, the draft in the third pass, required to burn oil in a Babcock & Wilcox boiler of, say 250-h.p. rating, is about 0.1 in. If this boiler be connected to a chimney 100 ft. in height, giving a working draft at the base of the chimney of, say 0.5 in., it is evident that this surplus draft is capable of flooding the boiler with an excess of air, if the draft be improperly regulated. Such an operation could easily result in such a large excess of air for combustion as to require the burning of 10 per cent excess oil, merely to heat to the stack temperature the air so admitted.

If for the given single boiler the chimney height be reduced approximately to 35 ft., the boiler outlet and breaching being of ample area, and the stack being direct connected to the boiler, the chimney would then produce a maximum draft practically equivalent to that required for the operation of the boiler at rating; and with boiler damper and ashpit doors wide open, it would be impossible for the most careless firemen to flood the furnaces with any material excess of air. The writer does not recommend that all chimney heights be reduced to 35 ft., but this illustration serves to indicate an extent of safeguarding the fuel economy of the boiler room, not possible by any other simple means.

In an office building in San Francisco, it was found necessary, by reason of the height of the building, to install a chimney extending more than 200 ft. above the boiler room floor line. On one occasion the analysis of flue gases, in connection with this chimney, indicated 200 per cent air over actual requirements, and a certain fuel loss, as compared with economical firing, of at least 20 per cent. While, in this instance, it was impossible to reduce the height of the chimney, the diameter could have been decreased to such an extent, that the available draft at the base would have been reduced by the chimney friction to an amount more nearly in keeping with the boiler requirements.

As illustrating the overloading and abuse of boilers possible with excessive drafts, the writer has in mind a Stirling boiler having a connected chimney of generous diameter, 80 ft. in height. The damper lever had been disconnected, and the boiler fired with both rear damper and ash doors wide open. The fireman was instructed in the regulation of dampers and ash doors, but failed to observe these instructions. Subsequent tests indicated overloads of several hours' duration, of 85 per cent, and momentary overloads of even greater extent. There were other boilers in service, having less draft power, which were not overloaded to this extent. In the plant in question, all boilers should have been operated practically at rating on a nearly uniform factory load. Obviously the overloading of this particular boiler led to a considerable fuel loss. To obviate these difficulties the writer has recently recommended a 40-ft. reduction in the height of this chimney. A greater reduction would be possible from the boiler standpoint, but is in this instance limited by height of building.

When operating boilers under variable load, a careless fireman is liable to discover that the steam gage reads 5 or 6 lb. low and rapidly falling. Through habit, he has learned that this loss can be overcome by a few moments of heavy firing. During such periods, the boiler is frequently fired at from 200 per cent to 300 per cent rating and boiler tube renewals are many times chargeable to this cause, not to mention the resulting excessive oil consumption. While a certain excess draft is necessary for proper regulation of boiler plants on variable load, it is self-evident that it can lead only to severe abuse of boilers in the hands of ordinary firemen.

Prior to the burning of oil in Pacific coast plants, chimneys were proportioned for coal-burning practice, and in many instances the subsequent failure to obtain favorable economy with oil fuel in everyday work was attributable to tall chimneys. In a number of those stations it was later found possible to increase largely the number of boilers connected to one chimney, the station economy was improved without apparent effort of the firemen, since the increased volume of gases passing through the flues and chimney reduced the draft available at the boiler outlet, and at once limited the extent of flooding the furnaces with excess air, formerly possible with an excessive draft.

It has been found by experiment that the draft necessary for the combustion of oil varies largely with the economy of firing, and in one series of tests, operating the same boiler at approximately rated capacity, the draft varied from less than 0.1 in. with economical firing, to nearly 0.5 in. with a large excess of air; also that the draft necessary to burn oil increases rapidly with the rate of overload on boiler.

It therefore becomes necessary, in the selection of chimneys for a given plant, to decide both the maximum capacity to which it is desirable momentarily to force boilers, and the excess air supply over the most favorable firing conditions, to be regarded as the limit of safety in everyday practice. The installation of fuel economizers, excessive breeching resistances, etc., will also influence the final result. These considerations determine the draft necessary at the base of chimney. There is a minimum height of chimney which will produce the desired draft, and should it become necessary to increase the chimney height over and above the necessary minimum, the diameter of the chimney, for economical firing, should be modified to absorb by chimney and breeching friction the excess draft thus produced. The provision for a later increase of boilers on a given chimney will of course modify these conditions.

There are many factory, pumping and heating plants where the load on the boilers in service is practically uniform and rarely exceeds rating. In certain of these plants, not operated by skilful firemen, it would be possible, building conditions permitting, to reduce materially the chimney height with an increase in fuel economy.

In reply to a query by Mr. Hunt, by controlling the firing of boilers by variation of oil pressure from a central point, all burners being connected to a common oil main, it is possible to indicate the rate of load on the individual boilers by pressure gages connected to the oil-burner branch line. At the Redondo plant we controlled the firing of boilers from a central point, the individual oil-burner regulating valves being wide open or nearly so. The pressure gage read about 20 lb. when the boilers were fired at rating, about 10 lb. at half load, and about 30 lb. when at 50 per cent overload. When used in this manner the pressure gage forms a reliable index for gaging the load on boilers, at least for the purpose of the firemen, and it is about as cheap an instrument as can be secured for the work.

W. F. Durand. In connection with Mr. Dunn's paper on chimney capacities, the accompanying formulae may be submitted as representing conservative practice under what may be denominated approximately normal operating conditions. The factors which enter into the problem of chimney draft and capacity are so numerous, their relations so obscure and values so difficult of numerical determination, that of necessity all chimney formulae are empirical, that is, they are simply practice expressed in algebraic form. The literature of engineering abounds in chimney formulae, but inasmuch as most of them relate to coal-burning practice, I have ventured to add one more to the list, intended to refer strictly to oil-burning practice.

While, as noted, all chimney formulae are empirical in character, yet they may to some extent be made rational in form and the more nearly such a condition is realized the better will the formula take care of variations in the operative conditions, outside the immediate range from which the empirical factors are drawn.

The general character of a chimney formula on rational lines may be readily developed, as follows: The function of draft involves the pushing of air into the furnace and the pushing of the gases of combustion through the tube spaces and then up the stack to the outer air. This involves the work of giving kinetic energy to a body of air and gas and of moving it against a resistance. In general, such work will depend on the quantity of gas moved and on the square of the velocity. This work must be supplied by the draft head or difference of pressure between the external air and minimum pressure within the boiler, and per pound the work will be measured by the difference of pressure in pounds per square foot multiplied by the volume of one pound of gas in cubic feet. We have thus in general the relation:

$$u^2 \sim VP$$

where

$u$ = velocity
$V$ = vol. per lb.
$P$ = draft head measured in lb. per sq. ft.

Again, let

$B$ = boiler h.p.
$w$ = lb. of gas per b.h.p.
$A$ = area of chimney

Then

$$BwV = \text{Total volume of gas} = Au$$

But $u \sim \sqrt{VP}$, and $P$ the draft head will depend in general on the height of the stack and on the stack temperature. According to the simple theory of stack draft, such head is measured by the difference in weight between a column of normal air and a column of hot gas, each of the height of the chimney.

In any event, we may put

$$P \sim hx$$

where

$h$ = height of chimney
$x$ = a factor or term depending on the temperature

We have then

$$u \sim \sqrt{Vhx}$$

and hence

$$A\ \sqrt{Vhx} \sim BwV$$

whence

$$A\sqrt{h} \sim Bw\sqrt{\frac{V}{x}}$$

In words, the product of the area by the square root of the height should follow closely the product of the number of pounds of gas by the square root of the volume per pound and divided by the square root of the function $x$.

But the volume of 1 lb. of gas $V$ varies directly as the absolute temperature. This of course varies widely between the furnace and the top of the stack. The temperature at the base of the stack is usually taken, however, as primarily related to the value of the draft function $x$, and for convenience we may use the same temperature as related in a general way to the value of $V$. Also $w$, the pounds of gas per boiler horsepower, will vary inversely as the boiler efficiency. Let $e$ denote the efficiency. Then we may write

$$A\ \sqrt{h} = \frac{B}{Qe}\sqrt{\frac{Ts}{x}}$$

where $Q$ is the general constant or factor.

The function $x$ takes the form $\frac{A}{Ta} - \frac{B}{Ts}$, where $A$ and $B$ are constants and $Ta$ and $Ts$ are absolute temperatures of the air and of the stack. Where draft head $d$ is expressed in inches of water and the height of the chimney in feet, this takes the form

$$d = h\left(\frac{7.6}{Ta} - \frac{7.9}{Ts}\right)$$

If 80 deg. fahr. is taken as a fair upper temperature of the air, this reduces to

$$d = h\left(0.1407 - \frac{7.9}{Ts}\right)$$

The entire $\sqrt{\frac{Ts}{x}}$ is therefore a function of the temperature and its value for a range of values of $Ts$ is given in Table 8.

It now remains only to find a value for the numerical constant $Q$. This has been done by using the results of practice and thus checking

TABLE 8 VALUE OF TEMPERATURE FUNCTIONS

| $t$ | $y$ | $t$ | $y$ |
|---|---|---|---|
| 400 | 4.19 | 560 | 4.02 |
| 420 | 4.16 | 580 | 4.01 |
| 440 | 4.12 | 600 | 4.00 |
| 460 | 4.10 | 620 | 4.00 |
| 480 | 4.07 | 640 | 4.00 |
| 500 | 4.05 | 660 | 4.00 |
| 520 | 4.04 | 680 | 4.00 |
| 540 | 4.03 | 700 | 4.00 |

the formula against the indications of experience.

In this manner, we find as follows:

$$(A - a) \sqrt{h} = \frac{By}{Qe}$$

where

$A$ = area of chimney in sq. ft.
$a$ = small constant area as below
$h$ = height in ft.
$B$ = b.h.p. actually developed, which equals number of lb. of total evaporation per hour reduced to conditions from and at 212 deg., divided by 34.5
$e$ = boiler efficiency
$y$ = temperature factor from the table
$Q$ = coefficient

values of $a$ and $Q$ are as follows: For large chimneys or from 300 b.h.p. up

$$a = 2.5$$
$$Q = 54$$

For small chimneys or from 500 h.p. down

$$a = 0.6$$
$$Q = 40$$

In choosing the values of the constant $Q$ the following special conditions are assumed:

Heat value of oil fuel .............................. about 18,500 B.t.u.
Temperature of external air .............................. 20 deg. fahr.
Excess of air in furnace .............................. about 100 per cent
Boilers working at rate of output not greatly exceeding rated load.

The particular numerical factors in the formula are perhaps not so important. I dare say further investigation, undoubtedly the results of Mr. Weymouth's data, might change the numerical factors. I believe, however, that the form of the formula may possibly be of some aid in passing from one set of conditions to another, or interpolating between various sets of conditions; and that is about all any engineering formula can hope to do.

In connection with the paper by Mr. Hunt on Atomization, I have been interested in estimating the work equivalent of this process. The nozzle of a burner is a more or less effective device for transforming energy of steam into jet energy, exactly in the same manner as does the nozzle of a steam turbine. The atomization of the oil and its projection at high velocity into the furnace involve the expenditure of work, and this work must be derived from the steam by way of the nozzle.

One-half lb. of steam per lb. of oil is perhaps a fairly representative figure for the amount of steam required. This amount of steam used with any reasonable nozzle efficiency and under the conditions of say 90 lb. initial pressure absolute and 15 terminal, should develop from 35,000 to 40,000 ft. lb. of energy, thus expended in work on the oil. This figure is impressive. It is probable that due to wire drawing and inefficiency in the nozzle the amount of work actually utilized is less than this figure. In any event, however, the price paid for the preparation and introduction of the oil into the furnace is a very heavy one, and the question not unnaturally arises as to whether or not this can be the ultimate method. May not some method be developed, mechanical or otherwise, which shall enable us to do the necessary amount of work on the oil without the heavy expenditure involved in the present systems of steam or air atomization. Mechanical atomization seems to present some possibilities and it may be that the future development may lie along this path. In any event, I feel that as engineers we should entertain a feeling of profound discontent with our present methods of preparing and introducing the oil into the furnace, and that we should not rest until either some less costly method is developed, or every possible method and expedient has been given a thorough trial.

Guy L. Bayley.[1] In order to get some information as to the efficiency of the furnaces in the station of the Municipal Light & Power

[1] Mgr., Municipal Light & Power Co., San Francisco, Cal.

Company plant, on Stevenson Street, we installed an Orsat apparatus in the fireroom. The four boilers are of Stirling make, and the samples were taken about a foot below the damper. The sampling tube used in each was a piece of ⅜-in. iron pipe, open at the end. Small lead pipes from each furnace were run to a header with a valve in each, so that a sample could readily be taken from any of the furnaces. A small water ejector was connected to the header to insure drawing over a fresh quantity of flue gas before a sample was taken. We experienced trouble with the lead piping from pin-hole air leaks, and from the piping sagging and forming pockets, which trapped water from the products of combustion and prevented a flow of flue gas. These troubles were overcome by the use of ¼-in. iron pipe.

The Orsat determinations were of great value at the start in educating the firemen as to the amount of air required. All of our men were experienced in the burning of fuel oil, but they were firing with from 80 to over 150 per cent excess air. By shutting down on the draft and making frequent determinations with the Orsat apparatus until a high per cent of $CO_2$ was obtained, the firemen were taught how a fire should appear with the minimum amount of air for complete combustion. We were unable to get much better than 12 per cent $CO_2$, as above this point the fire was liable to produce smoke, which would not long be tolerated in the neighborhood of our plant.

Although we had no direct means of measuring the economy due to better firing, an increase in kw-hr. per bbl. of oil followed at once. The second month we had the Orsat installed, we showed an increase of 19.3 per cent in the kw-hr. per bbl. of oil obtained the month before installing the Orsat. During this period the load factor on the turbine increased from 43 to 53.5 per cent, which would account for some of the increase in economy, but hardly for the amount obtained.

The Orsat apparatus is not a suitable instrument for constant fireroom use, as the rubber connections rapidly deteriorate and the glass parts get broken. It is well worth its cost, however, as it will awaken and maintain in the firemen a lively interest in the subject of combustion, which is sure to result in better firing. In order that the firemen may appreciate the importance of maintaining a high percentage of $CO_2$, we have posted in the fireroom two curves, one of which gives the relation between percentage of $CO_2$ and of excess air; the other, the relations between the percentage of excess air, flue temperature and calculated boiler efficiency.

To measure the oil in our fuel tanks, we run to each a ¼-in. brass pipe, which goes through the top of the tank to a point close to the bottom. To each pipe, at a convenient point in the engine room, a U-tube containing mercury is attached. Each pipe is connected to the compressed air system of the plant. To read the height of oil in a tank, the compressed air is turned into the pipe until it blows out the oil which may be standing in the vertical section leading down to the bottom of the tank. The air is then throttled down so that only a small amount escapes through the oil, and a reading taken of the difference in level of the mercury in the U-tube. A scale alongside the U-tube can be calibrated by means of known quantities of oil in the tank, so as to read direct the number of barrels contained in the tank at any time. In a tank 13 ft. deep and holding 110 bbl., we can read within a barrel of the true amount in the tank. By inclining the tubes so as to get a longer range of movement of the mercury, greater accuracy can be obtained. Should the gravity of the oil change from that used when calibrating the U-tubes, the readings must be corrected for the difference in gravity.

Thos. Morrin. The use of crude oil as fuel has been developed along the lines of unlimited extravagance in the vaporizing process. Until recently steam jets have been used in land plants at full boiler pressure for vaporizing oil at the burner tip, because of its convenience and low cost of application. At the same time it is perhaps the most expensive method for accomplishing this object. I believe that improvement in these conditions can be brought about only by a burner mechanism that will require air only at an extremely low pressure which may be furnished at a minimum cost so that its most extravagant use cannot go beyond a certain fixed range.

In regard to Mr. Hunt's statement that the form of the burner is of minor importance I am convinced that it has much to do with preparing the oil for satisfactory combustion inasmuch as it is necessary to vaporize the oil or work it up into minute atoms.

I have in mind mechanical burners of the turbine fanwheel type rotating at a high speed and delivering the oil from the periphery of the burner at a velocity of approximately 7100 ft. per min., equal to an air pressure of approximately $1\frac{1}{2}$ oz. per sq. in.

In tests of the quantity of oil and the percentage of power used to burn a fixed quantity it was noted that the energy expended was less than 1 per cent. In fact, the figures showed an actual consumption of energy amounting to but $\frac{6}{10}$ of 1 per cent of the actual heat results of the oil burned.

I refer to this scheme of vaporizing oil because I am sure that oil will be used more and more for fuel purposes if we convince the consumer that it is unnecessary to install a steam burner or an elaborate mechanical equipment. A simple centrifugal blower and a rotary gear pump driven by one electric motor that any unskilled person may use and operate is a possible equipment.

The form of furnace is also important. The hearth of the furnaces should be of good fire-resisting material, of high radiating efficiency, and thin, with air inlets well diffused over the surface, and while it is not necessary to heat the air for the most economical results, oil can be burned in the jet process with much less noise with heated than with cold air. This system for vaporizing oil is just as applicable to service on board ship as to the most remote fruit dryer, hop kiln, or malt house, where it would be necessary to install only a small motor and volume blower with the necessary oil pump, within the prescribed limits of the underwriters. With this method of vaporizing the oil, less energy per pound burned is required than in any other form now in use, and it should receive more attention from engineers and consumers than in the past.

## ORAL DISCUSSION

George W. Dickie said that the example given by Mr. Hopps of oil burning on one of the American Hawaiian Steamship Company's ships fitted with Scotch boilers, compared favorably with any examples he could give for water-tube boilers, although Mr. Hopps claimed that the furnace conditions of water-tube boilers are, generally speaking, superior to those of Scotch boilers. The Howden system of furnace combustion and the low-pressure air system may have contributed to the satisfactory result.

Mr. Dickie expressed approval of the mechanical system of atomization, having been an admirer of the Koerting system which he believed needed only careful study and adaptation to the various qualities of oils to make it ideal. So convinced was he that a practical system of this nature was feasible that if he were to design a large marine oil-burning installation he would endeavor to design a modification of the Koerting system that would successfully burn the California oils.

In reference to making producer gas in an ordinary gas generator for use in internal combustion engines, he urged Mr. Jones to make further experiments, suggesting that if a slow-burning gas could be made from oil which would behave behind the engine piston like slow-burning powders behind the projectile of a modern gun, giving a steady push instead of a blow, a remarkable instrument of propulsion would be produced. For two years past he had been interested in a crude oil gas producer known as the Nix-Frost producer by which oil is converted into a fixed gas which is essentially a power gas consisting mainly of carbon monoxide with a small percentage of hydrogen.

In this producer the oil is brought to the burners by any suitable pressure means and compressed air sprays it into the producer, which consists of a steel shell lined with fire brick with a central vertical chamber. A zone of high temperature is formed by partial combustion and through this is drawn the unconsumed carbon, and the gas produced, along with fine particles of carbon, is drawn out of the producer through a suitable scrubber by suction fan or by the engine direct; any particles of carbon are separated and blown away with the waste water. This producer or something like it may yet be made suitable for marine installations.

E. I. Dyer[1] said that the relation of the heat value of oil to its specific gravity was not commonly appreciated either by the average oil producer or the consumer. Lack of knowledge of the truth of the relations exhibited in Professor LeConte's paper, and of the part which hydrogen plays in the lighter oils, in the economics of combustion, together with a blind adherence to the traditional temperature of 160 deg. fahr. for fuel oil, have conspired to create an unwarranted prejudice in favor of light oils for fuel purposes. He thought that there was no insurmountable difficulty in handling and burning heavy crude oils at temperatures to the burner ranging from 240 to 350 deg. fahr. In fact, at one of the plants of his company, 285 deg. fahr. has been the standard temperature for months. Both the producers and consumers of oil would be benefited by further elaboration of the fact that not only do the heavier oils contain more heat units for a dollar, but within reasonable limits, a greater proportion of available heat units than the lighter. A real service to the general public might also be rendered by dispelling the confusion in the conversion of Baumé degrees to true specific gravity.

The relative heating value of oil and coal is of vital importance both to the producer and consumer. The characteristics of coal

[1] Engineer of Manufacturing Department of the Union Oil Company, San Francisco, Cal.

commonly available in this market and not the ratio as it relates to Pocahontas coal, are of interest on the Pacific Coast. The establishment of an evaporation of 11 lb. from and at 212 deg. per lb. of coal as representing the highest average of a good coal, would mislead every one on the coast who had anything to do with oil. The ratio which has been presented by previous speakers may be true of Eastern conditions, but entirely fails to represent those in the West. A ratio of 15.8 to 11.2 gives oil a superiority over coal by something over 40 per cent, weight for weight. Mr. Hopps has pointed out that in marine practice a vessel equipped with triple expansion engines from 1000 h.p. up, with everything in first-class condition, would consume about 1¼ lb. of oil per i.h.p-hr. This is probably a fair average.

The speaker had had access some two or three years ago to the records of performances of several steamers running on the coast with average coal for an entire year. One of these vessels averaged 2.1 lb. of coal per i.h.p-hr., and the other 2.5, and both had triple-expansion engines larger than the lower limit of size given by Mr. Hopps. The better record showed about 70 per cent more weight of coal and the poorer 100 per cent more than the 1¼ lb. average for oil. He gave these figures in the hope of showing why this subject should not be dismissed without receiving full justice.

With regard to furnace arrangements, he said that both producers and consumers were much indebted for the development of the efficient types of furnaces now in operation. These would be of still greater value if their operation could be made as nearly automatic as possible, or some system developed by which the specialized knowledge available could be taught to the men handling the fires. He also thought furnaces should be more liberally provided with peep-holes, so that all parts of the furnace and the heating surface exposed in it, as well as all parts of the fire, could be seen at all times. These were usually insufficient in number, often incorrectly placed, and in many cases entirely missing. Where present, they were often of a type which could not be operated without a hammer and consequently were never used.

Explosion doors, as often provided, are frequently not tight when inactive and will not close themselves after acting. Sometimes they are so situated that they become overheated, warping to such an extent as to nullify all attempts to regulate properly the air supply. An indicating $CO_2$ instrument should be a part of the equipment of every boiler furnace in every high-grade installation, as much as a steam gage. Similarly a draft gage reading to hundredths of an inch should also be a part of every standard boiler equipment, if any pretense is to be made of securing economical combustion of oil. More care might be given to the placing of burners to avoid possibility of oil, particularly sulphurous oil, lodging on the tubes. A checkerwork with variable opening operated by a lever from the front, if such a device could be made practicable, would probably be worth while. All dampers ought to be operated from the front and a draft gage maintained at that point.

The stack problem is, of course, intimately associated with that of furnaces. If the correct height were 80 to 100 ft., how could the fact be accounted for that a boiler plant of 600 h.p. capacity with stacks only 51 ft. above the floor line, recently installed by the speaker, developed an average of 170 per cent of rating with peaks running up to 200 per cent on a five-day test? Not only this, but the height is such that the firemen have to be watched to prevent the admission of an excess of air. Moreover, in the same building a recent storm has entirely destroyed a number of stacks on some return tubular boilers down to the roof line, and there is not the slightest difficulty in running these boilers up to capacity with the stacks in this condition. In this case, the height of stacks could not be more than about 25 ft. above the floor. If all the overload capacity consistent with safety could be secured and the firemen still get an excess of air if not watched, manifestly 50-ft. stacks are too high. At another plant of 1200 h.p. in four units, the stacks are 72 ft. high. These are made higher than would be ordinarily necessary on account of the configuration of the surroundings. With these stacks, the boilers can be operated at any reasonable overload and if the fireman is not watched he will get his $CO_2$ as low as 2 per cent. These stacks are, therefore, too high, except perhaps under conditions which might bring to bear the adverse influence of the winds passing over the surrounding hills. It is manifestly unsafe to generalize on either the height or diameter of stacks without knowing all of the conditions. The draft resistance differs in different types of boilers; the amount of overload desired has an influence on the height and area; the draft resistance in the boiler increases with overload; conditions which obtain at sea-level are not present at altitude; the direction of prevailing winds as regards the situation of the plant with reference to the configuration of the surroundings is of consequence; there is a great difference whether each boiler is equipped with an individual stack, one stack per battery of two, or one stack serving several, with connecting breeching; every turn in a breeching introduces a draft loss; the frictional resistance and the cooling effect of economizers must be taken into consideration; for construction purposes there is an economical ratio of height to diameter; the price of fuel oil is a consideration, etc. So many factors enter into the design and proportions of stacks that the subject is a complicated one, and worthy of more extensive exploitation.

As to the use of compressed air instead of steam for atomizing, a special occasion for using it in place of steam is probably offered by plants where exhaust steam does not exist in sufficient quantities for heating purposes within the limits of temperature obtainable by steam at or near atmospheric pressure. A plant of 2000 b.h.p. located in Seattle and used entirely for a district steam heating system would seem to present a possibility for this practice. Industrial operations involving the use of large quantities of heat at relatively low temperatures, of which there are a number of examples, might also be similarly situated.

J. A. Yeatman[1] expressed his interest in the production of power from California crude oil by means of gas engines, or producers for gas engines. California oil is not freely vaporized and in order to prepare it so that it might be burned in a gas engine, retorts were first used, heated externally or from the exhaust from an engine. Inasmuch as the oil had a deposit of clay or earthy matter which the oil companies were not extracting, the retort would foul in a short time and become incrusted with carbon and dirt. Gas producers were then taken up something after the lines of the hard and soft coal producers of the East, but it was found that the percentage of hydrogen was so great that they had to reduce the compression. There would then be ignition troubles if the proportions were not correct. Later Mr. Frost developed his producer which the speaker had observed in operation and found to work satisfactorily; but the gas engines operated in connection with it required excessive bore and stroke for a given amount of power, which increased the internal friction. The device, while simple to an engineer, is quite complicated to the average small gas-engine user.

With regard to the oil engine, Mr. Yeatman said the oil companies were now extracting the dirt from the oil by centrifugal separators so that engines would operate without fouling the cylinders, and its use was one of atomization.

[1] United Iron Works, San Francisco, Cal.

Ordinary carburetors, or most of them, are based on the suction principle, which is not sufficient to atomize the ordinary 10 to 18 deg. gravity oils. Some manufacturers have developed a pressure atomizing mechanism which takes the place of a suction carburetor and considerable success has been had along these lines. Mr. Yeatman had been informed by engineers who had observed tests that with the pressure atomizing apparatus they had been able to produce a horsepower with $\frac{6}{10}$ lb. of California crude oil of 14 deg. gravity, which he thought marked probably the greatest progress toward economical production of power that he had heard of, and indicated lines for progress improvements.

A. M. HUNT, the chairman of the meeting, said that the subject of the direct combustion of the fuel in the gas engine cylinder might profitably form a subject for discussion and referred to the Diesel engine which is used to a very considerable extent abroad, even in units of large size, but had never gained a foothold in California.

G. H. MARX said that in 1904 he visited the laboratories at Munich, and was shown the engine on which Professor Shröder had performed his experiments, by his assistant, who assured him that they had used California crude petroleum in some of their tests, and that the petroleum had worked very satisfactorily, and left no residue in the cylinder.

HOWARD STILLMAN spoke of the operation of Diesel engines, relating experiences in the shops of the Southern Pacific Company at Ogden, Utah, and at Tucson, Ariz. He recounted how attempts had been made to operate the engine at Ogden with California crude oil, which were without success because it was frequently stopping and tying up the shop. A lighter distillate was then used which worked very well and was exceedingly economical, but even then, the engine was not reliable. The shop could not be kept going without resorting to the old steam engine. There were records of three weeks at a time when the performance was remarkable and then would come a period of, say two weeks when the Diesel Engine was hung up for repairs and the steam engine had to be used.

At Tucson the engine was maintained longer, covering a period of three years, and the same attempts were made to use the crude oil or a lower gravity oil, but the engine was intermittent in its action. Finally, a Texas oil of lighter gravity than the California oil was adopted and the performance of the engine was fairly good, although it had its difficulties. When it was working it was a splendid machine. One attempt was made to dismantle the steam engine but fortunately this had not been completely done, when its services were required because of trouble with the Diesel motor. The motor was finally abandoned as it was found there was no net economy in operation. It could not be prophesied when it was going to stop and the steam engine was finally put into regular service again. Delays in operation of lineshafting in machine shop during working hours were expensive.

R. W. FENN said that he had been in Chili and had found Diesel engines quite common there and inquired particularly about their operation from engineers in charge of them. They pronounced them ideal, but were using a Peruvian crude oil of 34 deg. gravity.

A. F. L. BELL reported trouble in the operation of a 1000-h.p. Diesel engine installed at the United Verdi Mine. The engine had been bought without giving attention to where the oil was to be obtained and experiments were now being tried with samples of oil and distillate from different parts of the California oil fields. He thought that the California oil must have a carbonizing effect, causing this type of engine to stop at intervals.

THOS. MORRIN said that he had had occasion a few years previously to inspect all of the carburetors made in the vicinity and that he found by using the carburetors in duplicate so that if one fouled a change could be made to the other and by feeding water into the inoperative one while it was still hot the deposit of dirt and carbon would slough off easily and it could be readily cleaned. The carburetor must be so constructed that it could be easily opened and tried out. If the oil was very dirty it might be necessary to have the carburetors in triplicate. No difficulty had been found in operating when the carburetors were cleaned with water or steam.

# OIL FUEL FOR STEAM BOILERS

By B. R. T. Collins

## ABSTRACT OF PAPER

This paper calls attention to the possible use of oil fuel for steam generating purposes in the Atlantic Coast States, discussing its safety and permanency of supply, as well as conditions under which it has special advantages over coal. Typical analyses of crude and fuel oil are given, with a statement of advantages and disadvantages when used for fuel as compared with coal. Some of the principles involved in efficient oil burning are stated, with a classification of oil burners or atomizers, several typical burners being illustrated and described. A statement of general methods of installation is made, with the data of some recent tests, showing the results which can be obtained from well designed installations properly operated.

The principles on which ultimate economy of oil versus coal depend are briefly stated. The opinion is expressed that there is a small, but gradually increasing field for the economical use of oil fuel for steam generating purposes in the Atlantic Coast States, and also that the success of any oil fuel installation depends less on the burner used than on the general efficiency of the entire installation and the intelligence with which it is operated after the installation is made.

# OIL FUEL FOR STEAM BOILERS

By B. R. T. Collins, Boston, Mass.

Member of the Society

In view of the present gradually increasing cost of coal for steam generating purposes in the Atlantic Coast States and especially in New England, the question of a satisfactory and economical substitute naturally arises. Among various possible substitutes crude petroleum and its residual product, commonly known as fuel oil, have attracted more or less attention since the discovery of the Texas oil fields about ten years ago.

2 Fuel oil is more satisfactory for burning purposes than crude petroleum because it has had removed, by the process of partial distillation through which it has passed, practically all of the light and easily ignited products, such as naphtha, gasolene and kerosene, together with any water or muddy portion which the crude oil may contain. Hence, while the crude oil is burned with safety in tremendous quantities in the Gulf States and along the Pacific Coast under proper precautions, fuel oil, which has a considerably higher flash point and calorific value, can be used for fuel by men of ordinary intelligence with practically the same safety as coal.

3 The cost of fuel oil in the New England States has been decreasing recently so that at the present time it can be purchased there more cheaply than in the western part of Texas. This is due to the fact that the cost of transporting oil in tank cars to western Texas is greater per barrel than the cost of transporting it to New England in barges and tank steamers, the largest of which have a capacity of 100,000 bbl. each, containing the heat equivalent of 25,000 tons of high-grade coal. Advances in the construction and in the capacity of oil carriers have made it possible to transport petroleum and its products more cheaply than any other cargo and as safely, provided those who handle them use common sense and intelligence.

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4 Another reason for lower prices of petroleum products is the competition which now exists in the supply of these products for New England consumers. This condition tends also to keep prices on a more uniform and steady basis than was the case a few years ago when no competition existed.

5 The production of fuel oil at the present time is much greater than it ever has been, due partially to the great demand for gasolene for use by automobiles and other gasolene engines, thus producing more residuum and causing less crude oil to be burned in the immediate vicinity of the oil fields. This also causes more fuel oil to be available for shipment from Gulfport refineries.

6 This result is also partially due to the ease with which the crude oil is brought to the refineries by means of the increasing number of pipe lines which carry enormous quantities of oil at a rapid rate for hundreds of miles.

7 At present the major portion of the supply of oil for fuel purposes for the north Atlantic States comes from Texas, Louisiana, Oklahoma and Kansas, this group of States producing about 62,000,000 bbl. in 1909, or over one-third of the total production of petroleum for the United States in that year, in spite of the fact that California made an increase of over 20 per cent above her production of petroleum for 1908. During the year 1910 there was an increase to 72,000,000 bbl. in the production of crude oil in the states mentioned, as well as a phenomenal increase of 50 per cent in California, to 77,000,000 bbl., thus making the total production for the United States 216,500,000 bbl., or about two-thirds of the total production of crude petroleum for the world.

8 The interest that fuel users along the Atlantic coast have in California oil may seem at first thought to be very small, but with the opening of the Panama Canal now promised for 1915, a means will be provided for the easy and cheap transportation of California's surplus production to Atlantic coast ports. Furthermore, the strip of country between the mountain ranges and the Pacific Ocean in Mexico, Ecuador, Peru and Chili is known to be rich in petroleum, and with the completion of the canal all of this region as far south as Valparaiso, Chili, will be brought nearer to the Atlantic seaboard than the port of Los Angeles, Cal. Consequently, the permanency of the supply of liquid fuel would seem to be assured for a considerable period of years to come, especially after the opening of the Panama Canal.

9 It is understood, of course, that the supply of fuel oil at the pres-

ent time would take care of only a small portion of existing steam plants now using coal, but judging from the fact that the production of crude petroleum in this country increased over threefold during the last ten years, there should be sufficient fuel oil to take care of a gradually increasing class of plants which for various reasons and conditions can use it economically. Included in this class would be:

*a* Plants where the cost of handling coal by ordinary methods is higher than the average because of local conditions, and where the installation of suitable coal-handling equipment would not be warranted by the saving effected. For instance, a plant located on navigable water, but with the channel at a considerable distance from the shore, necessitating expensive wharves, docks, coal pockets and coal-handling equipment, in order to receive coal by water; or a plant at some distance back from the water front or at some elevation above it, or both, necessitating a similar large expenditure. In either of these cases, oil could be delivered to storage tanks located underground 30 ft. from the boiler room or above ground 200 ft. away for the cost of a properly installed pipe line and the power required to pump the oil from the barge into the storage tank; the barge being made fast to a few piles at the edge of the channel while unloading in the case where the channel is at some distance from the shore.

*b* Plants where boilers are fired by hand and more than one fireman is required on each shift. Take, for instance, a plant of four 500-h.p. boilers, requiring four firemen and possibly a water tender and coal passer on shifts where the full capacity of the boilers is required. With a proper fuel oil installation, one man could do all of the firing, water tending and tube blowing required and take care of the feed and oil pumps if located near the boilers, as well as all the polishing and cleaning required in the boiler room.

*c* Plants where greater capacity is required than can be obtained with the coal available. With oil, 35 per cent or more additional capacity can be obtained than with high-grade coal. This has been proved by plants in Pennsylvania changing from oil to coal and being obliged to install 35 per cent more boiler capacity to carry the same load as was carried before with oil.

*d* Plants where the boiler capacity is limited by the capacity of the existing stack or stacks and where it is not desired to install more stack capacity, although more boiler capacity must be obtained. Oil fuel can give this added boiler capacity without increasing the stack capacity, as the stack area required for the same boiler capacity with oil is only about 60 per cent of that required for coal.

*e* Plants where a very small amount of soot from the stack would cause damage to manufacturing processes if it entered the factory buildings. Oil can be burned with absolutely no smoke.

*f* Plants where it is necessary to keep smoke below certain fixed limits at all times, due to smoke ordinances.

## OIL ANALYSES

10 In order to make comparisons between the calorific value and other properties of crude oil, fuel oil and any particular coal, Table 1 is given, with the authority therefor in each case.

TABLE 1 PROPERTIES OF CRUDE AND FUEL OIL

| Oil | Field | Carbon | Hydrogen | Sulphur | Oxygen | Specific Gravity | Flash | Fire | B.t.u. | Authority |
|---|---|---|---|---|---|---|---|---|---|---|
| Crude | Sour Lake, Tex. | | | | | 0.9266 | 198 | | 18460 | Prof. A. C. Scott, |
| Crude | Beaumont, Tex. | | | | | 0.9179 | | | 18500 | Univ. of Texas |
| Crude | Beaumont, Tex. | 84.6 | 10.9 | 1.63 | 2.87 | 0.9240 | 180 | 200 | 19060 | U. S. Naval Liquid |
| Fuel | Beaumont, Tex. | 83.3 | 12.4 | 0.50 | 3.83 | 0.9260 | 216 | 240 | 19481 | Fuel Board |
| Crude | Whittier, Cal. | | | | | 0.9416 | | | 18513 | Prof. W. C. Blasdale, Univ. of Cal. |

## ADVANTAGES AND DISADVANTAGES OF OIL FUEL

11 The advantages of oil fuel may be summarized as follows:

*a* Calorific value per pound 30 per cent higher than that of high-grade coal, a less weight of oil being required to give the same heating effect.

*b* Space required for storage of oil is less than that for an equal weight of coal. Fifty per cent more heating value can be stored in the same cubic volume and at greater distance from the boilers without extra expense.

*c* Oil does not deteriorate by storage, as coal does to a greater or less degree, but maintains its heat value indefinitely in ordinary ventilated storage tanks.

*d* Lower temperature in boiler room.

*e* Area of stack 60 per cent of that required for coal for equal boiler capacity, thus enabling a plant having insufficient draft with coal to have an excess amount with oil, a change from coal to oil for fuel making installation of additional stack capacity unnecessary.

*f* Less heat lost up the stack, owing to cleaner condition of tubes and to smaller amount of air which has to pass through furnace for a given calorific capacity of fuel.

*g* Higher efficiency due to (1) more perfect combustion with less excess air, (2) more equal distribution of heat in combustion chamber, as doors do not have to be opened, and (3) small amount of soot deposited on the tubes.

*h* Increase in capacity of 35 per cent to 50 per cent over coal, depending on grade of coal and draft conditions with coal.

*i* Heat is easier on the metal surfaces, being more evenly diffused over the entire heating surface of the boiler.

*j* Ease with which fire can be regulated from a low to a most intense heat in a short time or entirely extinguished instantly in case of emergency, such as water dropping out of sight in gage glass, and quickly relighted when the emergency is over. In less than half an hour a boiler can be brought up to 150 lb. steam pressure from cold water, if necessary. By means of an automatic regulator varying the pressure of oil and steam or air to the burners or atomizers, the steam pressure can be maintained within 5 lb. total variation, with sudden changes in load amounting to 50 per cent and over.

*k* Smoke can be entirely eliminated.

*l* No cleaning of fires, thus boilers can maintain their maximum capacity continuously, if necessary.

*m* Much lower cost for handling oil, as it runs by gravity or is pumped into and out of storage to the boilers.

*n* Absence of coal dust and ashes, thus enabling everything in the boiler room to be kept clean; therefore less wear and tear on pumps or other machinery. No expense for handling and removing ashes.

*o* No firing tools used, consequently no damage to furnace linings from this source. No clinkers to be removed from grate bars or furnace side walls.

*p* Less shrinkage and loss in handling oil fuel than in handling coal.

*q* Great saving of labor of all kinds: firemen, coal passers, ash wheelers, tube blowers, etc.

12 The disadvantages of oil fuel are:

*a* Low flash point. Fuel oil should have a flash point not lower than 140 deg. fahr., and with oil of this quality, handled by men of ordinary intelligence and common sense, there is practically no more danger than with coal.

*b* The ordinary underwriters' or city requirements specify that storage tanks for fuel oil be located underground and at least 30 ft. from the nearest building. This can generally be complied with in the case of the power plant of the average manufacturing concern, but in the case of a plant in the congested districts of a city it is likely to be prohibitive.

*c* With boilers using feed water of considerable scale-making qualities, the cost of repairs is likely to be increased by changing to oil, owing to the intense temperature developed in the furnace. However, with a proper setting for burning oil, repairs due to overheated tubes or surfaces should be less than with coal, unless the feed water is very bad.

## PRINCIPLES INVOLVED IN EFFICIENT OIL BURNING

13 The requirements for the perfect combustion of liquid fuel are as follows: Reduction to a fine spray or complete atomization; bringing it into contact with the proper amount of air; mixture of oil spray and air burned in a furnace of a refractory material with room enough to complete combustion before the gases come in contact with the boiler heating surfaces.

14 The first condition is fulfilled by selecting a proper burner, and the remaining conditions can generally be obtained by making slight changes in, or additions to, the existing furnaces.

15 The question whether to use steam or air for atomizing the oil seems generally to have been decided in favor of steam, as experimental results show that it takes about the same amount of steam

to operate the air compressor as it does to atomize the oil at the burner and the additional investment and complication involved with greater possibility of interrupted service is avoided.

16 It is also easy to see that a flat fan-shaped flame presents a larger surface for heat radiation and uniform distribution of gases than any other shaped flame, and at the same time requires a minimum number of burners per boiler.

17 Heating of the oil is an aid to economical combustion, and should take place as near the furnace as possible and be carried as high as safety permits, but not so high as to cause the oil to decompose and carbon to be deposited in the supply pipes. If preliminary heating is limited to the temperature of the flash point of the oil used, there can be no trouble from the above-mentioned causes.

18 In oil burning, although a certain amount of skill is required for hand adjustment of the burners to obtain the best results, still, with automatic regulation, the skill is reduced to a minimum, the principal work of the fireman being to see that the oil pump is kept in constant operation and that the burners do not become clogged with small particles of foreign matter, scale, etc., especially when the installation is new. Strainers of proper design, however, introduced on the suction line to the pump and also between the pump and the burner, will reduce this trouble to a minimum. Burners should be so installed that they can be easily disconnected from the piping and taken from the furnace for the removal of any foreign substance from their restricted orifices.

19 One of the most important questions in the combustion of liquid fuel is the regulation of the air supply in such a way as to obtain perfect combustion before the gases come in contact with the heating surfaces of the boiler. This can be done with an automatic damper regulator, although its adjustment is rather difficult. It is therefore usually accomplished by hand regulation of the damper when considerable variations in the load take place. This is supplemented by changing the position of the ash-pit doors, which are kept partly closed until a slight tendency to make smoke is noticed in the furnace when they are opened until this tendency disappears; or, better, by using an Orsat or continuous $CO_2$ gas analyzer to determine the position of damper and ash-pit doors which gives most complete combustion under certain constantly recurring conditions.

## TYPES OF OIL BURNERS

20 Although thousands of patents have been granted for oil burners or atomizers two general subdivisions or five general classes, as designated by the U. S. Naval Liquid Fuel Board, cover practically all of the main features of construction.

21 The two general subdivisions are:

*a* *Outside mixing.* Oil and atomizing agent meet outside the burner.

*b* *Inside mixing.* Oil and atomizing agent meet inside the burner.

22 The five general classes included in Par. 21 are:

*c* *Drooling.* Oil oozes out on to steam or air jet.

*d* *Atomizing.* Oil is swept from orifice by steam or air jet.

*e* *Chamber.* Oil mingles with steam or air in body of burner and the mixture issuing from nozzle is broken into minute particles by the expansion of the steam.

*f* *Injector.* Similar in principle to boiler feeding injector.

*g* *Mechanical spraying.* Effected by mechanical means without the use of atomizing agents, such as steam or compressed air.

23 The important features which should be embodied in all burners are: easy method of installation, construction that will allow quick inspection, easy removal of all foreign material which may clog the burner at any point and rapid and cheap renewal of any parts which are subject to wear.

## METHOD OF INSTALLATION

24 In spite of the various principles involved in burner construction, the success of an oil fuel installation depends not so much on the type of burner or atomizer used as on the method of its installation, and the intelligence with which it is operated after the installation is made.

25 To conform with the underwriters' requirements, storage tanks above the surface of the ground should be placed at least 200 ft. from inflammable property, and the top of the tanks should be located below the level of the lowest pipe used in connection with the apparatus. When the tanks are located underground, they should be outside the building, at least 2 ft. below the surface and 30 ft. from any building, with the top of the tanks below the lowest pipe in the building used in connection with the apparatus. In small and medium

sized installations, steel tanks coated with tar, having a capacity of 8500 to 15,000 gal. each, or 200 to 370 bbl. of 42 gal., are generally used for storage. In larger installations, reinforced concrete tanks, generally rectangular in shape, are used. These are usually made with a partition in the centre, so that any sediment or thick material may be periodically cleaned out without interfering with the continuous supply of fuel. The capacity of the storage tanks may vary from a supply sufficient for two weeks, when the oil is near at hand, and more may be obtained on one day's notice, to a supply sufficient for two or three months when the source of supply is at a considerable distance and delivery is in large quantities at irregular intervals.

26 Storage tanks should be fitted with vent pipes, indicators showing level of oil in tanks, filling pipes, arrangements for freeing tanks from water, suction pipes, return or overflow pipes, steam pipes for filling space in tanks above oil with steam in case of fire, and suitable manholes for cleaning out purposes. A suitable strainer should be installed on the suction line between the storage tanks and the oil-pressure pumps. The suction line should slope so that it will drain all oil back to the storage tanks when the pump is stopped and a vent opened.

27 Duplicate oil-pressure pumps should be installed with pump governors and all piping in connection with these pumps should be cross-connected in such a manner that a change can be made from one to the other and repairs made to either without interrupting the service.

28 A suitable oil heater should be installed, so that the exhaust steam from the oil pumps can be utilized to heat the oil before it reaches the burners. A suitable relief valve should be installed on the discharge line between the pumps and the burners set at a definite maximum oil pressure.

29 An oil meter should also be installed in the discharge line to check the storage-tank indicator readings. All oil piping should be installed so that it can be drained back to the storage tanks by gravity in case of necessity.

30 Provision should be made for removing any condensation from the steam lines to the burners. Automatic regulating devices should be installed to vary the pressure of both oil and steam to the burners in accordance with the demand for steam on the boilers, thus keeping a uniform steam pressure with a variable load, relieving the fireman of constant adjustment of burner valves and enabling him to take care of a much larger capacity of boilers than he otherwise could.

31 In case a plant is operated only ten hours per day, no steam being required for the rest of the 24 hours, it is necessary to install a small auxiliary boiler for the purpose of providing steam to atomize the oil while firing up the main boilers. In case of horizontal return tubular or Heine boilers, the burners should be placed at the front,

TABLE 2 GENERAL DATA AND RESULTS OF

| | |
|---|---|
| Date of test, 1910 | Aug. 8 |
| Test number | 1 |
| Duration of test, hours | 7 |
| Steam pressure, lb | 184.9 |
| Steam temperature, deg. fahr | 473.3 |
| Superheat, deg. fahr | 91.8 |
| Feed water temperature, deg. fahr | 90.6 |
| Factor of evaporation | 1.237 |
| Average water level, in | 4 |
| Barometer, in | 29.97 |
| Temperature boiler room, deg. fahr | 88.7 |
| Temperature flue gases, deg. fahr | 385.3 |
| Draft, in. — In ash pit | 0.025 |
| Draft, in. — In furnace | 0.01 |
| Draft, in. — In rear pass | 0.005 |
| Carbon dioxide, per cent | 12.2 |
| Oxygen, per cent | 3.6 |
| Excess air, per cent | 28.7 |
| Smoke | None |
| Temperature first pass above third tube, deg. fahr | 1100 |
| Temperature top first pass, deg. fahr | 640 |
| Temperature top second pass, deg. fahr | 570 |
| Temperature bottom second pass, deg. fahr | 500 |
| Temperature bottom third pass, deg. fahr | 450 |
| Total water actually evaporated, lb | 85766 |
| Total water evaporated from and at 212 deg. fahr., lb | 106092 |
| Water evaporated from and at 212 deg. fahr., lb. per hr | 15156 |
| Steam used by burners, lb. per hr | 234 |
| Steam used by burners, per cent of total steam | 1.54 |
| Steam pressure to burners, lb | 48.2 |
| Oil pressure to burners, lb | 11.4 |
| Temperature of oil to burner line, deg. fahr | 131.3 |
| Specific gravity of oil at 60 deg. fahr | 0.9770 |
| Specific gravity of oil, Baumé, at 60 deg. fahr | 13.3 |
| Moisture in oil, per cent | 0.4 |
| Heat value of oil as fired, B.t.u | 18280 |
| Heat value of oil corrected, B.t.u | 18353 |
| Total oil as fired, lb | 6913 |
| Total oil corrected for moisture, lb | 6885 |
| Oil fired, lb. per hr | 987 |
| Oil corrected, lb. per hr | 983 |
| Water evaporated from and at 212 deg. fahr. per sq. ft. heating surface, lb | 2.58 |
| Boiler horsepower builder's rating | 604 |
| Boiler horsepower developed | 439.3 |
| Per cent of builder's rating | 72.7 |
| Water evaporated per lb. of oil from and at 212 deg. fahr — Oil as fired, lb | 15.35 |
| Water evaporated per lb. of oil from and at 212 deg. fahr — Corrected for moisture, lb | 15.41 |
| Boiler efficiency, per cent | 81.1 |

firing towards the bridge wall. However, in the case of boilers of the Babcock and Wilcox type, higher efficiency can be obtained by placing the burners at the bridge wall and firing towards the front of the boiler.

32 It is sometimes an advantage to be able to change quickly from oil to coal and from coal to oil. This arrangement can generally

TESTS ON OIL-BURNING BOILER, REDONDO, CAL.

| Aug. 9 | Aug. 10 | Aug. 11 | Aug. 12 | Aug. 13 | Sep. 5 | Average of all tests |
|---|---|---|---|---|---|---|
| 2 | 3 | 4 | 5 | 6 | 7 | |
| 7 | 7 | 7 | 7 | 7 | 7 | 7 |
| 184.9 | 186.0 | 184.7 | 183.5 | 184.6 | 184.9 | 184.8 |
| 457.4 | 468.8 | 465.1 | 473.8 | 493.8 | 526.7 | 479.8 |
| 76.0 | 86.9 | 83.7 | 93.0 | 112.5 | 144.3 | 98.3 |
| 92.6 | 92.7 | 93.4 | 90.8 | 94.6 | 101.2 | 93.7 |
| 1.225 | 1.232 | 1.229 | 1.237 | 1.245 | 1.259 | 1.238 |
| 4 | 4 | 4 | 4 | 4 | 4 | 4 |
| 30.00 | 30.00 | 30.09 | 30.08 | 30.04 | 29.68 | 29.97 |
| 86.6 | 84.4 | 85.2 | 87.3 | 86.7 | 84.4 | 86.2 |
| 397.5 | 409.1 | 406.2 | 429.0 | 477.1 | 537.5 | 434.5 |
| 0.035 | 0.055 | 0.044 | 0.071 | 0.127 | 0.230 | 0.084 |
| 0.005 | 0.025 | 0.014 | 0.060 | 0.130 | 0.188 | 0.062 |
| 0.014 | 0.061 | 0.046 | 0.133 | 0.296 | 0.471 | 0.147 |
| 13.4 | 13.3 | 14.3 | 14.2 | 13.3 | 12.1 | 13.2 |
| 2.7 | 2.4 | 1.8 | 1.7 | 2.8 | 6.8 | 3.1 |
| 17.7 | 18.5 | 10.6 | 11.3 | 18.5 | 43.0 | 21.2 |
| None | None | None | None | None | Light haze | ...... |
| 1090 | 1160 | 1180 | 12.40 | 1300 | 1600 | 1240 |
| 640 | 700 | 680 | 780 | 940 | 1170 | 793 |
| 540 | 620 | 610 | 650 | 740 | 820 | 650 |
| 500 | 520 | 510 | 550 | 600 | 700 | 554 |
| 450 | 505 | 495 | 530 | 570 | 660 | 523 |
| 111988 | 129628 | 129609 | 156622 | 191290 | 226558 | 147351 |
| 137185 | 159702 | 159289 | 193741 | 238156 | 285236 | 182771 |
| 19598 | 22814 | 22756 | 27677 | 34022 | 40748 | 26110 |
| 441 | 549 | 549 | 624 | 708 | 873 | 568 |
| 2.25 | 2.40 | 2.40 | 2.25 | 2.08 | 2.13 | 2.15 |
| 74.7 | 99.7 | 102.6 | 120.4 | 142.5 | 167.6 | 122.2 |
| 15.2 | 24.4 | 25.4 | 38.3 | 46.1 | 61.6 | 31.6 |
| 134.3 | 133.5 | 142.3 | 140.1 | 142.1 | 141.7 | 137.9 |
| 0.9770 | 0.9763 | 0.9770 | 0.9776 | 0.9776 | 0.9797 | 0.9776 |
| 13.3 | 13.4 | 13.3 | 13.2 | 13.2 | 12.9 | 13.2 |
| 0.5 | 0.45 | 0.4 | 0.8 | 0.65 | 0.6 | 0.54 |
| 18256 | 18131 | 18253 | 18214 | 18171 | 17985 | 18184 |
| 18347 | 18212 | 18326 | 18357 | 18289 | 18093 | 18281 |
| 8758 | 10322 | 10115 | 12602 | 16580 | 20205 | 12213 |
| 8714 | 10276 | 10075 | 12501 | 16472 | 20084 | 12144 |
| 1251 | 1474 | 1445 | 1800 | 2369 | 2887 | 1745 |
| 1245 | 1467 | 1439 | 1786 | 2353 | 2869 | 1735 |
| 3.24 | 3.78 | 3.77 | 4.58 | 5.63 | 6.74 | 4.32 |
| 604 | 604 | 604 | 604 | 604 | 604 | 604 |
| 568.0 | 661.3 | 659.6 | 802.2 | 986.2 | 1181.0 | 756.8 |
| 94.0 | 109.4 | 109.2 | 132.8 | 163.3 | 195.5 | 125.3 |
| 15.66 | 15.47 | 15.75 | 15.37 | 14.37 | 14.12 | 15.15 |
| 15.74 | 15.54 | 15.81 | 15.49 | 14.46 | 14.20 | 15.23 |
| 82.8 | 82.4 | 83.3 | 81.5 | 76.4 | 75.8 | 80.47 |

be provided for, although in some cases, on account of a lack of sufficient combustion chamber space, a more efficient furnace may be installed by making the change back to coal a somewhat longer process, requiring the insertion of bearer bars and grate bars, which would be left in place in the arrangement first referred to.

## TESTS OF OIL-BURNING BOILERS

33 Table 2 gives the data and results of a series of tests recently made by The Pacific Light and Power Company at their plant, Redondo, Cal., on a 604-h.p. Babcock and Wilcox boiler equipped with Hammel furnace and burners. The boiler was in regular service and under usual plant operating conditions. The ash-pit doors were wide open during all tests. The tests were under the direction of Frank T. Clarke of the power company. Six of the tests were conducted on six consecutive days. The boiler used for testing was No. 1, in battery 1, erected in 1906; heating surface, 6042 sq. ft. The oil used was crude from the Los Angeles fields, the calorific value being obtained by the New York Testing Laboratory, Los Angeles branch.

34 It will be noted that the average temperature of the flue gases is 435.5 deg. fahr. with a minimum of 385.3 deg. fahr. at 72.7 per cent of rating, and a maximum of 537.5 deg. fahr. at 195.5 per cent of rating. The average per cent of $CO_2$ is 13.2, and excess air 21.2 per cent; steam used by burners 2.15 per cent. The highest efficiency obtained was 83.3 per cent. This was on the test of August 11, while running at 109.2 per cent of the builder's rating, and the water evaporated per pound of oil from and at 212 deg. fahr., corrected for moisture, was 15.81 lb. The average efficiency for all seven tests, running from 72.7 per cent up to 195.5 per cent of rating, was 80.47 per cent, and the average evaporation from and at 212 deg. fahr. was 15.23 lb.

35 In Table 3 are given results of tests made at the Ravenswood plant of The New Amsterdam Gas Company, Ravenswood, N. Y. These tests were made on a 595-h.p. Babcock and Wilcox boiler, equipped with a Peabody furnace and four No. 1 burners. The tests were made for the company by N. E. Lewis. The boiler had 5946 sq. ft. of boiler heating surface, and 841 sq. ft. of superheating surface. The fuel used was a low grade of fuel oil, hardly higher in heat value than gas-house tar. Attention is called to the fact that only 1.43 per cent and 1.54 per cent respectively of the steam generated was used to atomize the oil in the burners. The two series of

tests show the results that can be obtained with good oil-burning equipment well installed and properly operated.

## RELATIVE COST OF OIL AND COAL

36 A tabulation could be made showing the number of barrels of oil equivalent to a ton of coal of varying calorific value, but this would

TABLE 3 GENERAL DATA AND RESULTS ON TESTS ON OIL-BURNING BOILER, RAVENSWOOD, N. Y.

| | | | |
|---|---|---|---|
| Number of test | | 4760 | 4761 |
| Date of test, 1907 | | July 2 | July 3 |
| Duration of test, hours | | 5 | 4 |
| Steam for atomizing, superheated or saturated | | Saturated | Saturated |
| Steam pressure by gage, lb | | 145 | 142 |
| Temperature of feed water, deg. fahr | | 132.4 | 119.6 |
| Degrees of superheat, deg. fahr | | 85 | 83 |
| Factor of evaporation | | 1.1750 | 1.1868 |
| Total oil burned, lb | | 8273 | 6687 |
| Oil burned per hour, lb | | 1655 | 1672 |
| Total water evaporated, lb | | 101546 | 82317 |
| Total water evaporated from and at 212 deg. fahr., lb | | 119317 | 97694 |
| Water evaporated per hour from and at 212 deg. fahr., lb | | 23863 | 24423 |
| Draft, boiler side of damper, in | | 0.29 | 0.29 |
| Draft in furnace, in | | 0.16 | 0.15 |
| Temperature waste gases in flue, deg. fahr | | 488 | 488 |
| Temperature air in boiler room, deg. fahr | | 89 | 82 |
| Temperature oil at burners, deg. fahr | | 97 | 97 |
| Flue gas analyses | Carbon dioxide, per cent | 13.14 | 13.25 |
| | Oxygen, per cent | 5.29 | 5.15 |
| | Carbon monoxide, per cent | 0 | 0 |
| Water evaporated per sq. ft. boiler heating surface per hour from and at 212 deg. fahr., lb | | 4.01 | 4.11 |
| Water evaporated per sq. ft. total heating surface per hour from and at 212 deg. fahr., lb | | 3.52 | 3.60 |
| Water evaporated from and at 212 deg. fahr. per lb. of oil | | 14.42 | 14.61 |
| Horsepower developed | | 691.7 | 707.9 |
| Per cent of rated capacity developed | | 116.2 | 118.9 |
| Steam used by burners per hour, lb | | 340 | 377 |
| Per cent of steam generated used by burners | | 1.43 | 1.54 |
| Net water evaporated from and at 212 deg. fahr. per lb. of oil (allowing for steam used by burners) | | 14.21 | 14.38 |
| B.t.u. per lb. of oil | | 17733 | 17425 |
| Efficiency based on gross evaporation | | 78.53 | 80.97 |

be of very little practical value taken alone, for the reason that the efficiency of a boiler using oil fuel would be from 5 per cent to 15 per cent higher than when using coal, due to more perfect combustion with oil. The gain in efficiency would vary with the size of the boilers, character of furnaces and other equipment, intelligence of firemen, etc.

37 Although a fair idea may be obtained of the comparative cost of the two fuels by making certain assumptions in regard to heat values, specific gravity, gain in efficiency, etc., still this will not enable one to figure the saving which could be made by changing from one fuel to the other. The reason for this is that the saving generally depends on other things than the cost of the fuel. The saving in firemen and coal passers, increase in capacity, facilities for fuel storage, advantage of pumping fuel over methods of handling coal, elimination of handling ashes, quantity of coal used for banking fires, elimination of smoke and other things, many of which cannot be figured out in advance in dollars and cents, would throw the ultimate cost decidedly in favor of oil. The only way to determine the exact saving is to operate the plant with each fuel for a long enough period to get accurate data on all the items entering into the question.

## CONCLUSION

38 The writer believes that there is a comparatively small, but gradually increasing field for the use of oil fuel for steam generating purposes in New England in plants where special conditions enable a net saving to be made when everything entering into the problem is taken into consideration.

39 The writer also believes that the success of any oil-fuel installation depends less on the type of burner or atomizer used than on the general efficiency of the entire installation and the intelligence with which it is operated after the installation is made. Therefore, the work of designing and constructing such installations should be entrusted only to those having had extended practical experience in burning oil fuel and the operation of these installations should not be given to unskilled labor, for, in order to obtain the economic results possible from the use of oil fuel, it will be necessary to employ men of intelligence and skill as firemen.

# APPENDIX No. 1

40 A few typical burners representative of the subdivisions and classes mentioned in Par. 20 are shown in Figs. 1–13. Although these cover only a few of the burners and furnaces now in use in this country, not to mention the large number of systems of oil burning, the writer believes that they are sufficiently typical to show general principles involved, which is all he can attempt in this paper. The author is responsible for the general classification given in the case of each burner, but the details of construction and operation are as given by the manufacturers in their descriptive literature.

Fig. 1 Peabody No. 1. Outside mixing. Drooling. Fan-shaped flame. Spraying from sharp edge. The cut shows clearly the details of construction, including oil strainer, steam by-pass for blowing out oil passages, oil pipe jacketed by steam and removable burner tip.

41 This tip contains two very narrow slots separated by a diaphragm, the lower slot for steam and the upper for oil. The oil falls at right angles upon the steam jet which atomizes it and the oil is burned in a fan-shaped flame. It will be noted that the tip is held in position by a single bolt so that it can be readily cleaned if necessary. The mixing or atomizing is done entirely outside the burner. This style is for use in connection with the Peabody furnace, in which the burner tip is located at the bridge wall and the flame projected towards the front of the boiler.

Fig. 2 Peabody No. 2. Similar to Peabody No. 1 except that it is designed to be placed at the front of the boiler and to project the flame toward the bridge wall in the ordinary manner.

Fig. 3 W. N. Best high-pressure oil burner. Outside mixing. Atomizing. Long slot. Spraying from sharp edge. The air or steam meets the oil at right angles, thus atomizing it externally. Either a long narrow flame or a fan-shaped flame can be provided as required.

Fig. 4 W. N. Best oil burner with piping connections. Same as Fig. 3, except fitted with piping of sufficient length to go through the front setting of boiler. By-pass is provided for blowing out any foreign substance that enters the oil pipes. The atomizer lip is hinged and means provided for raising the lip for blowing-out purposes without removing the burner from the boiler.

Fig. 5 Gem oil burner. Outside mixing. Drooling. Rose-shaped orifice. Spraying aided by centrifugal action from internal screw and cone. Oil heated by atomizing steam on the way to burner tip as it surrounds oil pipe.

Fig. 6 Gilbert and Barker oil burner. Outside mixing. Drooling. Rose-shaped orifice. Spraying aided by slight centrifugal action from internal helix. Adapted for use where very heavy consumption of oil is required, such as heavy metallurgical operations, brick kilns, etc.

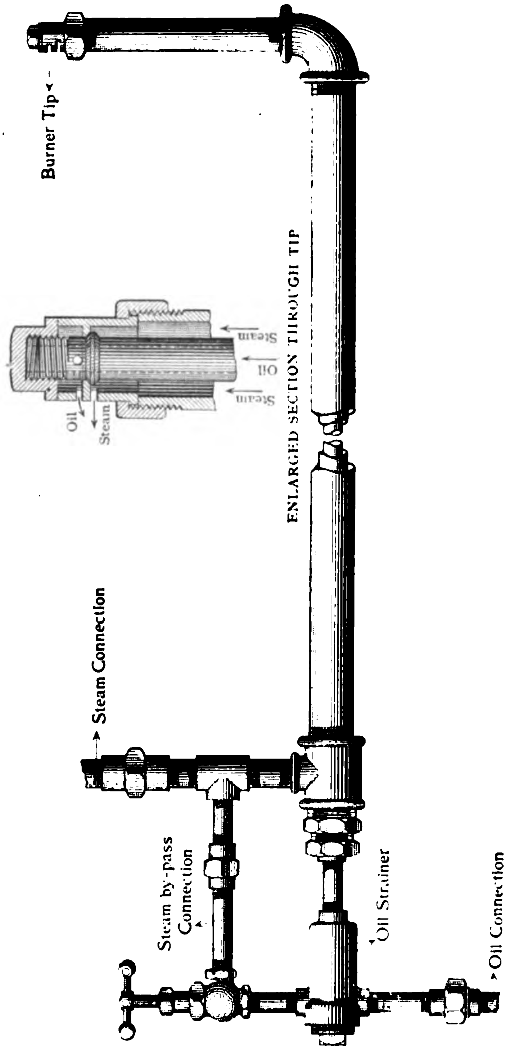


FIG. 1 PEABODY NO. 1 OIL BURNER

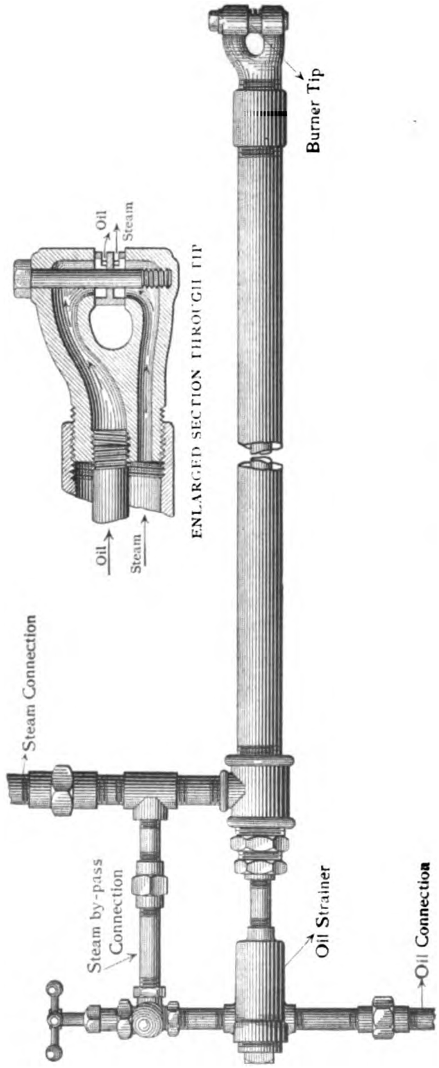


FIG. 2 PEABODY NO. 2 OIL BURNER

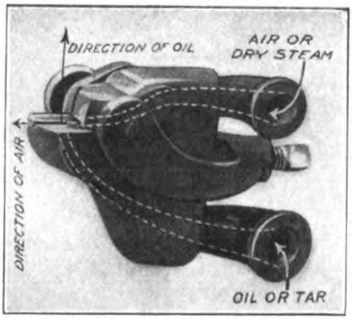


FIG. 3 W. N. BEST HIGH-PRESSURE OIL BURNER

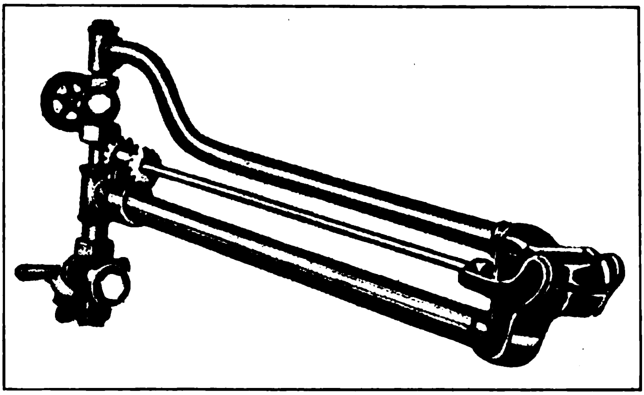

FIG. 4 W. N. BEST HIGH-PRESSURE OIL BURNER WITH PIPING CONNECTION

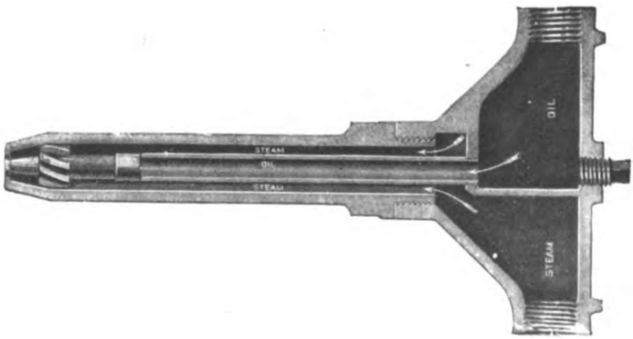


FIG. 5 GEM OIL BURNER

Fig. 7 Rockwell high-pressure oil burner. Outside mixing. Atomizing. Steam or air and oil nozzles removable for cleaning-out purposes. Steam or air nozzle outside of oil nozzle. Adapted for light or heavy work.

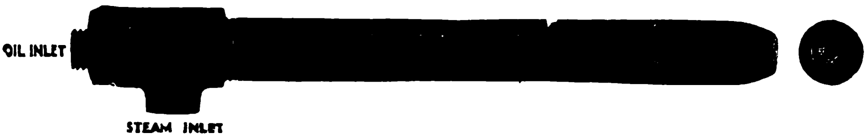


FIG. 6 GILBERT AND BARKER OIL BURNER

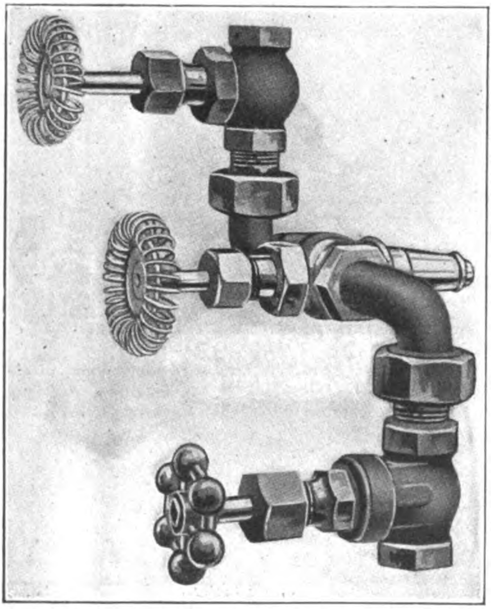

FIG. 7 ROCKWELL HIGH-PRESSURE OIL BURNER

Fig. 8 Hammel oil burner. Inside mixing. Chamber and atomizing. Long slot. Spraying from sharp edge. All parts are named in the cuts. Oil enters at *A* and flows through *D* into mixing and atomizing chamber *C*; steam enters at *B* passes through *F*, *E* and then through three small slots, *G*, *H* and *I* into mixing chamber *C*, where it meets the oil. The small steam jets break up the oil in the mixing chamber and the mixture is ready for ignition as it issues from the fan-shaped orifice. This orifice is provided with removable steel plates, which can be replaced easily in case of wear.

**Fig. 9 Kirkwood oil burner. Inside mixing. Injector. Rose-shaped orifice. Spraying from sharp edge. Both oil and steam valves seat at tip of the burner and are equipped with indexes showing the amount of oil and steam turned on.**

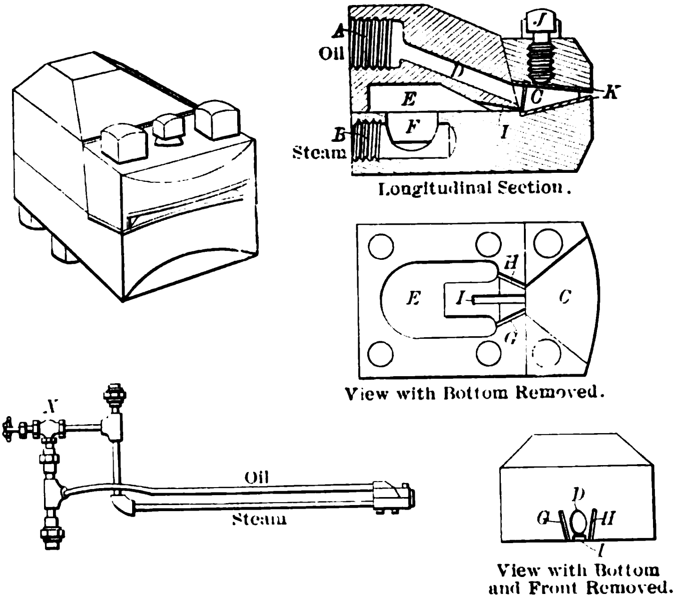


FIG. 8 HAMMEL OIL BURNER

*A* Orifice for Oil Supply Pipe. *B* Orifice for Steam Supply Pipe. *C* Mixing or Atomizing Chamber. *D* Oil Inlet Duct. *E* Equalizing Steam Chamber. *F* Steam Entrance. *G, H, I* Steam Ducts. *J* Set Screw holding Plate. *K* Removable Steel Plates. *X* By-Pass or Blow-Out Valve.

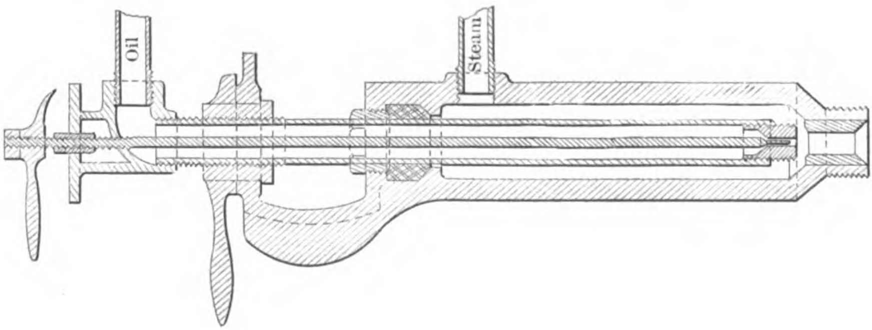


FIG. 9 KIRKWOOD OIL BURNER

**In another style of this burner one lever controls both the oil supply and the steam necessary for atomizing, the proportion being fixed before shipment from factory.**

Fig. 10 Improved Little Giant oil burner. Inside mixing. Chamber. Double long slot. Spraying from sharp edges. Oil pipe surrounded by steam

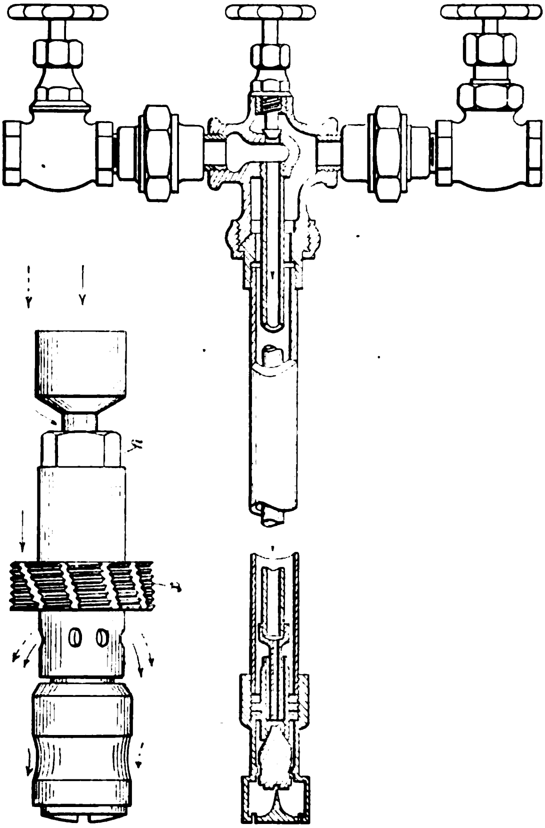

Fig. 10 Improved Little Giant Oil Burner

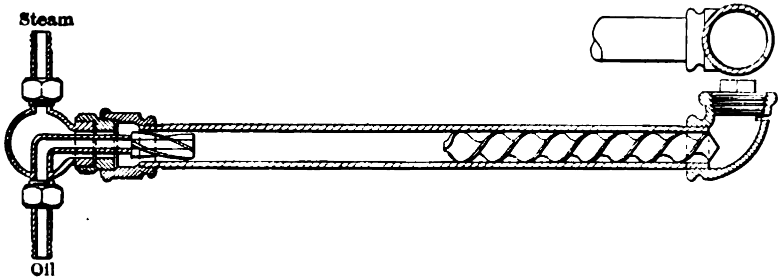


Fig. 11 Texas Oil Burner

which enters mixing chamber near tip. A separating diaphragm causes an equal amount of the mixture of oil and steam to issue from each opening in the tip. A special non-clogging oil valve is used.

Fig. 11 Texas oil burner. Inside mixing. Chamber. Fan-shaped flame. Spraying aided by centrifugal action from internal screw. As the oil flows into

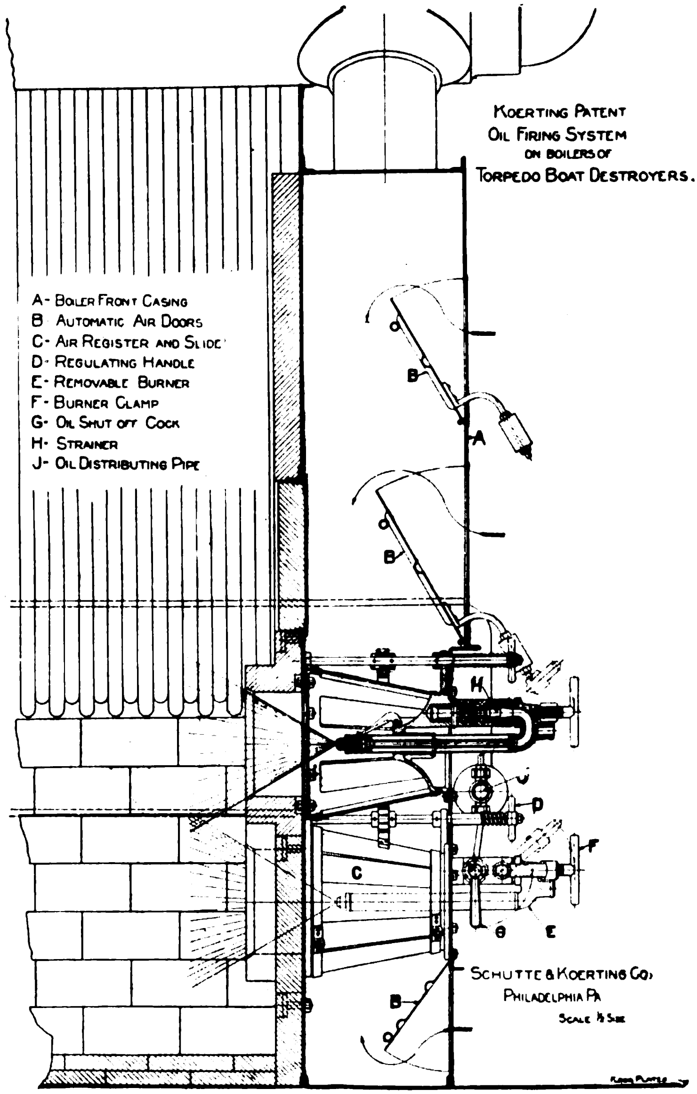


Fig. 12 Koerting Oil Burner

the large mixing chamber it is picked up by the steam to which rotary motion has been imparted by a short helix in the steam passage just back of the oil inlet. The mixture then passes along the chamber through a spiral passage occupying about one-half of its length which sets up a strong centrifugal action so that the oil is thoroughly atomized and vaporized when it issues from the fan-shaped orifice in the small chamber at the tip of the burner. This orifice is made to give any width of flame required and the tip is easily renewable in case of wear.

Fig. 12 Koerting oil burner. Mechanical spraying by pressure and centrifugal action from internal screw. Oil is delivered to the burner under sufficient pressure to break it up into a conical spray with the aid of spiral blades which set up a strong centrifugal action and a central cone at the tip which helps to maintain the centrifugal effect until the oil issues from the orifice. By loosening the clamp screw and throwing it into the dotted position shown, all working parts of the burner are quickly removable for examination or cleaning. The supply of air is introduced through adjustable openings shown in the cut so that it will impinge directly on the spray of oil thus effecting immediate combustion. The fact that this burner requires neither steam nor compressed air for atomizing makes it especially desirable for marine and naval boilers where fresh water for boiler feed make-up purposes is expensive.

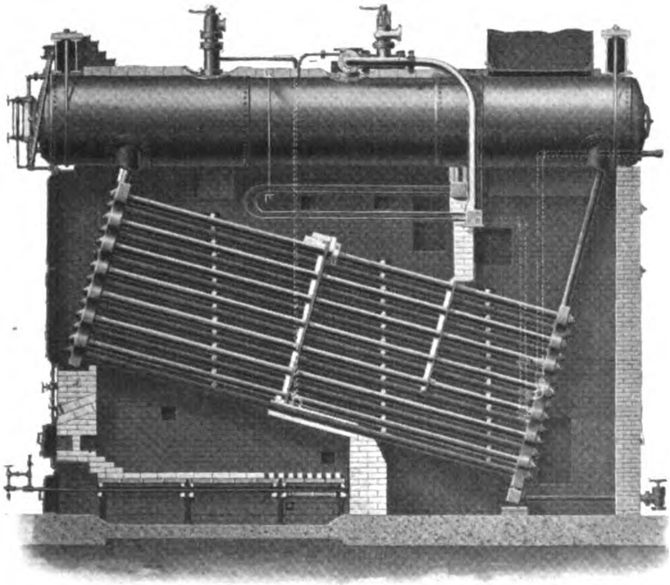

FIG. 13 PEABODY FURNACE FOR LIQUID FUEL

Fig. 13 Peabody furnace for liquid fuel. E. H. Peabody of the Babcock and Wilcox Company, while making an exhaustive study several years ago of methods of burning oil under water-tube boilers, discovered that by placing the burners at the bridge wall and projecting the flame toward the boiler front a large gain in efficiency and capacity could be made. This gain is due to the thorough distribution of the flame through the furnace and the complete combustion of the gases before coming into contact with the boiler tubes as well as the consequent improved utilization of the entire heating surface in the first pass of the boiler. All details of the furnace are clearly shown in the cut, including extension of furnace towards the rear of the boiler, arrangement of air openings, method of supporting burners and inserting them through special slide ways supported on the bearing bars which hold the floor of the furnace.

42 The Hammel furnace, used in the tests in Table 2, is based on the Peabody patent furnace (Fig. 13) with the addition of a slot in the bridge wall in which the burner is placed for protection from the heat and a separate air tunnel to each burner so that one or more burners may be extinguished and their air supply entirely shut off, thus maintaining the efficiency of the burners still in use.

## DISCUSSION

E. H. Peabody judged that the reference to the steam consumption of the oil burners, in Par. 33, pertained to the tests made by N. E. Lewis at the Ravenswood works of the New Amsterdam Gas Company, the results of which are given in Table 3. These tests were two incidental runs made in a series of experimental tests mainly with gas-house tar as fuel. It was not expected that they would achieve the distinction of appearing in the proceedings of the Society, and while very good tests, they should not be taken as a fair comparison of results obtained with Hammel burners, as their proximity to Table 2 of the paper would seem to indicate. In reference to Par. 42, Mr. Peabody said that in his original study of oil furnaces in California, he had experimented with separate air ducts or tunnels to the individual burners, and the earliest installations of the Peabody furnace on the Pacific coast in 1903 embodied this idea.

M. H. Bronsdon[1] stated that every one of the tests of crude or fuel oil made for him by Professor O'Neill at the University of California showed the same calorific value (practically), regardless of its specific gravity or whether or not the gasolene had been removed. The more fluid the oils, the less troublesome they were, as they required a much lower pressure to send them through the piping; and where the specific gravity is 17 deg. Baumé, or lighter, at 60 deg. fahr., no warming during the pumping process was necessary.

The use of fuel oil removes one of the most important and expensive items of power plant operation from the hands of unskilled labor (i.e., the ordinary fireman), and places it upon an efficient basis, as with proper installation economical operation is dependent only upon reliable and very simple mechanism.

Where oil is used for fuel, perfect combustion may be obtained under all conditions of load with proper installation, excepting when the fires are first lighted and the brick work is comparatively cold. Boiler settings and boiler tubes last much longer with fuel oil than with coal, provided the tubes are kept clean.

[1] Chief Engineer, The Rhode Island Co., Providence, R. I.

Presented at the Boston Meeting, April 1911, of The American Society of Mechanical Engineers. All discussion is subject to revision.

The impression should not be given, as stated in Par. 11, that by changing from coal to fuel oil the capacity of any boiler plant can be increased to from 35 to 50 per cent. In boiler plants with sufficient draft to burn large quantities of coal, or where the evaporation can be made to exceed, say 7 lb. of water per sq. ft. of heating surface, fuel oil will not increase the capacity 35 to 50 per cent.

His experience led him to favor burners of the type known as "outside mixers," i.e. where the oil and steam mix just beyond the tip of the burner. Carbon seldom causes trouble with burners of this type, even where the oil is quite hot before it reaches the burner. There seems to be no practical difference in the efficiency, however, in the use of either inside or outside mixer burners.

In a well designed and carefully operated boiler plant using coal for fuel, where the efficiency is approximately 75 per cent or better, the use of fuel oil will not change the efficiency materially. In a plant which operates from 20 to 24 hours a day, the standby losses will, of course, be lower with oil than with coal, due to the fact that there are no banked fires to be maintained under spare boilers, some of which are of use only during the peak load conditions. The gain in efficiency is not due simply to the use of fuel oil, but rather to better conditions which are maintained with less effort, such as the removal of soot from the tubes, cleaner back connections, and the fact that the fireman is not fatigued by his labors, but can without any particular effort see that perfect combustion is maintained. The $CO_2$ recorder becomes a valuable instrument in a boiler room using oil for fuel.

Comparing the cost of fuel oil with coal, we should consider, first, the cost of coal alongside, plus discharging costs, plus conveyor costs, plus the cost of removing ashes; second, the B.t.u. per ton of coal. In New England at tidewater, the cost of coal, and the discharging and conveying costs and the removal of ashes approximate $3.50 per ton, varying from year to year. One ton of bituminous coal contains approximately 33,000,000 B.t.u. and we should buy 33,000,000 B.t.u. in fuel oil for approximately $3.50; i.e., 33,000,000 B.t.u. equals

| | |
|---|---|
| 1774 lb | $3.50 |
| 224 gal | 3.50 |
| 1 gal | 0.0156 |
| 1 bbl | 0.65 |

These figures will be slightly reduced if credit is given for minor economies resulting from the use of oil, but they are amply accurate for general use.

D. S. Jacobus said that the efficiency results given in Table 2, secured in tests on an oil-burning boiler at Redondo, Cal., represented good practice. Better results, however, were secured in tests on one of the boilers at the same plant preparatory to making a test of the plant. The plant tests, already reported to the Society, indicated that a kilowatt-hour was turned out at the switchboard for each 25,000 B.t.u. contained in the fuel oil. In these tests the standard form of Peabody furnace was employed with burners of the outside mixer type.

S. F. McIntosh[1] believed that there is little to choose between the two when figuring on oil at $0.03 a gallon and coal at $5.00 a ton delivered in the boiler house on the B.t.u. basis. At the plant of the American Optical Company, Diesel engines were installed, and as more or less oil equipment was required for their operation, it was decided to try oil under the boilers. It has worked almost perfectly and there has been no trouble whatsoever. Its advantages in the way of ease of operation, cleanliness, efficient combustion, etc., appeal to them strongly. If, however, many manufacturers in New England should become interested and burn oil for the same reason, there would be no doubt that the price per gallon would increase to a point where it would be impossible to burn oil economically anywhere in New England. His firm contracted for oil during 1911 at $\frac{3}{10}$ cent a gallon more than in 1910, which is equal to an increase in the price of coal of 16 cents per ton at the mine. A slight increase in the price of oil offsets the saving of labor through its use. Taking the statement of the author that one man can handle four 500-h.p. boilers under which oil is used, where four men would be required if coal were used, and assuming the saving in labor to be 80 cents an hour, an increase of $\frac{1}{10}$ cent in the price of oil would entirely offset the saving in labor.

B. R. T. Collins referred to the fact that Mr. Bronsdon had had his experience with fuel oil in California, where the crude oil is quite different from the residue from Texas, which would alter his conclusions somewhat. The reason for more complete combustion referred to by Mr. McIntosh is that there is no loss in burning oil such as occurs in burning coal, at the period just after the coal is fired, especially with hand firing. At that time a large quantity of hydro-

[1] American Optical Co., Southbridge, Mass.

carbons are only partly consumed. It therefore stands to reason that an oil-burning equipment should be more efficient. There are more heat units of the oil utilized in producing steam than of the coal in an ordinary coal-burning installation.

In reply to an inquiry as to why oil could not compete with coal in modern plants using mechanical stokers, where from 75 to 80 per cent efficiency can be obtained, Mr. Collins replied that in large plants burning 100 or more tons of coal a day having docks, coal-handling equipment, mechanical stokers, etc., it is principally a matter of the comparative cost of the two fuels. The field for oil fuel at present is among plants that are hand fired where there is a chance to make a considerable saving in labor. Later, after the Panama Canal is opened, there will be more oil. Then, he thought, the time would come when oil would compete with coal in large plants as well as small.

C. F. Dietz. (Written.) Mr. Collins suggests the possibility of a lower price for coal, should it become known that many plants were operate oil-fired boilers. On the other hand, after the plants had been equipped and oil consumption increased in any given district, there would be the danger of a rise in the price of oil, thus to a great extent balancing the advantages of the liquid fuel. This brings to mind an instance of one of the large European steamship companies which seriously considered the introduction of oil-fired boilers and equipped a vessel with a plant for trying out the scheme. This was some ten years ago. When it became known that oil-fired boilers were contemplated, the dealers from whom the company had been in the habit of buying their fuel promptly offered a reduction of a shilling per ton of coal. Advantage was promptly taken of this, with the result that the extensive experimental plant proved a decidedly good investment. During the operation of this steamer it was found that the temperatures developed in the fire box were very much higher than those usually obtaining in the coal-fired boilers, and led to many serious troubles which were gradually overcome by proper protection, as well as proper deflection of the oil blast. These difficulties have been practically done away with, so that oil-fired boilers no longer present this disadvantage.

The two principal methods used for atomizing the oil call either for steam or air and it would appear that the steam blast might have advantages over the air blast in the way of flame temperature, and the consequent effect upon the surfaces where the flame impinges

I am not aware of the existence of any data regarding the effect of the dissociation of the steam on the temperature of the flame, nor do I know whether the reverse action takes place almost immediately so that the heat taken up by the dissociation of the water is partly returned to the boiler as useful energy.

For the purpose of reviewing the chemistry and physics of the combustion more clearly, I present herewith the following calculations which seem to me to indicate clearly that the steam after dissociation must necessarily be burned back to water at a point in the boiler where the heat thus produced from the exothermic reaction is utilized.

Assuming 1½ per cent of steam is used to atomize oil, then since, according to the tests, 15.4 lb. of water were evaporated per lb. of oil, it requires $15.4 \times 0.015 = 0.231$ lb. of steam to atomize 1 lb. of oil. The steam under the intense heat of the oil flame must be dissociated and requires 5806 B.t.u. per lb. of water, or $5806 \times 0.231 = 1341.186$ B.t.u. per lb. of oil is abstracted for dissociation of the steam.

Since the fuel has a given calorific value of 18,353 B.t.u., $\frac{1341.186}{18,353}$ = 7.3 per cent of the fuel required to atomize the steam is needed to dissociate it. If this dissociation is normal under the temperature conditions, it is practically certain that a partial reaction at least must take place, otherwise the efficiency of the boiler as an absorber of heat could not be 81.1 per cent as given. It would be interesting to know to what extent the steam blast for atomizing the fuel chills the combustion chamber. Of course the temperature in the combustion chamber may be reduced at a sacrifice of boiler efficiency by allowing an increase in the quantity of excess air, everything else remaining equal. From purely theoretical considerations it would appear that the steam blast burner might have advantages over the air blast burner, at least in so far as the heat of combustion is concerned, if the dissociation of the steam takes place without an immediate reformation of water. I would suggest that in boiler tests using oil for fuel with both methods of atomizing, the flue gases be analyzed for free H. This can be done effectively with a Palladium tube.

That the temperature of combustion of fuel oil in a furnace is much higher than when coal is used is found in practice and borne out by the following rough calculation:

Composition of oil from Table 1 of Mr. Collins's paper is C, 83.3 per cent; H, 12.4 per cent; S, 0.5 per cent; and oxygen, 3.83 per cent. Assuming the excess air to be 15 per cent, then for combustion there is required per pound of oil

| | | | |
|---|---|---|---|
| For C | 2.080 lb. oxygen | | |
| For H | 0.992 lb. oxygen | | |
| For S | 0.005 lb. oxygen | | |
| Total | 3.077 lb. oxygen | | |
| Less oxygen in oil | 0.038 lb. | | |
| Net oxygen required | | 3.039 lb. | |
| N with this oxygen | | 10.171 lb. | |
| Total air theoretical | | | 13.210 lb. |
| 15 per cent excess | | | 1.980 lb. |
| Total air required | | | 15.190 lb. |

Products of combustion per pound of oil are then

| | | | Per Cent by Weight |
|---|---|---|---|
| $CO_2$ | 2.080+0.833 | = 2.913 | 18.00 |
| $H_2O$ | 0.992+0.124 | = 1.116 | 6.87 |
| $SO_2$ | 0.005+0.005 | = 0.010 | 0.06 |
| O | 0.455 (excess air) | = 0.455 | 2.82 |
| N | 10.171+1.525 | =11.696 | 72.30 |
| | | 16.190 | 100.05 |

Assuming the analysis is made at 89 deg. fahr., the moisture in the gas can be only 3 per cent. At the temperature of the analysis gases are made up as follows:

| | Per Cent by Weight | Per Cent by Volume |
|---|---|---|
| $CO_2$ | 18.700 | 13.22 |
| $H_2O$ | 3.000 | 5.19 |
| $SO_2$ | 0 062 | 0.0297 |
| O | 2.930 | 2.86 |
| N | 75.200 | 78.69 |
| | 99.892 | 99.9897 |

In these calculations the air for combustion has been considered dry. Comparing the above calculated analysis with that given in Table 2, we see that both the $CO_2$ and oxygen content check very closely, the average of all eight tests being 13.25 per cent $CO_2$ and 3.1 per cent oxygen, thus precluding the presence of any considerable quantity of free H, and the steam used for atomizing the oil cannot be considered a great robber of heat. It would be interesting to know where the reaction takes place. In this connection the difference between the most modern practice as given in this paper and that of 15 to 20 years ago may be noted.

W. S. Hutton in his Steam Boiler Construction makes the statement that "from 8 to 13 per cent of the total quantity of the steam produced by the boiler is expended in atomizing the oil, or converting it into spray." Under such conditions the high efficiencies now recorded could not be attained.

Further the same author says: "The minimum quantity of air that should be provided in practice is 22 lb. of air per lb. of oil, but it is generally necessary to provide a larger quantity than this, in order to prevent the production of smoke."

In the light of recent practice it becomes somewhat difficult to understand the reason for the above statement. However it is likely that the reasons for the heavy excess of air were due to conditions other than the chemistry of the combustion, and necessitated probably by the physical character of the fuel, the form of burner and fire box, size of combustion chamber, and other physical conditions which have since been improved upon to such an extent as to more nearly realize the theoretical requirements.

The conditions under which oil is burned produces a hotter fire than coal and accounts for the increase in capacity for any given boiler when changed over to oil, as well as for the difficulties experienced with boilers and fire boxes before it was realized that the direct flame gave rise to serious troubles. An idea of the temperature of combustion of the oil under the conditions discussed above may be gained from the following:

For each pound of oil burned there are liberated 18,353 heat units and a total of 16.2 lb. of gas are produced. The specific heat of this gas is probably not less than 0.3 on account of the high temperature and the presence of water vapor. The specific heat of furnace gases when coal is the fuel and 570 deg. fahr. the chimney temperature, has been found to be 0.265, but at the temperatures existing in the fire box the specific heats of the gases are very considerably higher. However, with an average of 0.3 we would have a maximum increase of temperature over the temperature of the air and oil of

$$16.2 \times 0.3 \times t = 18{,}353$$

$$t = 3776 + \text{(say) } 90 = 3866 \text{ deg. fahr.}$$

which while not actually realized in the combustion chamber, still leaves an actual existing temperature after deducting all losses, sufficiently high to make precautionary measures for the protection of the fire box and boiler of vital importance.

D. W. Robb held a point of comparison to be the cost of oil and coal. While oil is easier to handle, cleaner, etc., it is surprising what can be accomplished in burning coal, from the standpoint of economy, even by old-fashioned means. Mr. Robb had visited the "wood worsted" mill at South Lawrence, Mass., which is equipped with return tubular boilers and fired with soft coal. He found the temperature of the gas at the stack after passing through the economizers to be usually not over 200 deg. It leaves boilers at 375 to 380 deg. and the $CO_2$ present under these conditions is 13 to 14 per cent. This record is obtained by training the firemen under a good superintendent. They are not allowed to fire more than six or seven shovelfuls at a time, and are really not getting smoke.

The author had very properly pointed out that the question of oil burning is largely a question of the installation and management of the fires. The subject of oil burning is well worth the attention of large fuel users in New England, but they will want to know who is to control the price of the oil and whether a regular and sufficient supply can be depended upon. It will require careful investigation by engineers with results proved by actual tests to determine the economy.

E. F. Miller called attention to the high efficiency, around 80 per cent, shown in the tests quoted by the author, whereas in the case of boiler tests with coal as fuel he thought he himself had never secured over 70 per cent efficiency.

Robt. C. Monteagle referred to the steamships Harvard and Yale, now out on the Pacific coast, but formerly running between Boston and New York. They were first fitted to burn coal, but almost invariably required more than the 15 or 16 hours running time between the two cities. After running a year they were changed over to burn oil and had no difficulty in making their time. He also instanced the case of an explosion and fire on a vessel due to water in the oil which put out the flame, after which the oil kept flowing into the furnace. The fireman did not make his rounds properly, and when he discovered that the flame was out thrust his torch into the furnace.

J. C. Riley called attention to the fact that the flame from an oil burner is much like that from a blast lamp; its very high temperature is localized over so small an area that the metal of the boiler must be protected from it, whether the atomization is by steam or air. He had measured some temperatures in the furnaces of Scotch boilers with burners fired by both air and steam atomization. The furnaces were of the usual corrugated cylindrical type, opening into separate combustion chambers at the back. Each had a complete ring of fire-brick lining which extended about 4 ft. back, and another ring in front of and around the saddle seams where they entered the combustion chambers. There was also a layer of fire brick along the bottom, between the two rings, and one burner in each furnace, placed just above the axis and terminating about a foot back of the tube sheet.

On looking in at the front, the burner could be seen to spread the flame in a cone of about 80 deg. total angle, striking on the ring of brick. Apparently it was hottest right where it struck. With the steam burners, the flame was so dazzling that it was quite impossible to see beyond the surface of the cone. With the air burners clean and properly adjusted, the flame was yellower and not so bright; a little practice enabled one to see through the cone, even into the combustion chamber, and it appeared that the whole furnace was filled with a long, transparent yellow flame. With the air burners partially clogged with carbon, or not properly adjusted for air supply, the flame was irregular and smoky; drops of oil could be seen spattering on the furnace walls.

For measuring temperatures throughout the furnace and back into the combustion chamber, a distance of more than 10 ft., the ordinary form of porcelain-covered thermo-electric cane was out of the question, so a special form of water-cooled pyrometer was made. The outer tube was of 1-in. pipe, 12 ft. long. Inside was a ½-in. pipe to which water was pumped through a length of garden hose. The electric couple consisted of two wires of platinum and platinum-iridium, twisted together at one end and soldered to copper wire leads at the other. The twisted ends were inserted into a protecting tube of fused quartz. The leads were encased in a ¼-in. copper tube, 12 ft. long, which passed through the ½-in. pipe. The quartz tube passed through a water-tight stuffing box at the end of the 1-in. pipe, and projected about 4 in. into the fire. The joint between the copper and quartz was made tight with rubber tubing. The cold ends of the couple were thus inside the ½-in. pipe, where they were both at the same temperature, and this temperature was known within a very few degrees. The incoming water on leaving the ½-in. pipe passed back through the outer pipe and escaped through another hose. There was no difficulty in making the total rise in temperature of the water less than 25 deg.

It was found that with an air burner just cleaned and in best condition, the temperature throughout the furnace, from the burner back into the combustion chamber, was remarkably uniform, and that it averaged about 2250 deg. fahr. It was hottest at the axis of the furnace, a foot or two in front of the burner, and not where the cone of flame struck the brick lining. After several hours use without cleaning, the air burner gradually clogged with carbon until the mean temperature dropped to less than 1500 deg., in which case the front of the furnace was comparatively cool and the highest temperature was in the combustion chamber. The steam burner never clogged with carbon, but its temperature was not so uniformly distributed as that for air. In the axis of the furnace it dropped from more than 2400, just beyond the burner, to less than 2000 in the combustion chamber. It was extremely hot where the cone of flame struck the brick along the bottom; one observation gave more than 2500 deg., a temperature which destroyed a quartz tube of the pyrometer.

The necessity for protecting the metal of a boiler from direct contact with the hottest point of flame is apparent to any one who has seen the flame marks which are sometimes burned in by careless firing. Burning of the steel is most likely to occur when the oil fuel contains much sulphur. It is also likely to occur when for any reason the rate of heat conduction is slow or the circulation is not active.

For burning oil it is especially desirable that the fireman should be a man of intelligence and good judgment. A few minutes of neglect or carelessness may injure the boiler seriously. When everything is operating well and the burners properly adjusted, a slug of water may come along with the fuel and put the flame out. To be sure it ought not be there, for the suction pipe of the fuel pump is floated near the surface of the oil in the supply tank, to guard particularly against this happening. But sometimes the thing which cannot happen does occur, and the flame goes out. Then when the next oil passes the burner, if there are other burners still lighted in the same furnace, or if the brick target is still hot enough to ignite the oil instantly upon contact, no harm is done; but if the oil does not light, and if the fireman does not notice the fact, there is great danger of an explosion, or at least a fire.

B. R. T. Collins, in reply to the inquiry as to what percentage of the steam produced by the boilers is required for the jet apparatus and pumps, said it varies from a little less than 1½ to 2 per cent for atomizing in the burners and for operating small oil pumps it takes an equal quantity, or from 3 to 4 per cent in all. Using air to atomize requires about the same amount of steam to operate the air compressors.

In reply, also, to an inquiry as to the relative loss in firing coal by hand and in using oil without automatic regulators, he believed that whereas with coal a poor fireman could make a difference of 10 to 15 per cent it would not be more than half this with poor oil firing.

Answering Mr. Monteagle with regard to water in oil, he said he had burned fuel oil or residuum, at Dallas, Texas, all summer and there was no water at all in it, all the moisture having been driven off by the process of partial distillation through which it had passed. In California there is considerable water in the oil because crude oil direct from the wells is burned almost entirely. In such cases, tests are made of the oil after delivery and contracts so worded that if the water exceeds 1 per cent there will be a rebate for all over that amount.

In the vessel spoken of by Mr. Monteagle, the fireman should have determined whether there was any gas or unburned oil in the furnace before applying the torch. This is why so much stress should be laid on having intelligent firemen.

# GAS POWER SECTION

## PRELIMINARY REPORT OF LITERATURE COMMITTEE

## (VIII)

### ARTICLES IN PERIODICALS[1]

BACK FIRING AND FUEL WATER IN A LARGE PRODUCER GAS ENGINE PLANT, Correcting, J. G. Callan. *Power, July 11, 1911.* 1 p. *bc.*

Abstract of paper presented before the Congress of Technology, Massachusetts Institute of Technology, Boston.

FIRE PUMP, PETROL-DRIVEN. *The Engineer (London), June 23, 1911.* ½ p., 1 fig. *bfB.*

Of interest in that it is supposedly the largest in the world. Capacity, 800 gal. per min. at 225 r.p.m. at high pressure; 4 vertical cylinders; 80 h.p.

GENERATORGASANLAGE, VERSUCHE AN EINER, Kurt Neumann. *Zeitschrift des Vereines Deutscher Ingenieure, June 3, 1911.* 5 pp., 1 fig., 2 tables, 5 curves. *bce.*

Tests of a producer gas plant.

KÜPPERS GAS PRODUCER, THE. *The Iron Age, June 22, 1911.* 1½ pp., 3 figs., 1 table. *bc.*

A German producer with revolving grate and revolving shaft.

MOTEUR À GAS. *Revue de Mécanique, May 31, 1911.* 8 pp., 27 figs., 1 table. *B.*

Description and detail drawings of the following types of gasolene motors; details of cylinder—Neustadter, Ehrhardt and Schmer, Knight and Kilbourne motor (1905), Knight motor (1908), Riley motor (1908), White motor (1908), Lanchester motor (1909). Sears motor, Mether and Platt motor, (1908).

OIL ENGINE PRACTICE, DEVELOPMENTS IN. *The Gas Engine, June 1911.* 2½ pp. *adfB.*

Extract of paper read before the Institute of Marine Engineers by Mr. Shacketon.

[1]Opinions expressed are those of the reviewer not of the Society. Articles are classified as *a* comparative; *b* descriptive; *c* experimental; *d* historical; *e* mathematical; *f* practical. A rating is occasionally given by the reviewer, as *A, B, C.* The first installment was given in The Journal for May 1910.

Oil Gas Producer, An. *The Iron Age, July 13, 1911.* 2 pp., 3 figs. *bf.*

Description and details of the International-Amet Gas Power Company's oil gas producer.

Petrol and Oil Tractors at the Norwich (England) Show. *London Engineering, June 30, 1911.* 6 pp., 14 figs. *bf.*

Describes 30-h.p. and 100-h.p. petrol tractor and 90-h.p. oil tractor.

Producers, Gas, W. A. Tookey. *The Gas Engine, June 1911.* 9 pp., 4 figs. *abdfA.*

Extracts of paper before the British Association of Engineers-in-Charge.

Producer Gas, Formation of, J. K. Clement, L. H. Adams and C. N. Haskins. *The Gas Engine, June 1911.* 1½ pp. *bcefB.*

Extract of Bull. No. 7, Bureau of Mines, Essential Factors in the Formation of Producer Gas.

Producer Gas from Crude Oil, F. C. Jones. *The Gas Engine, June 1911.* 1½ pp., 3 tables. *bfC.*

Gives data and description of producer.

Pumping Plant using Producer Gas, A Municipal. *The Gas Engine, June 1911.* 2½ pp. *bfC.*

Extract of report by R. C. Allen, The Equipment of the New Gravel Pond Station, Manchester, Mass., including data.

Schürlochverschlüsse für Gaserzeuger, L. Frick. *Stahl und Eisen, June 15, 1911.* 3 pp., 6 figs. *bf.*

An article on poke-hole closures in gas generators.

Stations Centrales, Conditions Économiques d'Etablissement Petites, A. R. Garnier. *L'Industrie Électrique, May 25, 1911.* 6 pp., 2 figs., 6 tables *abef.*

A continued article on the establishment of small central stations. Includes information data, etc., on motors, gas engines, and fuels.

Verwendung der Gase in Eisenhütten und Kokereien, Neuere Bestrebung in der, Fritz W. Lürmann. *Stahl und Eisen, June 8, 1911.* 9 pp., 15 tables. *bf.*

An article on later efforts toward the use of blast furnace and coke oven gases.

# GENERAL NOTES

## AMERICAN INSTITUTE OF MINING ENGINEERS

The 101st meeting of the American Institute of Mining Engineers will be held in San Francisco, commencing October 10, 1911, in the St. Francis Hotel. Technical sessions will occupy the afternoons of Tuesday, Wednesday morning and afternoon, and Thursday morning, when the party will go by special train to Bakersfield, arriving early Friday morning, for a visit to the various oil fields. On Friday night, the party will proceed by train to the heart of the gold-dredging district, near Folsom, spending the day in visits to the gold dredges and the great rock-crushing plant of the Natomas Consolidated Company. On Saturday afternoon a public reception will be held in the State Capitol, and the party will proceed by train through Napa and Sonoma valleys, arriving at the Bohemian Club amphitheatre on Sunday morning, where a barbecue luncheon will be held, and where the entire day will be spent. On Sunday evening, the party will return to San Francisco.

This meeting will be followed by an excursion to Japan, sailing from San Francisco on October 17, stopping at Honolulu, and reaching Yokohama November 3, in time to see the parade in honor of the Emperor's birthday. The excursion through Japan covers the chief points of historic, scenic and professional interest. The return trip will start from Yokohama, November 21, reaching San Francisco, December 7.

## AMERICAN SOCIETY FOR TESTING MATERIALS

The fourteenth annual convention of the American Society of Testing Materials was held at the Hotel Traymore, Atlantic City, N. J., June 27–July 1, 1911, with an attendance of over 400. Dr. Henry M. Howe delivered the annual address. One of the important features of the meeting was the presentation of reports from various committees, including that of the Committee on Preservation of Coatings, on Standard Tests for Road Materials, Standard Specifications for Steel, etc. Among the papers presented were, Practical Testing of Drying and Semi-Drying Paint Oils, by Henry A. Gardner; Novel Method of Detecting Mineral Oil and Resin Oil in Other Oils, by A. E. Outerbridge, Jr.; Practical Tests of Sand and Gravel Proposed for Use in Concrete, R. S. Greenman; Some Experiments on the Incrustation and Absorption of Concrete, A. O. Anderson; Apparatus for Determining Drop Point and Softening Point of Compounds, H. W. Fisher; Methods for Testing Sewer Pipe and Drain Pipe, A. Marston; Manufacturing of Pure Irons in Open-Hearth Furnaces, A. S. Cushman; Hardness Tests, Bradley Stoughton and J. S. McGregor; The Property of Hardness in Metals and Materials, A. F. Shore; and Behavior of Cast Zinc under Compression, J. C. Trautwine, Jr.

## THE INSTITUTION OF MECHANICAL ENGINEERS

The summer meeting of the Institution of Mechanical Engineers was held in Zürich and Northern Switzerland, commencing on July 24 and closing on the 27th. The program as announced included a number of technical excursions, as well as trips of more general interest, and the following papers to be presented at the technical sessions: Results of Experiments with Francis Turbines and Tangential (Pelton) Turbines, Dr. Franz Prásil; Some New Types of Dynamometers, Dr. Alfred Amsler; Railway Electrification in Switzerland, Emil Huber; Hydraulic Power Works and their Construction, with Special Reference to the Difficulties Encountered and the Methods of Overcoming Them, I. Zodel; Steam Turbines, H. Zoelly; Diesel Oil Engines, Jacob Sulzer; and Rack Locomotives of Switzerland, Mr. Pfander.

## AMERICAN CHEMICAL SOCIETY

Among the papers presented before the division of Industrial Chemists and Chemical Engineers of the American Chemical Society at the annual meeting in Indianapolis, Ind., June 28–July 1, were the following: Losses in the Storage of Coal, H. C. Porter, F. K. Ovitz; Need of a Professional Code of Ethics among Chemists, F. L. Parker, Jr.; Storage Battery Efficiency, J. S. Staudt; A New Modification of Gas Analysis Apparatus, B. G. Klugh; Refractories and Laboratory Appliances Made from Alundum, P. A. Boeck; Determination of Vanadium in Vanadium and Chrome-Vanadium Steels, J. R. Cain; Determination of Dust in Blast Furnace Gas, L. A. Touzalin; The Wood Distillation Industry of the Pacific Northwest, H. K. Benson; Ratfish Oil as a Paint Material, H. K. Benson, W. Eshleman; A Method of Analysis of Lead Ores, J. Waddell; Concentration and Purification of Iron Ore, High in Sulphur by Roasting in a Rotary Kiln.

## INTERNATIONAL ASSOCIATION FOR THE PREVENTION OF SMOKE

At the annual convention of the International Association for the Prevention of Smoke held in Newark, N. J., June 28–30, the following papers were presented: Enforcement of the Smoke Prevention Ordinance in New York City, E. J. Lederle; Smoke Prevention in Large Power Stations, J. T. Whittlesey and H. S. Vasser. R. H. Fernald, Mem. Am. Soc. M. E., gave an illustrated lecture on The Relation of the Gas Producer to the Smoke Problem and R. B. Watrous lectured on Smoke Versus City Beauty. The problem of the Prevention of Smoke on Railways was discussed by C. D. Young, F. T. Howley and J. P. Brown.

## PERSONALS

N. B. Ayers has resigned the position of chief engineer of the Dayton Power & Light Co., Dayton, O., to organize the Ayers Engineering Co., Dayton, O., for handling power plant engineering.

Charles L. Clarke has become associated with the General Electric Co., New York.

Alexander Dow received the honorary degree of Doctor of Engineering from the University of Michigan during the commencement exercises at Ann Arbor, June 29.

H. J. Freyn has become associated with the Allis-Chalmers Co., West Allis, Wis. He was until recently assistant engineer of construction of the Illinois Steel Co., South Chicago, Ill.

Geo. W. Fuller has associated with him as partners Jas. W. Armstrong, Jas. C. Harding and Jas. R. McClintock, all formerly of the staff of Hering & Fuller, New York.

Edwin S. Harrison, formerly sales engineer of the Busch-Sulzer Bros. Diesel Engine Co., St. Louis, Mo., has been appointed resident engineer of the new plant of the Bucyrus-Vulcan Co., Evansville, Ind.

Rudolph Hering and John H. Gregory have formed a partnership as consulting engineers and sanitary experts, with offices in New York.

Fritz A. Lindberg has been made a member of the firm of Brill & Gardner, Chicago, Ill. Mr. Lindberg was formerly associated with the company as assistant engineer.

Tracy Lyon, until recently associated with the Westinghouse Electric & Manufacturing Co., Pittsburg, Pa., as assistant to first vice-president, has become connected with the General Motors Co., Detroit, Mich.

J. E. Powell, chief mechanical and electrical engineer in the office of the supervising architect, Treasury Department, Washington, D. C., has resigned on account of ill health.

E. Burton Smith has been appointed superintendent of the Toledo Lamp Works of the General Electric Co., Toledo, O. He was formerly associated with the Harrison, N. J., branch of this company.

Alan G. Williams has assumed the duties of engine-house foreman of the Vandalia Railroad, Terre Haute, Ind. He was formerly general foreman of the Pennsylvania Railroad shop at Buffalo, N. Y.

# ACCESSIONS TO THE LIBRARY

WITH COMMENTS BY THE LIBRARIAN

This list includes only accessions to the library of this Society. Lists of accessions to the libraries of the A. I. E. E. and A. I. M. E. can be secured on request from Calvin W. Rice, Secretary, Am.Soc.M.E.

ADDRESS OF ALEX. C. HUMPHREYS, DELIVERED AT THE ANNUAL DINNER OF THE ALUMNI OF STEVENS INSTITUTE OF TECHNOLOGY, Feb. 4, 1908. Gift of C. W. Rice.

AMERICAN INSTITUTE OF ARCHITECTS. Annuary, 1910. Gift of the Institute.

AMERICAN RAILWAY ASSOCIATION. Proceedings of session held in New York City, May 17, 1911. Gift of the association.

THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS. The Journal. Vol. 33, Nos. 1–6. *New York, 1911.*

ANALYSIS OF PAINTS AND PAINTING MATERIALS. By H. A. Gardner and J. A. Schaeffer. *New York, McGraw-Hill Book Co., 1911.*

A book for chemists, but one of interest to mechanical engineers, because so little has been published on protective paints. It gives methods for the analysis of dry and mixed paints, paint vehicles and varnishes, and bituminous paints. In an appendix is reprinted the specifications of the Army and Navy Departments. Index.

ARMY LIST AND DIRECTORY. Officers of the Army of the United States, June 20, 1911. *Washington, 1911.* Gift of Superintendent of Documents.

BROADENING THE FIELD OF THE MARINE STEAM TURBINE: THE PROBLEM AND ITS SOLUTION. The Melville and Macalpine Reduction Gear. *Pittsburg, 1909.* Gift of C. W. Rice.

A BUSY WEEK. Andrew Carnegie at Dunfermline, Kirkcaldy, Dumfries, Portmahomack. *Dunfermline, 1899.* Gift of C. W. Rice.

CATSKILL MOUNTAINS WATER WORKS FOR THE EXTENSION OF THE WATER SUPPLY OF NEW YORK CITY, December 1910. *Pittsburgh, 1911.* Gift of Blaw Collapsible Steel Centering Co.

COMBUSTION AND THE COST OF POWER. (Bulletin No. 100, Uehling Instrument Co.). *Passaic.* Gift of Uehling Instrument Co.

COMPARISON OF UNIVERSITY AND INDUSTRIAL METHODS AND DISCIPLINE. By F. W. Taylor. Gift of C. W. Rice.

DELAWARE COLLEGE, NEWARK, DEL. Catalogue, 1911. *Newark, 1911.* Gift of Delaware College.

DUDLEY, CHARLES B., MEMORIAL VOLUME COMMEMORATIVE OF THE LIFE AND LIFE-WORK OF, 1842-1909. *Philadelphia.*

ENTROPY: OR THERMODYNAMICS FROM AN ENGINEER'S STANDPOINT, AND THE REVERSIBILITY OF THERMODYNAMICS. By James Swinburne. *New York, E. P. Dutton Co., 1905.*

General Contract and Specifications for the Purchase of Coal, State of Wisconsin Capitol Power and Heating Plant. By J. C. White. *Madison, 1911.* Gift of the author.

Handbook for Iron Founders. *London.* Gift of Frodair Iron & Steel Co. Ltd.

High Speed Steel. By O. M. Becker. *New York, McGraw-Hill Book Co., 1910.*

Internal Combustion Engines at the Brussels Exposition. By P. R. Allen. Reprinted from Cassier's Magazine, February-March 1911. Gift of author.

Johns Hopkins University. Register 1910-1911. *Baltimore, 1911.* Gift of the University.

Leland Stanford Junior University. Register, 1910-1911. *California, 1911.*

——Department of Medicine. Annual Announcement, 1911-1912. *California, 1911.* Gift of the University.

Louisiana State University. Catalogue, 1911. *Baton Rouge, 1911.* Gift of the University.

Marine Engine Design. By E. M. Bragg. *New York, D. Van Nostrand Co. 1911.*

A reprint of articles first published in International Marine Engineering, developed from several years of experience in teaching the subject to students of the University of Michigan. It is totally free from the descriptive part of the subject, confining itself to the laying out and designing of the engine. In this particular it differs from other works on the subject. No index, but a table of contents.

Metropolitan Water and Sewerage Board. Tenth Annual Report, 1911. *Boston, 1911.* Gift of Metropolitan Water and Sewerage Board.

More Busy Days. Andrew Carnegie at Dingwall, Tain, Kilmarnock, Govan, Waterford, Limerick, Cork, Barrow in 1903. *Philadelphia, 1903.* Gift of C. W. Rice.

Pacific Gas and Electric Company. Properties owned and operated territory served. *California, 1911.* Gift of Pacific Gas and Electric Co.

Pennsylvania State Railroad Commission in the Matter of the Complaints against the Philadelphia Rapid Transit Company. Report. Vols. 1-2, 1911. *New York, 1911.* Gift of Messrs. Ford, Bacon and Davis.

Polytechnic Institute of Brooklyn. Catalogue of the College of Engineering, 1911-1912. *Brooklyn.* Gift of the Institute.

Principles of Industrial Engineering. By C. B. Going. *New York, McGraw-Hill Book Co., 1911.*

This work is based on a series of lectures delivered to the senior students in the department of engineering at Columbia. The study is directed almost wholly to the discovery and definition of ideals and principles, or in some cases of institutions; very little attempt is made at the description of methods and devices. It thus supplements the works of Gantt, Emerson, Taylor and others. An entertaining book even for a layman.

Pumping Machinery. By A. M. Greene. *New York, J. Wiley & Sons, 1911.*

This book is based on a series of lectures given as a required course to the mechanical engineering students of the University of Missouri. The bibliography of thirteen pages is especially valuable, in that it includes references to the original accounts of tests of pumps. Many of these tests are given in the main text. The work seems very comprehensive, both on the theoretical and descriptive side. It is profusely illus'rated, and adequately indexed.

RELATIVE TO THE ELECTRIFICATION OF RAILROADS, STATEMENT OF GEO. F. SWAIN, BEFORE THE METROPOLITAN AFFAIRS AND RAILROAD COMMITTEES OF THE MASSACHUSETTS LEGISLATURE. April 6, 1911. Gift of author.

TEXAS AGRICULTURAL AND MECHANICAL COLLEGE. Thirty-fifth Annual Catalogue, 1910-1911. *Austin, 1911.*

——Announcement of the Third Session of the summer school, 1911. *Austin, 1911.* Gift of the Texas Agricultural and Mechanical College.

THREE BUSY WEEKS. Andrew Carnegie at Perth, Edinburgh, Greenock, Falkirk, Stirling, Hawarden, Liverpool, St. Andrews, Dundee. *Dunfermline, 1902.* Gift of C. W. Rice.

UNIVERSITY OF TORONTO. Calendar, 1911-1912. *Toronto.* Gift of the University.

UNIVERSITY OF UTAH. Catalogue, 1911-1912. *Salt Lake City, 1911.* Gift of the University.

VERZEICHNIS DER DEUTSCHEN PATENTKLASSEN UND IHRE EINTEILUNG IN UNTERKLASSEN UND GRUPPEN. ed. 2. *Berlin, 1910.*

VICTORIAN INSTITUTE OF ENGINEERS. Proceedings, Vol. 11. *Melbourne, 1911.* Gift of the Institute.

WENTWORTH INSTITUTE. Catalogue. 1911-1912. *Boston, 1911.* Gift of the Institute.

WESTINGHOUSE MARINE STEAM TURBINE WITH MELVILLE AND MACALPINE REDUCTION GEAR. Gift of C. W. Rice.

WHITTAKER'S ELECTRICAL ENGINEER'S POCKET BOOK. ed. 3. Edited by Kenelm Edgecumbe. *London, 1911.* Gift of Macmillan Co.

This is the third edition of this well known English pocket book, largely rewritten to bring it up to date. It has an extremely useful index, differing in this particular from many English technical works.

## EXCHANGES

AMERICAN SOCIETY OF CIVIL ENGINEERS. *Transactions.* Vol. 72, 1911. *New York, 1911.*

SMITHSONIAN PHYSICAL TABLES. ed. 5, revised. (Miscellaneous collections, Vol. 58, No. 1.) *Washington, 1910.*

SOCIETY OF AUTOMOBILE ENGINEERS. Handbook (data sheets), 1911. *New York, 1911.*

## TRADE CATALOGUES

AMERICAN SPIRAL PIPE WORKS, *Chicago, Ill.* Spiral riveted pipe, leg welded steel pipe, forged steel pipe flanges, hydraulic and exhaust steam supplies. 20 pp.

J. T. BAKER CHEMICAL CO., *Philippsburg, N. J.* The Chemist-Analyst, No. 2. 24 pp.

THE BRISTOL CO., *Waterbury, Conn.* Bull. No. 131, Recording voltmeter for direct and alternating current, 43 pp.; Bull. No. 117A, Bristol-Durand radii averaging instrument for circular chart records, 7 pp.

Consolidated Expanded Metal Co., *Pittsburg, Pa.* Handbook of design, containing tables, standards and useful information on reinforced concrete. 102 pp.

Green Fuel Economizer Co., *Matteawan, N. Y.* Planing mill exhausters. 20 pp.

Max Henning, *Berlin, Germany.* Addresses of commercial firms. 32 pp.

Hess-Bright Mfg. Co., *Philadelphia, Pa.* Ball bearings in flour and feed mill machinery, 19 pp.; Ball bearings in wood-working machinery, 29 pp

Fred. S. Hinds, *Boston, Mass.* Industrial plants. 76 pp.

A. L. Ide & Sons, *Springfield, Ill.* Bull. 17, Simple side crank "Ideal" engine direct-connected to generator. 10 pp.

Ideal Electric & Mfg. Co., *Mansfield, O.* Reducing expenses and increasing output of textile mills. 7 pp.

H. W. Johns-Manville Co., *Cleveland, O.* J. M. Packing Expert, June 1911. 8 pp. J. M. Roofing Salesman, June 1911. 8 pp.

Link-Belt Co., *Chicago, Ill.* Price list of flint-rim sprocket and traction wheels. 20 pp.

Niles-Bement-Pond Co., *Cleveland, O.* Aurora drills. 32 pp.

Robt. W. Paul, *London, England.* Electrical measuring instruments. 32 pp.

Pulsometer Steam Pump Co., *New York.* The pulsometer. 27 pp.

Rockwell Furnace Co., *New York.* Moyer tramrail in foundry practice. 8 pp.

Russell, Birdsall & Ward, *Port Chester, N. Y.* Bolts and nuts. 160 pp.

Stephens-Adamson Co., *Aurora, Ill.* The Labor Saver, June 1911. 25 pp.

Tate, Jones & Co., *Pittsburg, Pa.* Furnaces for annealing, hardening and tempering. 28 pp.

Vulcan Soot Cleaner Co. of Pittsburg, Pa. *Du Bois, Pa.* Soot cleaners. 32 pp.

Wilson-Maeulen Co., *New York.* Electric pyrometers. 12 pp. Melting points of the elements, 1 p., Conversion table for centigrade to fahrenheit and vice versa, 1 p.

## UNITED ENGINEERING SOCIETY

Davis Handbook of the Porcupine Gold District. By H. P. Davis. *New York, 1911.* Gift of author.

New Method Calculating the Cubic Contents of Excavations and Embankments, by the Aid of Diagrams. ed. 4. By J. C. Trautwine. *Philadelphia, 1871.*

Patente-Jahres, Katalog 22, Jahrgang 1910. *Brugg, 1911.*

# EMPLOYMENT BULLETIN

The Society has always considered it a special obligation and pleasant duty to be the medium of securing better positions for its members. The Secretary gives this his personal attention and is most anxious to receive requests both for positions and for men available. Notices are not repeated except upon special request. Copy for notices in this Bulletin should be received before the 12th of the month. The list of men available is made up of members of the Society and these are on file, with the names of other good men not members of the Society, who are capable of filling responsible positions. Information will be sent upon application.

## POSITIONS AVAILABLE

0109 Engineer of wide experience wishes to become associated with man of means with view to manufacturing on small scale and taking small contracts. Two small articles, one patented, other in course of preparation for patent office.

0110 Instructorship in mechanical engineering at State University of Iowa paying $1400 to person of proper experience and attainment. For particulars address William G. Raymond, Iowa City, Iowa.

0111 Man to assist in the building and development of automatic weighing machines, can machines, etc. Small machine shop employing 15 men at the present time. Requires a man capable of making drawings, following through the pattern and machine shops, and coöperating with the machine shop foreman in executing work. Location Illinois.

## MEN AVAILABLE

250 Superintendent of machine shops, foundries, etc. Extensive experience in the building of heavy engines, air compressors, pumps, conveying and power transmission machinery.

251 Junior member, technical graduate, several years' experience as draftsman, also experience in construction and in office work, power plant and industrial plant installations.

252 Mechanical and electrical engineer, technical graduate, practical shop experience, eight years in general engineering and manufacturing; designing, construction and executive experience; desires position as executive engineer with manufacturing concern or chief engineer with engineering or contracting firm.

253 Graduate mechanical engineer, six years' experience, designing and drafting, but mainly in research and experimental work along lines connected with steam engineering. At present employed, desires change with view to bettering condition. Best of references.

254 Member, technical education, civil and mechanical engineer, desires position by September 1. Last fifteen years chief mechanical engineer in responsible charge. Ability as business builder, designed and built special tools, air compressors, high duty pumping engines, electric cranes, compressed air cranes and other machinery, Corliss, high-speed and automatic engines, experience in selling, familiar with contracts, shop management and economical and systematic design of machines. Excellent references as to character and ability.

255 Technical graduate, four years' experience in all phases of plant engineering, cost reduction, accounting, tool systems, power plant operations construction and maintenance, with extensive study of scientific management and accounting. Thoroughly accustomed to handling men and working on own responsibility. Now employed.

256 Graduate Mass. Institute Technology, age 27, two years' experience in building construction and mechanical equipment, desires connection with architect or contracting engineer where there is opportunity for advancement. Salary expected, $25 a week.

257 Mechanical engineer will undertake development or extension of product of manufacturing company; experienced in engineering and physical research, formerly in charge of design and construction of internal combustion engines, small and large, gas producers, and power stations.

258 Member prepared to go into partnership or associate with manufacturing concern; desires interest in the business instead of salary. Equipped with all-round research and manufacturing experience in electrical and mechanical work.

259 Superintendent desires position in New York or vicinity; age 37; experienced machinist and shop foreman, including tool, die, fig, patternmaking, switchboard apparatus and miscellaneous electrical supplies. Competent to organize and take charge of production department.

260 Teacher of mechanical drawing and machine design, age 33, technical graduate with four years' drafting room and four years' teaching experience, seeks appointment.

261 Mechanical engineer, 12 years' experience; shop, sales and executive. Specialties conveying and elevating machinery, constructive work. Desires position as manager or chief engineer.

# CHANGES IN MEMBERSHIP

## CHANGES IN ADDRESS

ALDRICH, William Sleeper (1892), Life Member; Powell, Wyo.

ALLISON, John Franklin (Junior, 1910), 459 Martin St., Roxborough, Philadelphia, Pa.

AYERS, Norwood B. (1908), The Ayers Engrg. Co., Conover Bldg., and 422 Summers St., Dayton, O.

BIBBINS, James Rowland (1904;1909), Engr. with Bion J. Arnold, Rm. 1000, 105 S. La Salle St., Chicago, Ill.

BAILEY, Hazil Harding (Junior, 1910), Packard Motor Car Co., and *for mail*, 1453 Grand Blvd., E., Detroit, Mich.

BAUER, Chas. L. (1900;1901) Pres., The Bauer Bros. Co., and 1215 E. High St., Springfield, O.

BAYLIS, Arthur Raymond (1905;1906), N. E. Engrg. Co., 50 Church St., New York, and *for mail*, 1815 Ave. K, Flatbush, Brooklyn, N. Y.

CHAMBERS, Norman C. (Junior, 1905), Export Dept., Niles-Bement-Pond Co., 111 Broadway, New York, N. Y., and *for mail*, care of A. Cazzani, Boite Postale, 802, Rio de Janeiro, Brazil, S. A.

CHAPMAN, Frank T. (1909), Rep., Vento Dept., Am. Radiator Co., Rm. 501, 104 W. 42d St., New York, N. Y., and Montclair, N. J.

CHESTER, C. P. (Associate, 1908), Stone and Webster Engrg. Corp., Burleson, Tex.

CLARKE, Charles L. (1882), Genl. Elec. Co., Rm. 1923, 30 Church St., New York, N. Y.

CUMMINGS, Wm. Warren (1905), Cons. and Contr. Engr., Hanover, N. H.

CUNNINGHAM, Geo. H. (Junior, 1911), Consolidation Coal Co., Jenkins, Ky.

DANFORTH, Albert W. (1882), 881 Bridge St., Lowell, Mass.

DARRIN, David H. (1892;1900), Cons. Engr., 131 Liberty St., and Engrs. Club, 32 W. 40th St., New York, N. Y.

DIETZ, Carl F. (1903;1910), Cons. Engr., Dietz & Keedy, 6 Beacon St., Boston, and *for mail*, 214 Lynn Fells Parkway, Melrose, Mass.

DOUD, Arthur T. (Junior, 1907), Genl. Supt., Speakman Supply & Pipe Co., and 1320 Clayton St., Wilmington, Del.

EDWARDS, William J. (1910), V. P. and Treas., Binghamton Clothing Co., and *for mail*, 31 Stuyvesant St., Binghamton, N. Y.

FREYN, Heinrich Josef Karl (1906), Allis-Chalmers Co., West Allis, and 254 Mason St., Milwaukee, Wis.

FULLER, George W. (1910), Cons. Engr., 170 Broadway, New York, N. Y.

GOENTNER, William B. (Junior, 1905), Asst. Engr., Dept. of Water Supply, Gas and Elec., 13-21 Park Row, and *for mail*, 2020 Park Row Bldg., New York, N. Y.

JACKSON, Dugald C. (1890), Mass. Inst. of Tech., Boston, Mass., and D. C. & Wm. B. Jackson, 111 W. Monroe St., Chicago, Ill.

JACKSON, Wm. B. (1901), Life Member; D. C. & Wm. B. Jackson, Harris Trust Bldg., 111 Monroe St., and 5526 Everett Ave., Chicago, Ill.

LEWIS, Joseph E. (Junior, 1899), Treas., Bush Mfg. Co., Hartford, Conn., and *for mail*, Centerville, Cape Cod, Mass.

LINCH, Edward P. (1902), P.O. Box 612, Waterbury, Conn.

LINDBERG, Fritz A. (1908; 1911), Member of Firm, Brill & Gardner, 1135 Marquette Bldg., and *for mail*, 514 E. 62d St., Chicago, Ill.

LOWE, Henry Leland (Junior, 1903), 280 Downey Ave., Indianapolis, Ind.

LYON, Tracy (1893), Genl. Motors Co., Detroit, Mich.

HAMILTON, Chester B., Jr., (Junior, 1909), Mgr., The Hamilton Gear and Machine Co., and *for mail*, 43 Madison Ave., Toronto, Canada.

HARRISON, Edwin S. (Junior, 1905), Res. Engr., Bucyrus-Vulcan Co., and *for mail*, P. O. Box 201, Evansville, Ind.

HAYES, Frank H. (1906), N. E. Mgr., Platt Iron Wks. Co., 101 High St., Boston, and *for mail*, 13 Willow Ave., West Somerville, Mass.

HERING, Rudolph (1906), Life Member; Cons. Engr., Hering & Gregory, 170 Broadway, New York, N. Y., and 40 Lloyd Rd., Montclair, N. J.

HUTCHINSON, Charles Tripler (1910), Mgr., Min. Mchy. Dept., Joshua Hendy Iron Wks., 75 Fremont St., San Francisco, Cal.

McCLINTOCK, Edward H. (1901; 1905), Constr. Engr. and Mill Arch., 33 Lyman St., Springfield, and 71 Pearson Ave., West Somerville, Mass.

McDEWELL, Horatio S. (Junior, 1908), 94 Addington Rd., Brookline, Mass.

MacGREGOR, Walter (1906), 3118 W. 19th St., Chicago, Ill.

MARKS, Harry J. (1907), Mech. Engr., 90 West St., New York, and *for mail*, 86 Palmer Ave., Mamaroneck, N. Y.

MAROT, Edward H. (Junior, 1903), 38 Pastorius St., Germantown, Philadelphia, Pa.

NEWTON, Lewis W. (1903), Engr., 412 Main St., Amesbury, Mass.

NILES, Francis H. (Associate, 1907), Dongannas Farms, Rock Castle P. O., Va.

ORCUTT, Guy H. (Junior, 1909), Testing Engr., Allis-Chalmers Co., and *for mail*, 910 E. 62d St., Chicago, Ill.

PEARSON, Walter Ambrose (1907), Asst. Genl. Mgr., Rio de Janeiro Tramway, Light & Power Co., Ltd., Caixa 571, Rio de Janeiro, Brazil, S. A., and *for mail*, 25 Broad St., New York, N. Y.

PINGER, George C. (Junior, 1907), Beaver, Pa.

RAPLEY, Frederick Harvey (1905), M. Clark & Co., 1 Victoria St., Westminster, S. W., London, England.

RICHARDSON, Levi S. (1909), Ch. Draftsman, Lehner Engrg. Co., 149 Broadway, New York, and *for mail*, 134 Pelton Ave., West New Brighton, S. I., N. Y.

RICKETTS, Edwin Burnley (Junior, 1908), U. S. Glass Co., Glassport, Pa.

ROGERS, Robert W. (Junior, 1908), 5 Dey St., New York, N. Y.

SANGUINETTI, Philip C. (Associate, 1909), Production Engrg. Dept., Marwick, Mitchell & Co., 79 Wall St., New York, and 265 S. 1st Ave., Mt. Vernon, N. Y.

SCHAEFFLER, Joseph C. (1900; 1904; 1907), Mech. and Civ. Engr., Joseph C. Schaeffler & Co., Archs. and Engrs., 38-40 W. 32d St., New York, N. Y.
SCOTT, Arthur Curtis (1908), Pres., The Scott Engrg. Co., 632 Wilson Bldg., Dallas, Tex.
SMITH, Ellis Burton (Junior, 1905), Supt. Toledo Lamp Wks., Genl. Elec. Co., Toledo, O.
SMITH, W. W. (1909), Mech. Engr., 460 E. Adams St., Los Angeles, Cal.
SPENCER, William J. (Junior, 1906), 5116 N. 11th St., Philadelphia, Pa.
STOCKWELL, Rupert Kennedy (Junior, 1910), Mech. Engr., The Tenn. Copper Co., Copperhill, Tenn.
TAYLOR, Wyatt W. (Associate, 1908), Cons. Engr., 2 Rector St., New York, and *for mail*, Spuyten Duyvil, N. Y.
TORRANCE, Henry, Jr. (1897; 1902), V. P. and Treas., Carbondale Mch. Co., 50 Church St., New York, N. Y., and Tenafly, N. J.
WENTWORTH, Reginald Andrew (Junior, 1911), Engineer with H. L. Gantt, and *for mail*, 2045 N. 63d St., Philadelphia, Pa.
WERST, Charles Wm. (1909), Supt., Lima Loco. & Mch. Co., and *for mail*, 1534 Lakewood Ave., Lima, O.
WHITESIDE, Walter Hunter (1910), Stevens-Duryea Co., Chicopee Falls, Mass.
WILEY, James M. (Junior, 1909), Swink, Colo.
WILLIAMS, Alan Gillespie (Junior, 1909), Eng. House Foreman, Vandalia R. R., and *for mail*, 672 Eagle St., Terre Haute, Ind.

## NEW MEMBERS

ALBERT, Calvin D. (1911), Asst. Prof. Mch. Design, Sibley College, Cornell Univ., and 319 Eddy St., Ithaca, N. Y.
ANDREI, Camillo (Junior, 1911), Società Nazionale dei Radiatori, Borgo S. Giovanni, Brescia, Italy.
BRIGGS, Leroy Edmund (Junior, 1911), 235 Vine St., Bridgeport, Conn.
CLAYTON, J. Paul (Junior, 1911), 2149 Sinton Ave., Walnut Hills, Cincinnati, O.
CROSS, Charles N. (1911), Instr., Mech. Engrg., Leland Stanford Jr. Univ., and 340 Embarcadero Rd., Palo Alto, Cal.
DALLAS, Park Andrew (1911), Mill Arch. and Engr., 1023 Candler Bldg., Atlanta, Ga.
DENNIS, Basil Wrenn (Junior, 1911), Asst. Ch. Engr., Muskogee Gas & Elec. Co., Muskogee, Okla., and *for mail*, 1165 E. Long St., Columbus, O.
DONNELLY, James A. (1911), Pres. and Genl. Mgr., Positive Differential System, and 132 Nassau St., New York, N. Y.
DOUGLAS, Walter Cooley (Junior, 1911), Asst. Engr. Mechanigraph Dept., Topping Bros., 122 Chambers St., New York, N. Y.
FLICKINGER, Harrison William (Junior, 1911), Thompson-Starrett Co., Second Natl. Bank Bldg., Pittsburg, Pa.
FORSBURG, Henry A. (1911), Genl. Supt. Trunk Lines, Stand. Oil Co. of Cal., and *for mail*, 1616 Josephine St., Berkeley, Cal.
HAWTHORNE, Primm R. (1911), Supt. of Design, Nichols & Shepard Co., Battle Creek, Mich.

HALL, Walter Atwood (1911), Asst. Mgr., Lynn Wks., Genl. Elec. Co., West Lynn, and *for mail*, 15 Hardy Rd., Swampscott, Mass.

HATMAN, Julius G. (Junior, 1911), Asst. Supt., The Wyandotte County Gas Co., and *for mail*, 746 Ann Ave., Kansas City, Kan.

HOWARD, Henry Sherwin (Junior, 1911), Cons. Engr., West. Fuel Co., and allied Cos., and *for mail*, 430 California St., San Francisco, Cal.

HUMPHREY, Charles Scranton (Junior, 1911), Asst. Electrician, C. W. Hunt Co., and *for mail*, 320 Bement Ave., West New Brighton, S. I., N. Y.

JAMIESON, Charles Clark (1911), Genl. Supt., Walter A. Wood Mowing & Reaping Mch. Co., Hoosick Falls, N. Y.

KLOCKARS, Charles Oscar (Associate, 1911), Factory Supt., Essex Fdy., and *for mail*, 51 Parkhurst St., Newark, N. J.

LAW, Frank E. (1911), V. P., The Fidelity & Casualty Co., New York, N. Y., and *for mail*, 322 Claremont Ave., Montclair, N. J.

LONGACRE, Fredk. v. D. (1911), Ingersoll-Rand Co., 11 Broadway, New York, N. Y.

MUNSON, Stanley (Junior, 1911), M.M., Oliver Chilled Plow Wks., and *for mail*, 1119 Michigan Ave., South Bend, Ind.

RENTSCHLER, Gordon Sohn (Junior, 1911), V. P. and Fdy. Mgr., The Hamilton Fdy. & Mch. Co., Hamilton, O.

RIEGE, Rudolph (1911), 58 Washington Ave., Stamford, Conn., and *for mail*, care of Henry Wilcox & Son, 828 Equitable Bldg., Denver, Colo.

SCHIEFER, Fred William (Junior, 1911), Mech. Engr., Lackawanna Bridge Co., and *for mail*, 60 W. Parade Ave., Buffalo, N. Y.

STANLEY, Frank A. (1911), West. Editor, American Machinist, and *for mail*, 3556 Monteith Ave., Hyde Park, Cincinnati, O.

VENESS, Alfred E. (1911), Factory Supt., Union Typewriter Co. Bridgeport, Conn.

WATTLES, Joseph Warren, 3d (Junior, 1910), Commer. Engr. Sales Dept., Edison Elec. Ill. Co., 39 Boylston St., Boston, Mass.

WHITNEY, William S. (1911), Supervising Engr., Am. Woolen Co., Boston, and 177 E. Haverhill St., Lawrence, Mass.

## PROMOTION

de CAZENOVE, Louis A., Jr. (1905; 1911), Mech. Engr. and Asst. to Asst. Ch. Engr., Black Powder Dept., E. I. du Pont de Nemours Powder Co., and *for mail*, The Wilmington, Delaware Ave., Wilmington, Del.

## DEATHS

HAGUE, Charles A., June 27, 1911.
HAYWOOD, D. Howard, July 5, 1911.
HUMPHREY, Charles S., June 29, 1911.
SCHUMANN, Francis, June 29, 1911.

# COMING MEETINGS

### August–September

**Advance notices of annual and semi-annual meetings of engineering societies are regularly published under this heading and secretaries or members of societies whose meetings are of interest to engineers are invited to send such notices for publication. They should be in the editor's hands by the 15th of the month preceding the meeting. When the titles of papers read at monthly meetings are furnished they will also be published.**

AMERICAN ASSOCIATION OF GENERAL PASSENGER AND TICKET AGENTS
September 19, annual meeting, St. Paul, Minn. Secy., C. M. Burt, Boston, Mass.

COLORADO ELECTRIC LIGHT, POWER AND RAILWAY ASSOCIATION
September 13–15, annual convention, Glenwood Springs, Colo. Secy., F. D. Morris, 323 Hagerman Bldg., Colorado Springs.

INTERNATIONAL ASSOCIATION ON MUNICIPAL ELECTRICIANS
September 12–15, annual meeting, St. Paul, Minn. Secy., C. R. George, Houston, Tex.

INTERNATIONAL CONGRESS OF THE APPLICATIONS OF ELECTRICITY
September 9–20, Turin, Italy. President of the Organizing Committee, L. Lombardi, 10, Via San Paolo, Milan.

INTERNATIONAL RAILROAD MASTER BLACKSMITHS' ASSOCIATION
August 15, annual meeting, Toledo, O. Secy., A. L. Woodworth, Lima.

NATIONAL ASSOCIATION OF COTTON MANUFACTURERS
September 27–30, semi-annual meeting, Hotel Equinox, Manchester, Vt. Secy., C. J. H. Woodbury, Box 3672, Boston, Mass.

NATIONAL BUILDING MATERIAL EXHIBITION
September 9–16, Trade Show, Madison Square Garden, New York. Mgr., P. J. Powers, 508 Flatiron Bldg.

ROADMASTERS AND MAINTENANCE OF WAY ASSOCIATION
September 12–15, annual meeting, St. Louis, Mo. Secy., W. E. Emery, P. & P. U. Ry., Peoria, Ill.

TRAVELING ENGINEERS' ASSOCIATION
August 29–September 2, annual convention, Hotel Sherman, Chicago, Ill. Secy., W. O. Thompson, care of N. Y. C. Car Shops, East Buffalo, N. Y.

VERMONT ELECTRICAL ASSOCIATION
September 13–14, annual meeting, Lake Dunmore, Vt. Secy., A. B. Marsden, Manchester.

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NOTE—Numbers in parentheses indicate number of years the member has yet to serve.

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E. G. SPILSBURY
New York
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San Francisco, Cal.
C. J. H. WOODBURY
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*Engineering Standards*

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H. W. SPANGLER
CHAS. DAY
J. H. BARR

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NOTE—Numbers in parentheses indicate number of years the member has yet to serve.

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R. H. FERNALD

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G. I. ROCKWOOD (1)
C. J. DAVIDSON (1)
E. D. DREYFUS (1)
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| INSTITUTION | DATE AUTHORIZED BY COUNCIL | HONORARY CHAIRMAN | PRESIDENT | CORRESPONDING SECRETARY |
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| Stevens Inst. of Tech. | Dec. 4, 1908 | Alex. C. Humphreys | A. E. Bauhan | A. D. Karr |
| Cornell University | Dec. 4, 1908 | R. C. Carpenter | F. E. Yoakem | D. S. Wegg, Jr. |
| Armour Inst. of Tech. | Mar. 9, 1909 | G. F. Gebhardt | C. E. Beck | F. H. Griffiths |
| Leland StanfordJr.Univ. | Mar. 9, 1909 | C. H. Shattuck | H. H. Blee | C. W. Scholefield |
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| University of Kansas | Mar. 9, 1909 | P. F. Walker | W. H. Judy | M. C. Conley |
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| Univ. of Illinois | Nov. 9, 1909 | W. F. M. Goss | F. J. Schlink | E. J. Hasselquist |
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| Univ. of Missouri | Dec. 7, 1909 | H. Wade Hibbard | F. T. Kennedy | Osmer N. Edgar |
| Univ. of Nebraska | Dec. 7, 1909 | C. R. Richards | W. O. Forman | C. A. Bennett |
| Univ. of Maine | Feb. 8, 1910 | Arthur C. Jewett | A. H. Blaisdell | W. B. Emerson |
| Univ. of Arkansas | Apr. 12, 1910 | B. N. Wilson | W. Q. Williams | H. W. Barton |
| Yale University | Oct. 11, 1910 | L. P. Breckenridge | F. M. Jones | W. St. C. Childs |
| Rensselaer Poly. Inst. | Dec. 9, 1910 | A. M. Greene, Jr. | G. K. Palsgrove | H. J. Parthesius |
| State Univ. of Ky. | Jan. 10, 1911 | F. P. Anderson | G. C. Mills | H. L. Moore |
| Ohio State University | Jan. 10, 1911 | W. T. Magruder | H. A. Shuler | H. M. Bone |
| Washington University | Mar. 10, 1911 | | | F. E. Glasgow |
| Lehigh University | June 2, 1911 | | | |

# MEETINGS OF THE SOCIETY

*The Committee on Meetings*

L. R. POMEROY (1), *Chmn.*
C. E LUCKE (2)
C. J. H. WOODBURY (5)
H. DE B. PARSONS (3)
W. E. HALL (4)

*Meetings of the Society in Boston*

I. N. HOLLIS, *Chmn.*
I. E. MOULTROP, *Secy.*
R. H. RICE
E. F. MILLER
R. E. CURTIS

*Meetings of the Society in New York*

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R. V. WRIGHT
F. H. COLVIN
E. VAN WINKLE

*Meetings of the Society in St. Louis*

E. L. OHLE, *Chmn.*
F. E. BAUSCH, *Secy*
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*Meetings of the Society in San Francisco*

A. M. HUNT, *Chmn.*
T. W. RANSOM, *Secy.*
E. C. JONES
T. MORRIN
W. F. DURAND

*Meetings of the Society in Philadelphia*

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D. R. YARNALL, *Secy.*
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JAMES CHRISTIE
A. C. JACKSON
J. E. GIBSON
J. C. PARKER

*Meetings of the Society in New Haven*

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E. H. LOCKWOOD, *Secy.*
H. B. SARGENT
L. P. BRECKENRIDGE
F. L. BIGELOW

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*Administration of Industrial Establishments*

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STEVENSON TAYLOR
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NOTE—Numbers in parentheses indicate the number of years the member has yet to serve.

# THE JOURNAL

OF

# THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS

VOL. 33 SEPTEMBER 1911 NUMBER 9


## OCTOBER MEETING IN NEW YORK

The New York meeting of the Society to be held in October will have the following general program, subject to minor modifications. A paper will be presented by L. P. Alford, Engineering Editor of the American Machinist, and H. C. Farrell, Mechanical Engineer of the United Shoe Machinery Company, on Factory Construction and Arrangement with special reference to the construction, development and arrangement of the United Shoe Machinery Company's plant at Beverly, Mass.

Owing to the limited time, it has been decided to confine the discussion to three subjects, as follows:

*a* Machinery Arrangement, covering the different methods of arranging machinery for manufacturing.

*b* Artificial Shop Lighting, dealing with the advantages and disadvantages of diffused illumination, and the best type of lamps versus the advantage of individual lights at each machine.

*c* Factory Floors, giving the relative advantages and disadvantages of concrete floors, composition floors and wood floors.

It is expected to limit the various discussions to ten minutes, making them brief and to the point, and so far as possible illustrating them with lantern slides. These are all live subjects and the Committee on Meetings of the Society in New York hopes to have a large attendance and a lively discussion.

## REPORT OF THE NOMINATING COMMITTEE

The Secretary, according to B 29 of the Constitution and By-Laws, announces the receipt of the following report from the Nominating Committee, consisting of R. C. Carpenter, Chairman, R. H. Fernald, A. M. Hunt, E. G. Spilsbury, C. J. H. Woodbury:

The Committee appointed for the nomination of officers of the Society met on May 31, 1911, at the Hotel Schenley, Pittsburgh, Pa., and nominated by unanimous action the following officers: President, Alexander C. Humphreys, Hoboken, N. J.; Vice-Presidents (for two years), Wm. F. Durand, Stanford, Cal., Ira N. Hollis, Cambridge, Mass., Thos. B. Stearns, Denver, Col.; Managers (for three years), Chas. J. Davidson, Milwaukee, Wis., Henry Hess, Philadelphia, Pa., George A. Orrok, New York; Treasurer, Wm. H. Wiley, New York. All of the nominees have been notified and have accepted.

## MEETING OF THE A. I. M. E. ON PACIFIC COAST AND IN JAPAN

A cordial invitation is extended by the American Institute of Mining Engineers to all accredited members of The American Society of Mechanical Engineers, to participate in their 101st meeting, to be held this year in San Francisco, commencing October 10, 1911, in the St. Francis Hotel, to be followed by a trip to Japan. The special train secured for the party will leave Chicago, Saturday, September 30, at 8 p.m., stopping en route at the Grand Canyon, Los Angeles, Santa Barbara and Del Monte, and arriving in San Francisco on the morning of October 10. In addition to the usual sessions for the reading and discussion of professional and technical papers, the Local Committee in San Francisco has in contemplation a number of excursions in and about the city, including the oil fields, gold dredges, Mt. Tamalpais, Lick Observatory, Mt. Hamilton, University of California and Stanford University, and possibly longer trips to Grass Valley, Nevada City, and the Mother Lode district.

After the week spent in San Francisco, those who plan to go on to Japan will sail on October 17, stopping at Honolulu, and reaching Yokohama November 3, in time to see the parade in honor of the Emperor's birthday. The excursion through Japan covers the chief points of historic, scenic and professional interest. The return trip will start from Yokohama, November 21, reaching San Francisco, December 7.

Further details may be secured on application to Dr. Joseph Struthers, Secretary of the American Institute of Mining Engineers.

## COMMITTEE ON STANDARD RULES FOR CARE AND CONSTRUCTION OF BOILERS

At a meeting of the Executive Committee, held July 27, the following committee on Standard Rules for Care and Construction of Boilers, was appointed, subject to the approval of the Council: John A. Stevens, Lowell, Mass., Chairman; Edward F. Miller, Boston, Mass.; Chas. L. Huston, Coatesville, Pa.,; Herman C. Meinholtz, St. Louis, Mo.; R. C. Carpenter, Ithaca, N. Y.; Wm. H. Boehm, New York; and Richard Hammond, Buffalo, N. Y. From the experience of the Society in regard to its codes for testing boilers, engines, etc., there is reason to believe that a set of carefully prepared specifications, formulated and recommended by such a committee, will be recognized as a standard by legislatures and officials, and that uniformity in legal provisions will thus be obtained.

## NECROLOGY

### CHARLES SCRANTON HUMPHREY

Charles Scranton Humphrey, who died in an automobile accident on June 29, 1911, was born at Kokomo, Ind., September 2, 1888. Two years later he moved with his parents to West New Brighton, N. Y. He received his preparatory education at the Westerleigh Collegiate Institute and entered Cornell University in 1904, receiving the degrees of B.A. in 1908 and of M.E. in 1910. He was interested in automobile construction and also spent several months in the gas engine department of the Bethlehem Steel Company, South Bethlehem, Pa., and later in the shops of the C. W. Hunt Company, West New Brighton, assisting in the design and construction of a combination fuel oil electric locomotive for use on the west coast of South America. He wrote a number of papers on automobile design and construction and had for some time been a regular contributor to one of the leading journals devoted to the motor industry.

# THE PURCHASE OF COAL

BY DWIGHT T. RANDALL, PUBLISHED IN THE JOURNAL FOR MARCH

## ABSTRACT OF PAPER

Most boiler rooms are now conducted in a manner which permits of considerable saving along two lines: (*a*) the selection of a coal which is suited to the plant and at the same time is capable of delivering the greatest amount of heat to the boiler for a unit of cost; (*b*) burning the coal by approved methods to obtain the highest practical efficiency.

The coals which are offered in almost any market vary in price and in quality to an extent which justifies a careful study of their character and heating value in order to determine which coal will prove most economical when the equipment, the load conditions and the price are considered. A coal which is entirely satisfactory in one plant may be unsuited to another.

It is possible to burn almost any fuel with reasonably good efficiency provided the furnace is properly designed for the particular fuel to be burned.

Coals which are suitable for any given equipment depend for their value principally upon the B.t.u. and the size of the coal. A thorough study of coals and the variations in their quality has naturally led to the purchase of coal under specifications with a guaranteed analysis, which provide for a definite procedure in case of a variation in the quality of coal delivered.

## DISCUSSION

C. W. RICE, speaking as a member of the Committee of the Society on the Conservation of Natural Resources, said he desired to emphasize, without in any way conflicting with the idea of this paper, the importance of designing plants to use low-grade fuels. The tendency of the paper is to direct purchasers to be particular with the coal dealer, with the result that in the effort to meet specifications only 14,500 B.t.u. coal is furnished, and there is no market for the low-grade material. Hand in hand with the idea of purchasing coal on the heat unit basis should go the designing of the plants to fit market conditions, taking advantage of the fact that the coals of slightly less B.t.u. than the best are materially less expensive. Engineers dealing with the forces of nature have a duty to direct their

Presented at the Spring Meeting, Pittsburgh, 1911, of THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS.

work along the lines of conservation, an idea inclusive of the efficiency of those forces.

Charles Whiting Baker emphasized the points brought out by Mr. Rice and called attention to the fact that in the East a number of plants are successfully burning a very low grade of fuel, which it would be impossible to burn by ordinary methods, through the use of the steam jet blower. While the use of the steam jet may be criticised from a thermodynamic point of view, its advantage lies in the fact that it keeps the fuel bed cool enough to prevent trouble with clinkering.

R. C. Carpenter held that the ideas just expressed did not constitute an argument against the necessity for testing coal or for purchasing coal by analysis. He had lived for a number of years in the district bordering the anthracite coal region, where it was necessary to burn the small grades of anthracite that were in little demand for general purposes, and he was very familiar with the methods employed in burning this low-grade fuel. The material contains large quantities of slate for which thousands of dollars are spent annually, and the loss in this respect can be stopped only by the purchase of coal on analysis. He believed the paper to be just as valuable from the standpoint of the utilization of poor fuel as from that of the purchase of the more valuable kinds.

W. F. M. Goss agreed with this point of view, and believed that the coal producer must take more responsibility for the suitable preparation of his coal before delivering it to the consumer. The poor coal should, of course, be mined and used, thereby carrying out the policy of conservation, but before the delivery of this material, the operator should be encouraged by the development of markets which will take a superior fuel, to improve its quality by washing, sorting, and even by briquetting.

E. D. Meier stated that he was a firm believer in the analysis of coal, and the practice of basing the purchase price on the analysis, provided, however, that this policy be applied only to a particular district. Analyses cannot justly be applied to comparison of coals from different districts because other things besides the chemical composition of the coal must be considered. For instance, a certain coal in Illinois contained as an impurity a bituminous shale which carried 75 per cent ash, and although this coal may have compared favorably with other coals on a B.t.u. basis, this was not a true comparison, because the shale fused and choked the fire, making it necessary to clean the grates very frequently. Again coal from a certain Indiana mine high in B.t.u. gave poorer results in boiler furnaces than coal from other districts lower in B.t.u. because it was extremely friable, causing much loss by dropping through the grates.

E. W. Rutherford wrote that in Par. 6 and Par. 49 the author calls attention to the fact that considerable variation exists in the quality of coals sold under the same general trade name, but does not tell us how much difference may exist. Two contracts for coal purchased on specifications had recently come to his attention which he thought might be of interest in this connection. Two different dealers guaranteed the same B.t.u. and furnished coal of the same trade name. While these contracts have not terminated, practically all of the coal due has been delivered. The analyses show that one dealer will receive a bonus of from $0.01 to $0.02 per ton and that the other dealer will be penalized about $0.10 per ton, the two contracts showing a difference in value of $0.11 or $0.12 per ton, or about 3 per cent. Since approximately 20 samples were taken in each case by experienced men, there should be no appreciable difference due to sampling.

Undoubtedly, in some cases more than 3 per cent difference exists in the full value of coals sold under the same trade name when purchased on the heat unit basis. This leads to the question how much more, if any, it is necessary to pay for coal purchased on the heat unit basis than for coal purchased in the ordinary way. If the plant is favorably located the cost per ton should not be increased, because the specifications should protect the dealer as well as the purchaser, as pointed out by Mr. Randall in Par. 41. The "as received" basis is occasionally objected to by the dealer and does not seem fair in all cases, as, for example, in all-rail shipments, but is undoubtedly preferable to the dry basis when the coal can readily be sampled at the loading and weighing point.

If the author can give us any further information on these points, it will be appreciated.

Perry Barker, representing Mr. Randall, said in reply to Mr. Rice's criticism of the paper, that its opening paragraphs drew attention to the necessity for choosing the character of the fuel desired. If the plant can be so designed and the fuel is so available that a low grade can be used, it will be profitable to change the equipment to suit those low-grade fuels. However, the variation in this coal is such that it is not profitable for the average plant to attempt to burn it without special attention. He cited as an example the small size of anthracite which comes to the New England market, ranging all the way from 14 to 24 per cent of ash. It would be conserving some of our natural resources if that 24 per cent of ash could be burned at all efficiently. If the ash be kept down to 18 per cent, probably the coal is a good proposition in a plant, either burned alone or mixed with a certain portion of good grade of bituminous coal, but if it comes to the market with from 14 to 25 per cent of ash there should surely be some correction for this variation in quality.

In reply to Mr. Baker's suggestion that the steam jet be used in burning low-grade fuel, Mr. Barker said that if it is in the hands of an experienced operator, it is a very efficient piece of apparatus, by the use of which a small size of anthracite may be burned. He had found a number of cases where the steam jet was a very dangerous thing in a power plant on account of the improper regulation.

Professor Carpenter had touched on the question of the variation of ash in small sizes of hard coal which are marketed. It is reasonable to suppose that some penalty should be inflicted if a large percentage of ash is going to be delivered in coal.

Professor Goss had spoken in regard to the improvement of the product along the lines of preparation. The seller who will take care to pick or wash his coal properly will receive compensation accordingly. A mine in Pennsylvania ran about 1½ to 2½ per cent higher in ash than an adjacent mine, due to a change in the nature of the seam. The quality of the miners' work compared favorably with their neighbors', and in order to reduce their ash, a picking table was put in and improved methods of mining were introduced, so that they reduced their ash 2 to 3 per cent, which put them on the same basis as their neighbors and on whatever coal they were selling on specifications they were obtaining compensation accordingly.

President Meier's remarks in regard to the analyses of fuels are along the line of notations in the paper in regard to the character of the coal, which may show the same heat value and the same percentage of ash and of volatile matter, but the nature of this last should be considered as well as the amount. The same ash is distributed in the relative proportions of bases and acids contained in that ash, which will tend to produce fusion or clinker.

# PRESSURE-RECORDING INDICATOR FOR PUNCHING MACHINERY

By Gardner C. Anthony, Published in The Journal for January

## ABSTRACT OF PAPER

The use of an indicator for the direct recording of stresses due to punching boiler plates, under the working conditions of a boiler shop punch, is believed to be new. This paper is largely descriptive of a device for obtaining cards from an ordinary indicator applied to a pressure cylinder, which enables the operator to obtain results as easily and rapidly as is done in indicating an engine. The cards illustrated were taken under the above conditions and also with the apparatus applied to an Olsen testing machine. The latter was for the purpose of checking certain results and introducing a variety of conditions which it is proposed to investigate.

Although the number of tests so far made is insufficient for conclusive evidence, a demonstration has been made of the efficiency of the device as a piece of laboratory apparatus which will serve admirably for determining data relating to the following: the maximum pressures for which punching machines should be designed, the point of maximum stress in the punching of plates and other material, the effect on the maximum stress of the increase of clearance between punch and die, the advantages to be derived from the use of shearing punches, and finally, the effect of time on the flow of metal in punctured.

## ADDITION TO PAPER

15 Since the publication of this paper, the pressure-recording device has been quite thoroughly tested by Messrs. G. E. Couillard and W. M. Edmonstone, students of Tufts College, for determining the maximum stresses produced in steel plate, its shearing value, the effect on this value by increasing the clearance between punch and die, and the relative efficiency of various types of punches.

16 At first there arose the question of the error due to the irregularity in the pressure line caused by the viscosity of the oil, and a series of calibrations were made to correct the errors in previous experiments with this apparatus. This use of an indicator has not been

Presented at the Spring Meeting Pittsburgh 1911, of The American Society of Mechanical Engineers.

an approved one, and our experiments showed too great an irregularity in the pencil movement because of the slow motion of the punch in the testing machine. It was then discovered that a continued tapping of the indicator cylinder during the process of punching eliminated this error most completely, leaving us a constant for the variation in the spring during the upward movement and another constant for the downward movement. As these calibrations were made several times during the punching tests, any slight variation due to the differences between old and new oil was noted. There were such differences, although but slight. With reasonable care in calibration, which in a series of tests is very quickly made, I believe that the error due to the indicator should not be greater than 2 per cent, and this is less than the observed reading on the beam of the testing machine.

17 Another check was applied by connecting a 2000-lb. gage with the oil space. This served for calibration as well as for the reading of maximum pressures.

18 A 600-lb. spring was used for all tests, having a maximum pressure of 1220 lb. to the square inch and equivalent to a pressure of 61,000 lb. on the punch.

19 The series of tests alluded to were made on mild steel plate of 60,000 lb. tensile strength, having an elastic limit of about 37,000 lb. Plates of $\frac{1}{4}$, $\frac{5}{16}$, $\frac{3}{8}$, $\frac{7}{16}$, $\frac{1}{2}$, and $\frac{5}{8}$ in. were used and punches of $\frac{1}{2}$, $\frac{5}{8}$, and $\frac{3}{4}$ in. nominal diameter, variations in these sizes being made to obtain clearances between punch and die diameter of 0.015, 0.030, 0.060.

20 Observations on the shearing stress per square inch, using the minimum clearance between die and punch, and figuring the shearing area as the circumference of the die, multiplied by thickness of plate, showed a remarkable difference between the $\frac{1}{4}$-in. plate and all thicker plates, the former having a shearing value of 59,800 while the $\frac{5}{16}$ to $\frac{5}{8}$ plate averaged but 45,800. All curves drawn of the stresses showed great regularity from $\frac{5}{16}$ in. to $\frac{5}{8}$ in. thickness, but the ratio between $\frac{1}{4}$ and $\frac{5}{16}$ being in all cases much greater.

21 The reduction in the maximum pressure due to increasing the clearance between punch and die proved very interesting. Assuming the $\frac{1}{2}$-in. flat punch with minimum clearance, 0.015 as the base, the punching pressure was reduced $7\frac{1}{2}$ per cent by doubling this clearance and 15 per cent by quadrupling this clearance. This percentage was much less with larger punches.

22 Three classes of shearing punches were used, the spiral, an

outside bevel, and an inside bevel, and comparative tests were made between these and a flat punch in the punching of nearly 500 holes. On the ¼-in. plate the decrease in pressure by the use of a shearing punch varied from 6 per cent with minimum clearance to less than 2 per cent with maximum clearance. On plates thicker than ¼-in. there was an increase in the shearing pressure which in some cases was as great as 34 per cent. Besides this, the difficulties of stripping the plate were greatly increased.

23 Although the device in question does not afford us an opportunity for deriving stripping values, we have made some observations on this subject, and although very incomplete, it is of interest to note that the force required to strip a ½-in. plate from a ¾-in. punch varied from 800 lb. to 5 tons, the latter value being with a shearing punch and maximum clearance.

## DISCUSSION

R. C. Carpenter said that although the paper referred to the hydraulic indicator, it seemed to be an ordinary steam indicator of a well-known type, and the author did not state what means were taken to prevent leakage in the indicator, and the consequent reduction of pressure. The drawings indicate that the volume of the fluid which acts on the indicator is very limited, and any leakage would materially affect the results. It is a well-known fact that indicators used under such conditions are very likely to leak or to stick, and either condition would have quite a serious effect.

Julian Kennedy believed that if the die on which the punching was done were mounted on a steel bar of suitable length and fitted with a multiplying apparatus for measuring the deflection of the spring, making a total travel of about ⅛ in. under the heaviest pressure, it would be possible to obtain more accurate results than with a hydraulic piston. There is no other means of measuring strains so accurate as a tempered steel spring with exact means for measuring its deflection.

The Author. As regards the leakage to which Professor Carpenter refers, it has already been stated that the amount is so small that pressure has been maintained for a period of eight minutes, as shown by card No. 40, Fig. 5.

An indicator spring operating under such conditions will, of course, record a lower pressure than when operated rapidly, and must be calibrated for this speed and the fluid used. Irregularities which at first were caused by the sticking of the piston were almost entirely eliminated by the continued tapping of the indicator cylinder, thus enabling us to obtain a very great degree of precision.

A Crosby indicator was used, of the type catalogued as a hydraulic indicator. We have since checked these results by using a Crosby hydraulic press recording gage in which all leakage was eliminated, and the results from the latter did not differ from the former.

In using the pressure indicator on a punching machine, for which it was designed, the rapidity of the operation suggested the use of an indicator rather than a recording gage.

# MILLING CUTTERS AND THEIR EFFICIENCY

By A. L. DeLeeuw, Published in The Journal for April

## ABSTRACT OF PAPER

Observations of present day practice and a number of experiments point to the fact that better results can be had from milling cutters by increasing the tooth space and depth. A number of cutters constructed along these lines were tested and it was found that they have a number of points in their favor, among which are less consumption of power, a greater amount of work done for one sharpening and a greater number of possible sharpenings per cutter. A change in the form of chip breaker made it possible to use cutters with chip breakers for finishing, as well as for roughing. It was further found advisable to use a special kind of key, here described, for heavy work. Finally, this paper describes a new style of face mill and what is called a helical mill.

A number of diagrams are presented showing the relative efficiency of different styles of mills for removing a given amount of metal. In general, attention is called to the possibilities which lie in a more scientific construction of milling cutters and the desirability of discarding our ideas of milling cutters, which are largely based on conditions no longer existing.

## DISCUSSION

John Parker. Much study and many years of actual experience have been involved in the design of cutters as made today, and any type of cutter that possesses any one quality to such an abnormal extent that its other attributes are made less efficient cannot be accepted as the ideal cutter for general use.

The type of cutter Mr. DeLeeuw has introduced has undoubtedly the merit of consuming less power than the regular cutter, as shown by his tests and confirmed to a large extent by a number of comparative tests made at the works of the Brown and Sharpe Manufacturing Company. This distinctive quality is of interest and gives the cutter a value which would be greater were it not that while for the heavier class of milling machines the new cutter proved entirely capable, on the lighter class satisfactory results were not obtainable.

Presented at the Spring Meeting, Pittsburgh 1911, of The American Society of Mechanical Engineers.

It is evident that the new cutter, having so few teeth, produces a hammering action on the work greater than that of the standard cutter, because there are not sufficient teeth in contact to steady the action; and, unless the machine has the rigidity and massiveness possessed by the heavier class of machines to withstand this pounding effect, the smooth action, so essential to good milling practice, is not obtained. This undesirable feature was very noticeable on a No. 2 Universal milling machine, which is essentially a tool-room machine and necessarily of a light character to enable it to be handled quickly and easily. The pounding was so severe that the tests had to be suddenly terminated, owing to the abusive action to which the machine was subjected. In another machine, somewhat heavier than the one referred to, work, when using the ordinary cutters, could be held in a vise clamped in the usual way; but, with the new cutters it would be pushed bodily out of the vise, and auxiliary means had to be provided to hold it in place. This would indicate that the new cutters would not be suitable for that class of work, when, for some reason it could not be so firmly secured as desired, or when great care would have to be exercised in clamping down work to the fixture or machine table, to prevent springing.

Comparative tests were made between the special and the standard milling cutters, in both cast iron and steel, on the No. 5 Brown and Sharpe plain milling machine. The machine was motor-driven and was connected to a Westinghouse graphic meter for recording the tests. This is probably one of the best existing methods for making comparative tests. The cutters used were 3¾ in. in diameter, 12 deg. spiral, right- and left-hand. The special cutters had 9 teeth, and the standard 16. These tests showed that, in removing 24 cu. in. of cast iron per minute, the new cutters consumed 20 per cent less power than the standard cutters, 15 per cent in removing 15 cu. in., and 14 per cent in removing 12 cu. in. of machinery steel. As regards the smoothness of action, there was very little difference noted between the two types; both were very good. A finishing cut was taken with each cutter in both cast iron and steel; all the surfaces were excellent, the standard cutter having a trifle better finish.

Comparative tests were made on the No. 3 Brown and Sharpe plain milling machine with both the new and the regular type end mills, of the following diameters and number of teeth: 1 in., 4 and 10; 1½ in., 6 and 12; and 2 in., 8 and 14. In all cases the end mills with the small number of teeth consumed less power in both cast iron and steel. The gain in cast iron was 19 per cent for the 1 in. diameter, 16 per cent for the 1½ in. diameter, and 18 per cent for the 2 in. diameter; and in steel, 14 per cent for the 1 in. diameter, 12 per cent for the 1½ in. diameter, and 9 per cent for the 2 in. diameter. In these tests it was found that the new style mill had a tendency to work loose, notwithstanding that the hand of the spiral in relation to the rotation of the mill, had the effect of pushing it in towards the spindle. This trouble was undoubtedly caused by the fact that the mills had so few teeth that the work imposed upon each tooth was sufficient to produce a pounding effect which jarred the mill loose. It is only fair to say that the cuts taken were far beyond what would be used in ordinary practice, and that possibly under ordinary working conditions no bad effect might result. However this may be, this point would have to be carefully tried out before this type of cutter could be accepted in place of the regular, which developed no such trouble.

In making the tests on the No. 5 plain milling machine with the milling cutters, the point regarding lack of chip room that Mr. DeLeeuw emphasizes was closely watched in the standard cutters, and, although the chip taken was far in excess of what would be demanded in ordinary practice, namely, $\frac{4}{10}$ in. deep and 10 in. feed per minute, there was apparently sufficient space, as not the slightest sign of clogging was in evidence.

For some time past, stock face milling cutters have been made with the teeth set at an angle, both on the face and periphery, whereas the older type had radial teeth, both on the face and periphery; in both cases the pitch of teeth approximates 1½ in. As a matter of interest, comparative tests were made. The results were, with the new type, a saving of 12 per cent of power in cast iron, and a gain of 6 per cent in favor of the old type in steel. This latter was somewhat surprising; and, were it not for the very careful manner in which these comparative tests were made and recorded, the result might be questioned.

A test was made in steel with the new and old side milling cutters, 4 in. diameter, 14 and 28 teeth respectively. One pair of each was used. A gain in power of 20 per cent in favor of the new was obtained. In this test the cutters with the less number of teeth cut the easier and the work had a better finish.

In briefly summing up the situation, I believe Mr. DeLeeuw has developed an interesting type of cutter which possesses to a marked degree a valuable attribute, that of saving power; and, in certain classes of work, such as heavy manufacturing milling, it will doubtless find a field to which its characteristics are most suitable. But, in view of the knowledge gained by the comparative tests made, I doubt very much whether it will be as successful a cutter for general purposes as its predecessors.

A. F. MURRAY. The results of Mr. DeLeeuw's experiments are in accordance with theories which I have been advocating for several

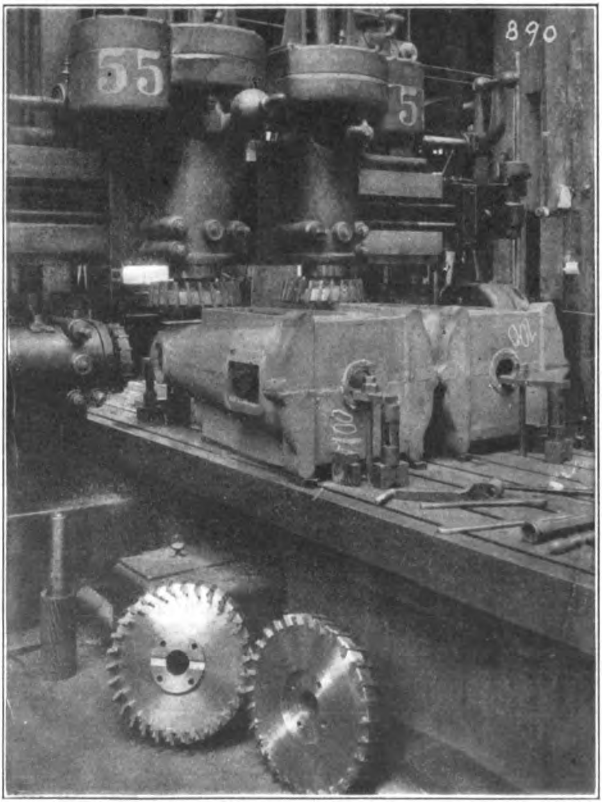


FIG. 40 TWO 16-IN. CUTTER HEADS AT WORK

years. At the Blake and Knowles Steam Pump Works we are continually recutting old milling cutters for our manufacturing departments, and invariably reduce the number of teeth about half, setting the mill deep enough to cut out completely every other tooth. In most cases we have done this with standard bevel cutters for milling

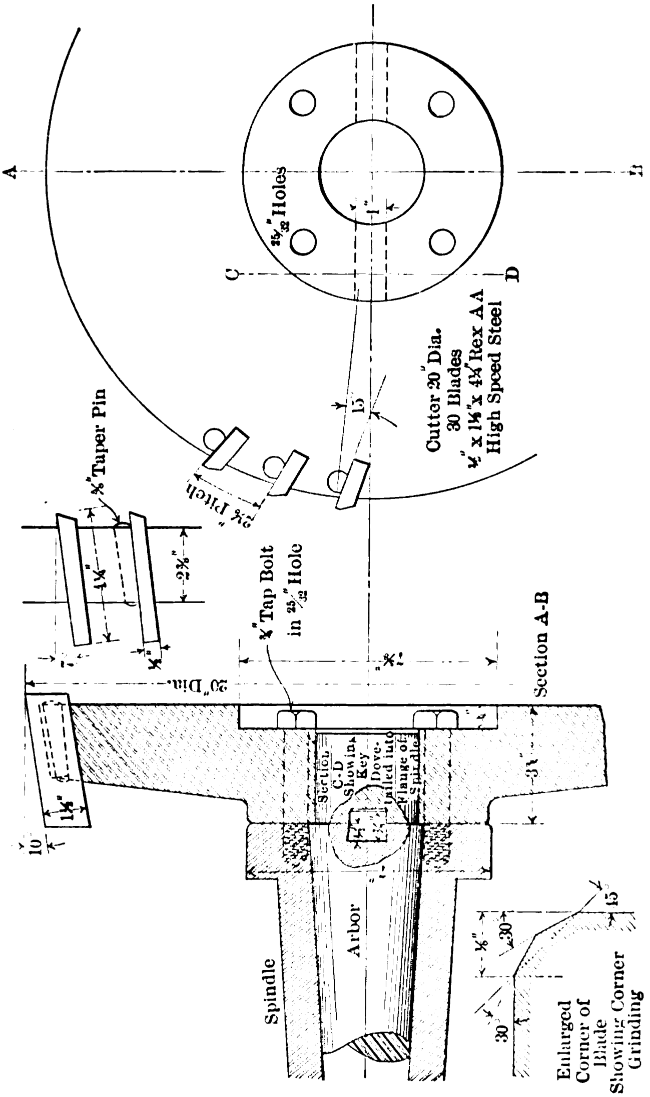


FIG. 41 SHOWING CONSTRUCTION OF CUTTER HEADS

the teeth. We are now glad to avail ourselves of the results of Mr. DeLeeuw's experiments as to changes in these cutting angles for end and spiral mills.

We have an equipment of the high power face mills, shown in Fig. 16, and we have recently had some new high-duty 16-in. and 20-in. face mills made for a heavy 4-spindle milling machine. Fig. 40 shows the two 16-in. cutter heads at work with the two 20-in. cutter heads standing alongside the machine. An old pattern 12-in. cutter head is shown on the horizontal spindle.

The method of attaching these cutters to the spindle is worth noting. The spindle has a taper hole in which is fitted a short arbor

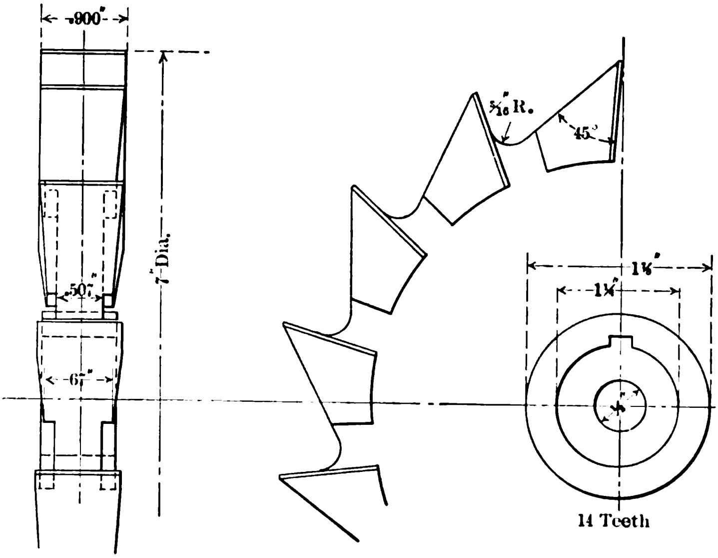


FIG. 42 CUTTER USED ON HEAVY TYPE LINCOLN MILLING MACHINE

3 in. in diameter used only for centering the cutter. The spindle also has a flanged end 7 in. in diameter and a key 1 in. wide permanently dovetailed across its face. The flange is also tapped for four ¾-in. bolts which hold the cutter firmly and squarely against the face of the spindle but do not assist in driving, as they go through clearance holes in the cutter head. This holding means was suggested by one of the cutter manufacturers and adopted after a careful trial of the cutters screwed on the end of the spindle and several arrangements with drawback bolts and with both face and longitudinal keys. Fig.

41 shows the construction of these cutters. It will be noted that the bodies are shaped like the frustum of a cone with the blades pitched back at an angle of 10 deg. and projecting beyond the rear of the body as much as the design permits. In this way long life of cutter blades is secured with a minimum amount of grinding. The other clearance angles, it will be noted, are practically the same as in Fig. 16. Instead of three settings in grinding required for cornering the blade, we have obtained good results with two settings as shown in detail in Fig. 41.

It is our intention to construct experimental cutters with coarser pitch of blades than those we have at present (2½ in. and 3 in. circular pitch instead of 2⅛ in.), as we do not believe we have reached the limit in this direction.

Referring to Mr. DeLeeuw's remarks on end mills, results obtained in a splining machine recently put on the market, by the use of fishtail cutters running at high speed with ample lubrication, have served

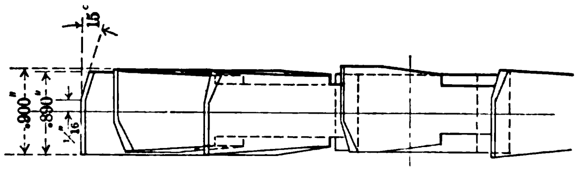


Fig. 43 Showing Cutter with Opposite Corners of Alternate Teeth Removed

to indicate that a reduction in the number of teeth of end mills was desirable. We have recently put into use several 3-in. and 4-in. inserted blade end mills with 6 and 8 teeth respectively, the blades being constructed of ⅜ by 1 $\frac{1}{16}$ in. high-speed steel, raked in the same manner as the larger face mills shown in Fig. 16.

Saws, slotting and side mills, as ordinarily made, have too many teeth. It is my opinion that a large proportion of the success obtained by the use of inserted tooth mills for this purpose has been due to the enforced reduction in the number of teeth. Several years ago, while connected with a small arms factory, I assisted in some experiments which were made for increasing the production of a very heavy slotting operation in which a 7-in. cutter, 0.900 in. wide with a 1½ in. hole, buried itself to the hub in a steel forging set at an angle of 45 deg. The operation was performed on a heavy type of Lincoln milling machine. The first cutter employed was a high-speed side mill of regular pattern, which gave very unsatisfactory results and stalled the machine with light feed, choking with chips, although the cut was flushed with a heavy stream of soda water. Some one suggested the cutter shown in Fig. 42 which practically doubled the production, but the output was still below requirements. Opposite corners of alternate teeth were then removed, as shown in Fig. 43. This slight change enabled us to feed from 1 to 1¼ in. a minute as against about ⅝ in. with the cutter (Fig. 42) and about ⅜ in. with the standard form of side milling cutter.

About two years ago I repeated this experiment with an inserted tooth side milling cutter 10 in. in diameter, 1½ in. face, 2 in. hole. The pitch of the blades was about the same as that shown in Fig. 17 (being a side mill the blades were set in parallel to the axis), approximately 1 in. circular pitch. This cutter was being used to mill a slot 3½ in. deep by 1¾ in. wide in U. S. Navy Class *A* steel forgings, having a tensile strength of 80,000 lb. per sq. in.

The cutter, as furnished by the manufacturer for straddle milling work, was unable to cut through this material more than ⅜ in. per min. and the machine could be heard all over the room. This recalled to my mind the former experience above referred to and alternate corners of the inserted blades were ground off at an angle of 15 deg., $\frac{1}{16}$ in. beyond the center, and they were sufficiently offset to enable the 1½ in. cutter to machine the 1¾ in. slot to size at only one cut. This change increased the feed possible from ⅜ in. up to 1⅛ in. per min. and gave 200 per cent increase in efficiency by making the chip three times as thick and half as wide as at first and providing additional chip clearance. It is believed that some of the side mills shown in Figs. 14*A* and *B* and Fig. 15 would be improved by the adoption of this staggered tooth when used for cutting slots.

The practice above referred to has been used quite frequently in connection with small tee-slotting cutters, but I have never seen it used elsewhere on the larger types of slotting cutters.

W. S. Huson. From the point of view of product, the operation of cutters is paradoxical. In a gear-cutting machine, we have not been able to get the same results with the wide-spaced edges of the standard cutter of today as with cutters having several times as many cutting edges. Gear teeth are smoother and run better, though the cutter is much more expensive to maintain. Even after all the investigation by prominent cutter people, the larger number of teeth in a milling cutter gives better gears.

We get better results in surface milling from wide-spaced cutting edges than from the usual close-spaced. We have found in testing work milled with cutters having many teeth that when the cut was finished, say at 3 p.m., and tried with straight edge and gages, it was right, while the next morning it was out. There are two causes for this: the peening effect of the cutter, and another which I think is not fully considered, but which I believe is borne out by experience, namely, that the teeth of a milling cutter punch or force little particles of cutting dust into the interstices or pores of the iron, which finally respond to the force exerted on them, and throw the work out of alignment. A cutter with fewer cutting edges for surface milling does not give a bright finish, but the product requires less subsequent filing and fitting. It is for this reason that the question of milling cutters is paradoxical, for in the case of gear cutters with many cutting edges we get a smoother gear tooth, whereas in surface milling we get a truer surface with fewer edges.

I agree with the paper that in surface milling the fewer cutting edges, the more chip clearance, and hence the more permanent, if not quite so smooth, work will give better final results than cutters with close-spaced edges. The amount of power consumed is of little importance in the final cost, if as a result of rapid machine output, manual labor must be used to make the work acceptable.

The Author. In a general way, the results of Mr. Parker's experiments are in line with mine and perhaps the greatest difference between them is a matter of amount. The difference between the power consumed with the old and new style cutters I found to be greater than that obtained by Mr. Parker, and further experiments which I have made since writing this paper show even greater differences than were found at first, due to the fact that they were made with cutters with a wider spacing of the teeth.

As to the hammering effect produced by the wide-spaced cutter, I found this to exist only with roughing cuts of very moderate depth and it was overcome entirely by making the spiral steeper than 10 deg. Experiments carried out with cutters with 20-deg. spiral were entirely successful and it was found impossible to produce a set of conditions in which this cutter would cause hammering. At the same time, the end thrust was so slight, that its effect could not be noticed.

Mr. Parker's method of using a Westinghouse graphic meter for recording the tests raises doubts in my mind as to whether it is possible to get a simultaneous reading of power consumed and speed of machine, though, of course, I have no reason to doubt that Mr. Parker has taken care of this feature in some way. If so, it would be interesting to know in detail his method of testing.

The results of his tests of wide and narrow spaced face mills, (the wide spaced mills having double rake), are widely at variance with my results; and if I had not repeated carefully these tests a great number of times, I might be tempted to repeat them again. It is probable that there are some essential constructive differences between the cutters used by Mr. Parker and by myself, which may explain this great difference in results.

The only thing I want to add to Mr. Murray's remark is that there seem to be some points in the construction of this cutter which I would consider improvements, especially the cutting away of one side of the alternate teeth.

In regard to Mr. Huson's remark that "the amount of power consumed is of little importance in the final cost, if as a result of rapid machine output, manual labor must be used to make the work acceptable," I would not wish anyone to think that I have advocated rapid removal of metal at the expense of finish, nor that these new cutters produce such an undesirable result. On the contrary, I found less disturbance of flatness and straightness, on account of pressure and heat. Another angle of this question is that it is not so desirable to use less power because power costs money, but because all power used which is not needed directly for separating the chip from the work, is power used to dull or break cutters, to distort work and to wear or ruin the machine, and if I would get a bonus for every horsepower used on machine tools, I would still aim to make the machines in the shop do their work with the smallest possible amount of power.

# ENERGY AND PRESSURE DROP IN COMPOUND STEAM TURBINES

By Forrest E. Cardullo, Published in The Journal for February

## ABSTRACT OF PAPER

It is customary to design multi-stage impulse turbines on the assumption that the entropy of the steam remains constant. The effect of fluid friction is to increase the total heat and the entropy of the steam as it flows through the turbine, and to increase unduly the proportion of the power developed in the later stages. An empirical formula is proposed for estimating the quantity of power developed in each stage of such a turbine. This equation is modified so that by its aid the proper pressure drop in each stage may be determined. A graphical solution of the problem is also developed. The methods outlined are applicable to the solution of problems in turbine design when a temperature-entropy table or a total heat-entropy diagram is used.

## DISCUSSION

W. H. Herschel (written). Referring to Fig. 1 the total available heat is not $AB = \Delta H$, but $AB'$, and it is the main object of the paper to determine the value of $AB'$. The method is based upon tnat of Professor Peabody, and differs from it in leaving out all consideration of temperature so as to permit the use of the Marks and Davis entropy diagram. We are therefore concerned only in proving whether the accuracy of the method is as great as that attainable in the customary use of the diagram.

The proposed graphical method is open to the objection that the long line $BB'$ must be drawn parallel to the much shorter line $pI'$. This cause of inaccuracy may be removed by computing and laying off the length $AB'$, and then drawing $qq'$ parallel to $BB'$. To serve as a check $qq'$ should also be parallel to $pI'$.

From the graphical construction $AB' = \dfrac{AB^2 AI}{Ap^1 AM}$ where $AM = AB + (us + dg - tv)$. The quantity in parenthesis is the sum of the intercepts between the lines $EF$ and $AB$, ordinates above $AB$ being

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plus, and those below $AB$, minus, all these ordinates being proportional to their distances from $O$.

$$od + os + (-ot) = \frac{nAB}{2} - (n-\tfrac{1}{2})\,Ap - (n-1\tfrac{1}{2})pq - (n-2\tfrac{1}{2})\,Bq$$

To make this equation more general, we may designate the segments of the line $AB$ by the symbols $S_1$, $S_2$, etc., and then

$$od + os + (-ot) = \frac{n\,\Delta H}{n} - (n-\tfrac{1}{2})\,S_1 - (n-1\tfrac{1}{2})\,S_2 \ldots\ldots [n-(n-\tfrac{1}{2})]\,S_n$$

$$us + dg - tv = \frac{[od + os - ot]\ \mathrm{AE}}{\frac{\Delta H}{2}}$$

$$AM = \frac{od + os - ot}{\frac{\Delta H^2}{2\,(AC)\,S_1}} + AB$$

and finally

$$AB' = \frac{\Delta H^2\left[S_1 + S_1\,\frac{AC}{(\Delta H)^2}\,(\Delta H - S_1)\right]}{S_1\left\{\Delta H + \frac{\frac{n\Delta H}{2} - (n-\frac{1}{2})S_1 - (n-1\frac{1}{2})S_2 \ldots [n-(n-\frac{1}{2})]S_n}{\frac{(\Delta H)^2}{2(AC)\,S_1}}\right\}} \qquad [1]$$

Equation [1] looks somewhat formidable, but is in reality simple to use, since it contains only $n$, the number of parts into which $\Delta H$ is divided, the lengths of each of these parts, and a constant $AC = 0.00056\ (\Delta H^2)\ (1-E)$, where $E$ is what Professor Peabody calls the overall internal heat factor. If $AB$ is divided into equal parts, $AB' = nAI = nh_1$.

According to the proposed modification of Professor Peabody's method

$$\mathrm{h}_1 = \frac{\Delta H}{n}\left[1 + 0.00056\ (1 - E)\ \Delta H\left(\frac{n-1}{n}\right)\right]$$

*and*

$$h_1 - h_2 = \frac{2(\Delta H)^2}{n^2}\,0.00056\ (1 - E)$$

Referring to Fig. 2, we will call $B_2$ the point where the perpendicular dropped from the point $B$, intersects the line of constant pressure $P_2$. If the power to be developed in each stage is the same, $h_1 = AH_2$

$= BB_2$. Because it is fairly obvious that the method under consideration does not apply to the superheated steam part of the diagram, and because it is customary to design turbines for dry steam, I shall confine my attention to the part of the diagram below the saturation curve, where the pressure lines are substantially straight. Let $\Theta_1$ = the angle between the line $BH_2$ and the vertical $AH_2$. Then in order that $AH_2$ shall equal $BB_2$, $\frac{BB_2 - H_2H_3}{\tan \Theta_1 h_1 (1-E)}$ = rate of divergence of lines $P_2$ and $P_3$ in the horizontal distance between the verticals $N_1$ and $N_2$.

$$\frac{\frac{2(\Delta H)^2}{n^2} 0.00056 \; (1 - E)}{\tan \Theta_1 \left\{\frac{\Delta H}{n}\left[1 + 0.00056 \; (1 - \mathrm{E}) \; \Delta H \left(\frac{n-1}{n}\right)\right]\right\}(1 - E)}$$

$$= \frac{2 \Delta H \; 0.00056 \cot \Theta_1}{n\left[1 + \left(\frac{n-1}{n}\right) 0.00056 \; \Delta H \; (1-E)\right]}$$

It should be noted that the horizontal distance between $N_1$ and $N_2$ must not be measured in the scale of entropy, but in the scale of $H$, 1 in. = 50 B.t.u. But if $\Theta_2$ is the angle between the lines $N_1$ and $P_3$, then the rate of divergence of lines $P_2$ and $P_3$ is equal to $\cot \Theta_1 - \cot \Theta_2$ and we have

$$\cot \Theta_1 - \cot \Theta_2 = \frac{2 \; \Delta H \; 0.00056 \cot \Theta_1}{n\left[1 + \left(\frac{n-1}{n}\right) 0.00056 \; \Delta H \; (1 - E)\right]} \quad \ldots [2]$$

The rate of divergence is thus seen to depend on the quantities $\Delta H$, $E$, $n$, and $\tan \Theta_1$, and under ordinary conditions their variation will be about as follows:

$\Delta H$ from 350 to 140 B.t.u.
$E$ from 0.50 to 0.70
$n$ from 2 to 25 to include the Rateau type, but not the single-stage De Laval
$\Theta_1$ from 55 deg. at 200 lb. to 65 deg. at 1 lb.
$\cot \Theta_1$ from 0.700 to 0.466

Equation [2] will give a maximum value when $\cot \Theta_1 = 0.700$; $n = 2$; $\Delta H = 350$ and $E = 0.70$; and a minimum value when $\cot \Theta_1 = 0.466$;

$n = 25$; $\Delta H = 140$ and $E = 0.50$. This gives for the maximum divergence in 8 in. horizontal length, 53.4 B.t.u. and for the minimum divergence for the same difference of entropy, 1.13 B.t.u.

If we restrict the formula to land Curtis turbines, $n$ would not have a maximum value above 6 (the highest number of stages mentioned by the author), and the minimum divergence would become 4.72. If we leave out low-pressure and non-condensing machines, $\Delta H$ would not be less than 250 and the minimum divergence would be 8.56. I have thus far treated, $\Delta H$, $E$, $n$ and cot $\Theta_1$, as independent variables, following the example of the author who assumes the same efficiency for a two-stage as for a six-stage turbine with the same value of $\Delta H$. However as $E$ depends upon bucket speed as well as on $\frac{\Delta H}{n}$ and as the bucket speeds are not given, we may assume that with suitable speeds and types of machines, the two turbines might have the same efficiency.

Professor Peabody applies his method to a somewhat wider range of conditions than does the author, but in order that the latter may not make the objection that I attempt to apply it to conditions for which it was not intended, I shall confine myself to the two cases which he has himself given, where $\Delta H = 322.2$ and $E = 0.60$ in both cases and $n = 2$ and 6.

Where $n = 6$, $\Theta_1$ varies from 58 deg. to 64 deg. and we may take the average value of cot $\Theta_2$ to be 0.546 where $n = 2$, $\Theta_1 = 62$ deg. and cot $\Theta_1 = 0.532$. Therefore, we have from [2]

$$\left.\begin{array}{r}\text{Divergence in 8 in.}\\ \text{if } n = 2\end{array}\right\} = \frac{2 \times 322.2 \times 0.00056 \times 400 \times 0.532}{2\,[1 + \frac{1}{2}\,(0.00056)\,322.2\,(1 - 0.60)]} = 37.1 \ldots [3]$$

$$\left.\begin{array}{r}\text{Divergence in 8 in.}\\ \text{if } n = 6\end{array}\right\} = \frac{2 \times 322.2 \times 0.00056 \times 400 \times 0.546}{6\,[1 + \frac{5}{6}(0.00056)322.2\,(1-0.60)]} = 12.4 \ldots [4]$$

Now it is an easy matter to find the actual divergence on the entropy diagram in 8 in. horizontal distance and for a drop of say 2 in. = 100 B.t.u. If we measure the distance apart of two pressure lines at entropy 1.30 and again at 1.46, the difference, to the scale of 1 in. = 50 B.t.u., will give us the divergence in B.t.u. for 4 in. horizontal distance, and double this would be the rate of divergence of those particular pressure lines in 8 in. In the case of the lower pressures the full 8 in. may be measured directly, as from entropy 1.46 to 1.78, the horizontal entropy scale being 1 in. = 0.04 units. In this way

I find the actual divergence in 8 in. horizontal and 2 in. vertical is about 25 to 35 B.t.u. in the most used part of the diagram and has about double those values for very high pressures.

In the author's problem of the two-stage turbine, the entropy at admission is 1.560 and for the second stage 1.663. The horizontal range is thus $\frac{1.663 - 1.560}{0.04} = 2.57$ in. From [3] we might therefore expect a divergence of $\frac{2.57 \times 37.1}{8} = 11.9$ B.t.u., while the actual divergence as found by the author is 167.0 − (1026.3 − 871.1) = 11.8. A divergence of 11.8 for a horizontal distance of 2.57 in. and a vertical drop of $\frac{1026.3 - 871.1}{50} = 3.10$ in., corresponds to a divergence of 24 B.t.u. for our standard conditions, instead of 25 to 35 B.t.u. which I found by scaling from the diagram. Another estimator might find a different value by scaling, but even if we suppose 30 to be correct, this would not change very greatly the available heat per stage. The divergence for our two-stage turbine would become 14.8 and the drop would be 168.5 instead of 167.0. This would be equivalent to increasing the factor 0.00056 to 0.00071. As the steam velocity = $C\sqrt{h}$, an increase of $h$ from 167.0 to 168.5 would increase the steam velocity only about half of one per cent. Since the proper steam velocity for a given bucket speed is not known within half of one per cent, we may conclude that the proposed method is accurate enough for a two-stage turbine working under moderate pressure.

Coming now to the six-stage turbine, the entropy at admission is 1.560 as before. The entropy of the last drop is not stated but it may be found as follows: The drop in each stage is $\frac{\Delta H}{n}(1+K) = 56.9$, so that the drop from $A$ to $D$ (Fig. 2) would be 0.60 (6 × 56.9) = 204.8 and the drop from $A$ to $P_{n+1}$ ($P_4$ on Fig. 2, or $P_7$ for the six-stage turbine) would be 204.8 + (56.9 × 0.40) = 227.6. The end of the last drop would be at $H$ = 965.7 and pressure = 1.00, and the entropy of this point would be 1.729. The horizontal range would be $\frac{1.729 - 1.560}{0.04} = 4.22$ in. and so we should expect from [4] a divergence of $\frac{4.22 \times 12.4}{8} = 6.5$ or 1.3 B.t.u. for each of the five drops. This should be equal to $h_1 - h_2 = 56.7 - 55.4$ in Table 1. The author takes $\frac{322.2}{6} = 53.5$ instead of 53.7, but allowing for this inaccuracy $h_1 - h_2 = 56.9 - 55.6 = 1.3$ as before.

The author says, Par. 9, "So far as the writer is aware there is no particular reason why this method should give correct results, but experience shows that it does do so." In Par. 6 he uses the word empirical which is the only indication furnished by the author that his method is not applicable with perfect accuracy to all parts of the entropy diagram. As I have already pointed out, the method does not apply to superheated steam or to wet steam of very high pressure, and in regard to the part of the diagram in most frequent use, it would be more accurate to say the error is so small as not to be readily detectable, than to leave it to be inferred that there is no error.

The author has carefully omitted all references made by Professor Peabody to errors in the method. For example, Professor Peabody's Table 6* (corresponding to the author's Table 1) contains the following data:

| Pressure | Entropy | Heat Drop | |
|---|---|---|---|
| | | 1193.3 | |
| | | 1136.7 | |
| 164.8 | 1.560 | | 56.6 |
| | | 1158.4 | |
| | | 1101.5 | |
| 80.1 | 1.588 | | 56.9 |
| | | 1123.5 | |
| | | 1066.4 | |
| 38.1 | 1.618 | | 57.1 |
| | | 1088.6 | |
| | | 1031.9 | |
| 16.9 | 1.651 | | 56.7 |
| | | 1053.7 | |
| | | 996.7 | |
| 7.09 | 1.685 | | 57.0 |
| | | 1018.8 | |
| | | 962.1 | |
| 2.76 | 1.722 | | 56.7 |
| 1.00 | 1.761 | Sum ........... | 341.0 |

In reference to this tabulation Professor Peabody remarks that the

* A Method of Determining Pressures for Steam Turbines, Cecil H. Peabody, Trans. Soc. Naval Archs. and Marine Engrs., 1909, p. 32.

sum of the several amounts of heat assigned to the six stages for adiabatic action should be equal to $322.2 \times 1.054 = 339.6$, instead of 341.0, the discrepancy being due to lack of precision in the calculation.

In the case of the two-stage turbine Professor Peabody assigned a drop of 166.4 B.t.u. to the first stage and obtained 166.1 for the second. In short, even with the most careful interpolation in his entropy table Professor Peabody found that his method was subject to error, though to be sure the error in the cases cited, is negligible for all practical purposes.

Returning to the author's statement in Par. 9, we are left in doubt as to the extent of the experience which shows that the method gives correct results. There is nothing to show that the experience covers more than the examples given in Professor Peabody's and the author's papers. However, if it is desired to apply the method to any part of the diagram, an idea of the error involved may be obtained by the help of [2], either by scaling the divergence of the lines $P_2$ and $P_3$ or by measuring with a protractor the angles $\Theta_1$ and $\Theta_2$. For this purpose the location of the lines $P_2$ and $P_3$ may be obtained with sufficient accuracy if $AH_3$ is taken equal to $H_2H_3 = \frac{\Delta H}{n}$.

But the author's method, in addition to assuming a constant rate of divergence for a certain drop and a certain difference of entropy, is based on other assumptions which affect its usefulness. In Fig. 1 it will be noted that $B'z$, $q'y$ and $I'x$ are parallel, which signifies that the efficiency of each stage is the same, and Professor Peabody says, "The method assumes that the efficiencies of the several stages are the same or nearly the same, and most concordant results will be obtained when the same amount of heat is assigned to each stage. But the method is insensitive to reasonable changes in the heat factor and will give good comparison with practice with any type of turbine."[1]

That the method is insensitive to changes in $E$ is shown by Professor Peabody's calculations, and it also follows from [2]. When Professor Peabody says "any type of turbine," it is to be supposed he means any multicellular turbine, since the method does not apply to a single-stage De Laval machine, and its application to the Parsons type has not been demonstrated. As for the comparison with "prac-

[1] A Method of Determining Pressures for Steam Turbines, Cecil H. Peabody, Trans. Soc. Naval Archs. and Marine Engrs., 1909, p. 30.

tice" it depends upon what is meant. Writers show a "strange reticence" in telling all they know and it is a question whether practice is to be considered as represented by what is published, or by the methods actually used by designers.

I question whether it is good practice to assume a constant-stage efficiency as it is obviously contrary to fact. As the efficiency can only be constant if the losses are constant, we must consider the losses in each stage. Leaving out radiation, leakage between stages and the loss due to residual velocity, $\frac{w_2^2}{2g}$, the chief losses are due to the steam passing through the nozzles and blades, and to the discs and blades rotating in steam. I shall call these two frictional losses, blade losses and windage.

If $c$ = the theoretical velocity due the heat drop assigned to a stage, $c_1 = \varphi c$ = velocity of steam leaving the nozzle, and $w_2 = \chi w_1$ where $w_1$ is the resultant of $c_1$ and the peripheral velocity. Then the blade loss will equal

$$\frac{1}{2g}[(c^2 - c_1^2) + (w_1^2 - w_2^2)] = \frac{1}{2g}[c^2(1 - \varphi^2) + w^2(1 - \chi^2)]$$

As $\varphi$ and $\chi$ may be considered constant, it follows that the blade loss will be constant only when $c$ and $w$ are the same for all stages. If the heat assigned to a stage is constant, $c$ is constant, but $w$ will vary with the blade angle. It is well known that at the low-pressure end of marine turbines, semi-wing, wing and double-wing blades are employed, and this same flattening of the blade takes place in land turbines, though perhaps not so often referred to. Consequently the blade losses vary with changes in the value of $w$ from stage to stage.

The variation in the windage losses is much greater. While the absolute numerical value of the windage losses may be difficult to discover, on account of disagreement between authorities whose tests were made with different types of running wheels, the following equation from Stodola[1] may be taken to illustrate our point.

$$N = \beta 10^{-9} D n^3 L \gamma$$

$N$ = windage in kw.
$\beta$ = a factor depending upon the number of rows of blades
$D$ = diameter to middle of blade
$L$ = mean length of blade
$\gamma$ = specific weight of steam

[1] The Steam Turbine, Aurel Stodola, ed. 4, p. 129.

$D$ may be constant in all stages and in some cases, $\beta$ is also a constant. $L$ may vary from a fraction of 1 in. to over a foot, and the variation in the density of steam is enormous. Consequently the windage will be greatest in the first stage, where $\gamma$ is a maximum, in spite of the fact that $L$ is there a minimum, and it will gradually decrease to a comparatively insignificant quantity in the last stage. Of course, if there are very few stages, or the turbine is running non-condensing, the windage in the last stage may be considerable. The assumption that the efficiency is the same for each stage is thus far from the truth, and can be justified only on the ground that it is one commonly made in books.

In Par. 6, the author defines $E$ as the probable thermal efficiency of the turbine and gives the formula $E = \frac{2545}{S \times \Delta H}$ where $S$ is the probable steam consumption per horsepower per hour. In using this formula, it does not seem to me clear how he allows for the fact that there are losses which do not increase the entropy of the steam. Stodola[1] explains the matter more fully somewhat as follows: Add to $N_e$ the effective horsepower, the losses outside the turbine casing, such as bearing friction and the power used to drive auxiliaries, and the sum is called $N_i$. If $G_e$ is the steam consumption per effective horsepower per hour, then $G_i = G_e \frac{N_e}{N_i}$, the difference in total heat between initial and final conditions will be $\frac{2545}{G_i}$ (neglecting losses due radiation and the increase in steam velocity between the steam chest and the exhaust), and finally the efficiency will be equal to $\frac{2545}{G_i \Delta H}$. Professor Peabody uses practically this same method, except that he takes $G_i = 0.9\, G_e$. He then goes on to say, "There may be a reasonable dislike to using a factor based on the gross horsepower of the turbine, but it will be shown that a considerable variation in that factor will have only a small effect on the computations of pressure; and after all there appears to be no way to avoid the difficulty."

As I understand Professor Peabody, the heat drop between the point $A$ and the point $D$ (Fig. 2) is equal to $\frac{2545}{G_i}$ and there is no objection to this method of finding the point $D$. But he does admit

[1] The Steam Turbine, Aurel Stodola, p. 116.

there might be a reasonable dislike to taking the overall turbine efficiency $\frac{2545}{G_1 \Delta H}$ as the efficiency of each stage.

It might also be objected that the steam does not actually pass through the changes represented by the broken line $AH_2B$, etc. This could occur only if there were no friction and consequently no increase of entropy in the nozzles and no decrease of pressure in passing through the blades. In reality there is nozzle friction and especially in Curtis turbines using intermediates or reversing blades, there is often a fall in pressure in passing the blades. On this account some writers do not classify the Curtis turbine as a pure impulse turbine. However, the error introduced by considering that the steam follows the path $AH_2B$ is slight compared with that due to taking $E$ constant. An inaccurate value of $E$ has, as Professor Peabody shows, but slight influence on the calculated steam velocities, but it should not be overlooked that its influence on the calculated steam volumes is much greater.

However, the total amount of heat that may be assigned to the several stages is obtained, and this is but a beginning. The real task is in so arranging blade lengths, blade angles, disc diameters, heat drops, etc., that the ratio of steam speed to bucket speed shall be as desired. Professor Peabody,[1] and the author (Par. 3), assume a constant steam velocity and the same heat drop in each stage. Now the theoretical ratio between bucket and steam velocity in an impulse turbine is one-half and if there were no losses this value would be used. On account of the losses, which increase approximately as the cube of the bucket speed, there is a certain bucket speed less than half the steam speed, which gives the greatest net power. Furthermore, not only has a turbine a most efficient speed of revolution, but each separate row of blades has a most efficient linear velocity depending on the losses in the separate stages. The angular velocity of every row of blades must be the same, but the linear velocity may be regulated within certain limits, by changes in blade length and disc diameter. Thus if the author assumes that the diameters of the moving elements of each stage are the same, he should not assume a constant steam velocity in each stage.

The method presented by the author gives results that agree

[1] A Method of Determining Pressures for Steam Turbines, Cecil H. Peabody, Trans. Soc. Naval Archs. and Marine Engrs., 1909, p. 29.

with those obtained by the method of assuming a constant reheating factor, with an error so small as not to be readily detectable by scaling on the entropy diagram, so long as operations are confined to the more usual pressures, with steam initially dry. However, the reheating factor actually varies from stage to stage with changes in the internal losses, so that any method which assumes a constant stage efficiency is but a preliminary to the more difficult task of proportioning the pressure drop between the stages so as to obtain a suitable variation in the ratio of bucket speed to steam velocity, which can be accomplished only by the method of successive approximations.

C. H. Peabody[1] (written). I desire first to express my appreciation of the kind manner in which Professor Cardullo refers to my paper on A Method of Determining Pressure for Steam Turbines, which serves as a point of departure for his own investigations.

In his paper Professor Cardullo shows that his empirical equation is both accurate and convenient, and the few applications I have made of it lead to the same conclusion. But I cannot agree that in practice it will be found either more simple or exact than the method offered in my paper. Though it does not much change conditions, I will say that the computations of ratios for determining temperatures and pressures has been abbreviated since my paper was presented.

I should like to explain the derivation and use of these factors. Taking 164.8 lb. and 1 lb., or 366 deg. and 102 deg., Professor Cardullo's paper shows that the middle temperature for adiabatic action is 223.5 deg. But if only 0.6 of the available heat is changed into work and the other 0.4 remains in the steam, the entropy will increase to about 1.65. Let $h$ stand for the heat contents and find the ratio $\frac{\Delta h_{1.56}}{\Delta h_{1.65}}$ for a range of temperature of 40 deg. at entropy 1.56 and at entropy 1.65 as follows:

| Temperature | Heat Contents | |
|---|---|---|
| | Entropy 1.56 | Entropy 1.65 |
| 243 | 1056.0 | 1122.8 |
| 102 | 1006.7 | 1069.6 |
| | 49.3 | 53.2 |

Ratio: $\frac{53.2}{49.3} = 1.08$

[1] Prof. Naval Arch. and Marine Engrg., Mass. Inst. of Tech., Boston, Mass.

To find intermediate temperatures for a six-stage turbine draw a diagram like Fig. 3 in which $h_1h_2$ represents the adiabatically available heat, 322.2 B.t.u. At a convenient scale the ratio 1.080 is laid off at the top and a diagonal line is drawn through the middle point. The line $h_1h_2$ is divided into six equal parts. There may in any case be as many parts as there are stages which may be equal or unequal. At the middle points of the segments of $h_1h_2$ draw abscissae and on them read their values as indicated. Then calculate the intermediate

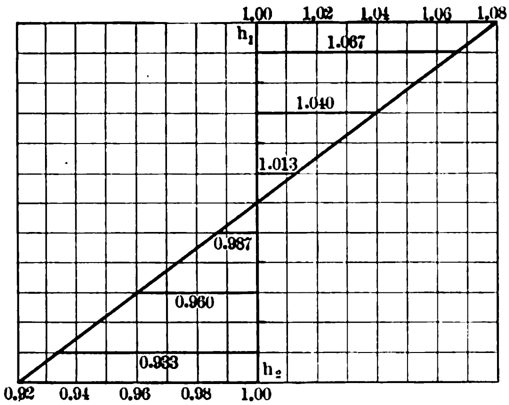


FIG. 3 DIAGRAM SHOWING INTERMEDIATE TEMPERATURES FOR A SIX-STAGE TURBINE

temperatures and pressures as follows:

$$\frac{322.2}{6} = 53.7$$

| | | Temperature | Pressure |
|---|---|---|---|
| 53.7 × 1.067 = 57.3 | 1193.3 − 57.3 = 1136.0 | 312.5 | 80.5 |
| 53.7 × 1.040 = 55.9 | 1136.0 − 55.9 = 1080.1 | 263.5 | 37.6 |
| 53.7 × 1.013 = 54.4 | 1080.1 − 54.4 = 1025.7 | 218.0 | 16.5 |
| 53.7 × 0.987 = 53.0 | 1025.7 − 53.0 = 972.7 | 176.5 | 6.95 |
| 53.7 × 0.960 = 51.5 | 972.7 − 51.5 = 921.2 | 138.0 | 2.74 |
| 53.7 × 0.933 = 50.1 | 920.2 − 50.1 = 871.1 | 102.0 | 1.00 |
| 322.2 | | | |

The temperatures and pressures are looked up in the temperature-entropy table at entropy 1.56, interpolating to half degrees, but not to a greater degree of refinement. Great refinement is wasted in this matter, for the straight adiabatic method of text books gives a maximum error in this case about 0.06 error in energy which corresponds to 0.03 error in velocity. A variation of 10 per cent from the normal velocity of a turbine has barely an appreciable effect on the efficiency, and a variation of 0.015 would be imperceptible either in computation or experiment.

There is, however, no use in allowing a preventable error of 3 per cent to creep into one computation and derange the results, consequently some method of correction should be used. I propose the ratio in Table 2 for my method.

TABLE 2 RATIO FOR PRESSURE DISTRIBUTION

| Heat Factor | 150 Gage Pressure to 28 in. Vacuum | 150 Gage Pressure to Atmosphere | Atmosphere to 28 in. Vacuum |
|---|---|---|---|
| 0.55 | 1.09 | 1.050 | 1.040 |
| 0.60 | 1.08 | 1.045 | 1.035 |
| 0.65 | 1.07 | 1.035 | 1.030 |
| 0.70 | 1.06 | 1.030 | 1.025 |
| 0.75 | 1.05 | 1.025 | 1.020 |

Having the ratio of heat changed into work by the turbine to the total available heat for adiabatic expansion, the designer may select the nearest ratio from the table and with it draw a diagram like Fig. 3 and complete the distribution of heat as shown by Table 2. The ratio should be read to three decimal places because any error there may be in the method of distributing pressure is spread over the entire range of temperature and the intervals of temperature and pressure are obtained with a desirable degree of regularity.

To show the insensitiveness of the method we may note that variation in the ratio of heat changed into work to the total available heat is as follows:

| | | | |
|---|---|---|---|
| Heat factor | 0.55 | 0.65 | 0.75 |
| Intermediate temperature | 218 | 219 | 220 |
| Intermediate pressure | 16.5 | 16.9 | 17.2 |

And further to show that a considerable variation in pressure has but a slight effect we may compare results with a ratio selected from Table 2 and with the proper ratio for the range of pressures.

| Heat factor 0.65 | Tabular Value | Special Calculation |
|---|---|---|
| Initial temperature | 366 | 400 |
| gage pressure | 150 | 232 |
| Final temperature | 102 | 102 |
| vacuum, in | 28 | 28 |
| Ratio | 1.07 | 1.075 |
| Intermediate temperature | 231.8 | 232.1 |
| pressure absolute | 21.49 | 21.61 |

While I have no question that Professor Cardullo can use his graphical method effectively, I remain of the opinion that a numerical computation with the aid of the temperature-entropy table will be found more accurate and rapid.

W. D. Ennis (written). The simplicity and exactness of Professor Cardullo's method lie in the use of the corrective factor $K$ which he has discovered. In designing a multi-stage turbine, either some inequality in the heat drops for the different stages, or a rather prolonged adjustment must be contemplated. There seems to be no clear reason for the form of this new corrective factor and one is inclined to doubt the generality of application of such expressions. I have, however, found it to fit another set of conditions than those given in the paper and am prepared at least to try it in additional cases.

TABLE 3 HEAT DROP IN 6-STAGE TURBINE

| Absolute Pressure Lb. per Sq. In. | Entropy | Heat Contents, B.t.u. |
|---|---|---|
| 160 | 1.629 | 1252 0 |
| 81 | 1.661 | 1216.8 |
| 39 | 1.6935 | 1181.6 |
| 17.3 | 1.731 | 1146.4 |
| 7.3 | 1.772 | 1111.2 |
| 2.9 | 1.814 | 1076.0 |
| 1.0 | 1.863 | 1040.8 |

Consider a turbine having an initial pressure of 160 lb. abs., with 100 deg. of superheat. Expanding down to 1 lb. abs.: six stages, steam consumption 12 lb. per h.p-hr. The initial heat contents is 1252, the final (after adiabatic drop) 911: making the heat drop 341 B.t.u., the efficiency $E = 0.62$, and $K = 0.0608$. The ideal heat drop per stage, corrected by the $K$ factor, is then 60.2 B.t.u.; the actual drop is $\frac{341}{6} \times 0.62 = 35.2$ B.t.u. This leads to Table 3.

The whole heat drop is very nearly 1252 − 1040.8 = 212.8 = 341 × 0.62. It would be interesting to know how the expression for $K$ was obtained and whether it has further justification than the one that it "works," which is of course excellent.

THE AUTHOR. The objections raised by Mr. Herschel may be classified as follows:

*a* That the method proposed will not give satisfactory results when wet steam is used in the turbine.

*b* That it will not give satisfactory results when superheated steam is employed.

TABLE 4 FOUR-STAGE TURBINE

INITIAL STEAM PRESSURE 14.70 LB. ABS., INITIAL QUALITY 85 PER CENT, TERMINAL PRESSURE 0.594 LB. ABS., ASSUMED EFFICIENCY 70 PER CENT.

$$\Delta H = 168.8 \quad \frac{\Delta H}{n} = 42.2$$

$$0.00056\,\Delta H\,(1 - E) = 0.028$$

| $\frac{n-k}{n}$ | $0.028\,\frac{n-k}{n}$ | $h$ | $H$ | Pressure | Entropy | Actual Heat Drop | Actual Heat Content |
|---|---|---|---|---|---|---|---|
| 0.75 | 0.021 | 43.1 | 1004.6 | 14.70 | 1.54 | | 1004.6 |
| | | | 961.5 | 7.19 | 1.54 | 43.1 | 961.5 |
| 0.25 | 0.007 | 42.5 | | | 1.56 | | 974.45 |
| | | | 919.0 | 3.278 | 1.56 | 43.1 | 931.85 |
| 0.25 | 0.007 | 41.9 | | | 1.582 | | 944.2 |
| | | | 877.1 | 1.426 | 1.582 | 43.1 | 901.1 |
| 0.75 | 0.021 | 41.3 | | | 1.604 | | 918.05 |
| | | | 835.8 | 0.594 | 1.604 | 43.1 | 869.95 |

*c* That it assumes the losses to be equal in each of the stages.

*d* That it assumes all of the losses to be of such a character as to increase the entropy of the steam.

The answer to the first objection, namely that the method is not satisfactory when applied to wet steam, may be seen in Table 4, in which will be found the calculations for a turbine taking a steam of 85 per cent quality and expanding it from a temperature of 212 deg. to a temperature of 85 deg. This is an extreme case and there is no reason why a turbine should be supplied with steam of this quality even though the steam rejected by the engine unit is of 85 per cent quality. The use of a separating receiver between the engine and the turbine would eliminate the water without appreciably decreasing the admission pressure to the turbine. It will be seen from Table 4 that the calculation by this method of the pressure and energy drops in the different stages give results which check absolutely.

Mr. Herschel's objection that the method does not apply to superheating steam is valid, although a much closer approximation to the proper pressure and energy drops per stage may be obtained by employing this method than by the assumption of adiabatic expansion. In Table 5 will be found the calculations for a very extreme case. The turbine is assumed to take steam at 215 lb. pressure and 226 deg. superheat and to expand it to atmospheric pressure. It will be seen there that the calculated energy drop per stage is 59.3 B.t.u., while the actual energy drop in the first stage is 59.3 B.t.u., in the second, 60.2, in the third, 62.8, and in the fourth 59.3 B.t.u. By employing the method, the energy drop per stage is much more nearly equalized than it would be otherwise.

TABLE 5 FOUR-STAGE TURBINE

INITIAL STEAM PRESSURE 215 LB. ABS., INITIAL SUPERHEAT 225 PER CENT, TERMINAL PRESSURE 14.70 LB. ABS., ASSUMED EFFICIENCY 70 PER CENT.

$$\Delta H = 230.6 \quad \frac{\Delta H}{n} = 57.65$$

$$0.00056\ \Delta H\ (1 - E) = 0.039$$

| $\frac{n-k}{n}$ | $0.039\ \frac{n-k}{n}$ | $h$ | $H$ | Pressure | Entropy | Actual Heat Content | Actual Heat Drop |
|---|---|---|---|---|---|---|---|
| | | | 1322.5 | 215 | 1.67 | | |
| 0.75 | 0.029 | 59.32 | 1263.2 | 122.7 | 1.67 | 1263.2 | 59.3 |
| | | | | | 1.6885 | 1281.0 | |
| 0.25 | 0.010 | 58.22 | 1205.0 | 66.0 | 1.6885 | 1220.8 | 60.2 |
| | | | | | 1.71 | 1238.9 | |
| 0.25 | 0.010 | 57.08 | 1147.9 | 31.97 | 1.71 | 1176.1 | 62.8 |
| | | | | | 1.7345 | 1195 0 | |
| 0.75 | 0.029 | 55.98 | 1091.9 | 14.70 | 1.7345 | 1135.7 | 59.3 |

It must be remembered that this method is in the nature of a rule of thumb for determining as closely as possible the pressure of the steam as it enters the several stages of a turbine, on the assumption that the energy drop is the same in every stage. It is intended as a preliminary to the actual design of the steam passages and the vanes of the several stages of the turbine. In order to obtain a workable rule the difference in the efficiencies of the several stages was disregarded. Had this difference been taken into account the method would become tremendously complicated and the final results practically identical with those obtained by employing the method in its simplified form. While the method is theoretically incorrect and inexact, in practice it is much more accurate than is our knowledge of the properties of steam or the efficiencies of turbines, and therefore as accurate as is necessary or desirable.

The only losses in a steam turbine which do not increase the entropy are those due to bearing friction and radiation. In any case these are an exceedingly small fraction of the total heat supplied to the turbine and are therefore negligible in comparison with the losses which increase the entropy of the steam. To separate these losses is impossible and unnecessary and, as pointed out by Professor Peabody, slight changes in the assumed efficiency of the turbine have almost no effect in changing the value of the factor $K$ in the equation.

I agree with Professor Peabody that a numerical computation by the aid of the temperature entropy table is more accurate than the employment of the Mollier diagram and that, in general, analytical methods are to be preferred to graphical ones for work of this kind.

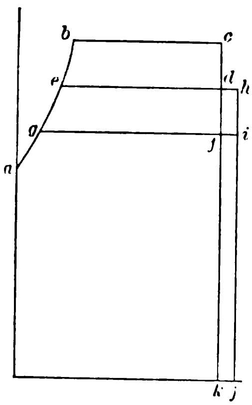


Fig. 4

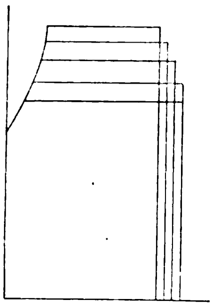

Fig. 5

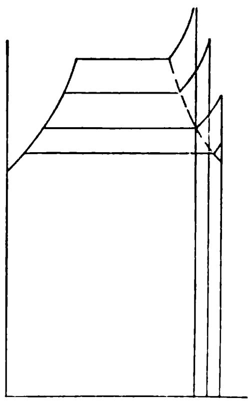

Fig. 6

Diagrams Illustrating Effect With Wet Steam and Superheated Steam

Professor Ennis shows that when the amount of superheat is not extraordinarily high, the method gives satisfactory results. On the other hand, for extreme conditions of superheating, it is not so exact.

Why the method works is shown in Fig. 4 which represents the temperature-entropy diagram of a turbine employing wet steam as a working fluid. The line *ed* is drawn so that the area *gbcf* is divided into two equal parts, in order that there shall be an equal distribution of energy in the two stages. Then the heat transformed into work in the nozzles of the first stage is *ebcd*. Of this a certain fraction is retransformed into heat and passed on to the second stage, this heat being represented by the area *dhjk*, of which *dhif* is retransformed into work in the second stage, and the total quantity of heat transformed into work in both stages is *gbcdhi*. It will be seen that as the total heat drop increases, the proportion of the heat supplied which is transformed into work, also increases, so that the quantity *dhif* becomes a larger and larger proportion of *dhjk*, as the total heat drop increases. The extra amount of heat added per stage is therefore proportional to the total heat drop. By increasing the number of stages to four, we will get the condition of affairs shown in Fig. 5, in which the shaded areas are added as well as the areas already added in Fig. 4. Hence we must introduce the factor $\frac{N-1}{N}$ in obtaining the value of $K$. The amount of heat added to the steam entering the second stage by the inefficiency of the first stage is of course proportional to one minus the efficiency of that stage; hence we have the factor $1-E$. Finally the factor 0.00056 is obtained by trial and adjustment.

Fig. 6 shows why the method is not exact when applied to superheated steam. It might be made exact by introducing a factor whose value would depend upon the degree of superheat of the steam, but this introduces a complication, which destroys the simplicity of the method, and which is therefore objectionable. Rather than complicate the method, we may calculate the heat drops in the several stages as in Table 5, take their average, and employ that as the heat drop per stage. The average of the actual heat drops is 60.4. The computation of the proper pressures for each stage may be made accordingly.

# SYMPOSIUM ON CEMENT MANUFACTURE

## SOME PROBLEMS OF THE CEMENT INDUSTRY

By Walter S. Landis, Published in The Journal for April

### ABSTRACT OF PAPER

Progress and improvement in the cement industry has and will resolve itself into the development of the plant as against the process. The chief features of interest in this plant development are the question of size of first crushing unit, the fineness of grinding of the raw materials before entering the kiln, the gradual displacement of the wet process by the dry one, better utilization of the fuel in the clinkering of the raw material, and the abandonment of the air separator. The older mills must be remodelled along the lines of more economical power distribution and labor requirements to compete successfully with the modern mills, now that profits in cement manufacture have dropped so low.

## THE EDISON ROLL CRUSHERS

By W. H. Mason, Published in The Journal for April

### ABSTRACT OF PAPER

The causes leading to the design of the Edison crushing rolls are outlined and a comparison made of the energy of coal as compared with that of dynamite in breaking up stone in the quarry, with a description of the method of quarrying now employed in conjunction with Edison roll crushers. These rolls store up kinetic energy for use in crushing and sledging large stones and a comparison is made in this connection of rolls of various sizes. The power required for crushing by this method is shown by tachometer records, from which speed, energy and horsepower curves are plotted. Records are given covering a period of two years of the time lost and the cost of repairs on the crushing plant at the Edison Portland Cement Company. Comparisons are made between the theoretical capacity of these rolls and the actual capacity as shown by tests. Both of these are enormously greater than for the gyratory crushers and in addition, the larger size of the stones which can be handled by the rolls greatly simplifies and cheapens the quarrying operation. The crushing plant of the Tomkins Cove Stone Company which has a capacity of 1000 tons an hour, is described.

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Presented at the Spring Meeting, Pittsburgh, 1911, of The American Society of Mechanical Engineers. All discussion is subject to revision.

## POWER AND HEAT DISTRIBUTION IN CEMENT MILLS

By L. L. Griffiths, Published in The Journal for June

### ABSTRACT OF PAPER

**This paper compares the methods used and the results obtained in five different cement plants for converting the thermal power of the fuel into productive mechanical work. A brief description is given, both of the power installation and of the mill arrangement; and the relative efficiencies of different raw materials, types of grinding machinery and engineering arrangements are considered. The data are such as to enable comparisons to be made between the same types of machinery, and in most cases, the same size and make of machinery, at least in individual departments, if not throughout the entire plant.**

### DISCUSSION

H. Struckmann (written). In Par. 26, Professor Landis calls attention to the value of using the heat from the discharged clinker, stating that this practice has proved unsatisfactory in this country. The writer wants to add his testimony that utilizing the heat in the discharged clinker is of the greatest value for preheating the air necessary for combustion. In Europe when the first rotary kilns were installed, the heat was pulled by exhausters from the underlying rotary cooler and blown into the kiln mounted above it. Considerable difficulty was experienced in handling the large volume of air at the temperature at which it was received from the cooler.

The modern installations are now practically all using a process by which fans are blowing the necessary amount of cold air into the cooler, which is virtually put under pressure. This air, after having absorbed the heat from the clinker, is delivered through air ducts, entering the kiln on both sides of the hood, at a temperature as high as 1000 deg. fahr. The advantage of this installation is very evident, since the cold air handled by the fans is a very much smaller volume than the heated air. The heat available in the clinker is not only sufficient to furnish the necessary air for combustion, preheated to a temperature of 1000 deg. fahr., but also to dry the coal preparatory to the grinding process, resulting in a large saving of fuel.

The statements which Professor Landis makes about the wet process are not borne out by experience with the most modern wet installations in Europe. The explanation in Pars. 17 and 18 indicates that Professor Landis is comparing the old-style short-kiln installation, where the material was dried before it was ground, with a modern dry-process installation with long kilns. Such a comparison is hardly fair to the modern wet plants now being designed and operated in Europe. There is no question but that a 60-ft. kiln burning wet is an extremely wasteful proposition, but with the development of the long kiln the situation has been entirely changed.

It has been conclusively proved that grinding the raw material in wet condition with proper machinery reduces the horsepower from 30 to 40 per cent, besides increasing the fineness very materially and entirely eliminating the mill dust problem, which deserves a good deal of attention.

If we combine the drying and burning in one rotary, we would have a kiln about 185 ft. long, basing the figures on a 60-ft. dryer and 125-ft. kiln, the two sizes now most generally used.

As a general rule in comparing the wet and dry processes, only the 125-ft. dry kiln is compared with the same size wet kiln, no attention being paid to the fact that the dry kiln requires an additional 60-ft. rotary to take care of the drying of the material. Of course as a result greater economy is apparently effected on the dry process. If, however, we compared the burning unit of the dry process with the corresponding burning unit of the wet process, the result would be entirely different.

The writer has made a number of experiments in order to ascertain how many feet of the kiln are required to evaporate the 30 per cent of water contained in the slurry, as it is being fed to the modern wet kiln, and finds that approximately 35 to 40 ft. is all that is necessary to put the material in virtually the same condition as when being fed to the dry kiln. If we deduct this 35 to 40 ft. from the wet 185-ft. kiln, we have a larger kiln with a resulting larger output and lower fuel consumption.

There are quite a few plants in this country today which would turn out a much more superior and reliable cement under the wet than the dry process, because in handling the slurry a perfect mixture is obtained. While this would not be the case with the Lehigh Valley plants, where a natural cement mixture is found, judgment ought scarcely to be passed on a process based on the condition of one small part of a country. There are a number of plants in the West in which the raw material in natural condition contains from 10 to 20 per cent of moisture, requiring a large amount of heat to evaporate, and considering all these facts, the writer fails to see why the wet processes should be eliminated entirely in the investigation of a cement proposition.

Professor Landis failed to touch on one subject in connection with the wet process, namely wet grinding, and the laboratory tests given in Table 5 may be of some interest. In carrying out these tests the raw material was prepared to a fineness ranging between 20 and 30 mesh sieve and 1500 grams were used as a charge in a laboratory mill. Ten separate tests were run, each lasting 55 min. The first test was run with dry material and afterward various percentages of water were added, as indicated in the test.

From these tests it is clearly demonstrated that from 30 to 32 per cent of water gives the greatest efficiency in grinding the material. With the increased fineness made possible by the wet grinding process, a great deal of fuel is saved. In some of the plants with which the writer is connected, natural gas is used for fuel and each kiln is equipped

TABLE 5 LABORATORY TESTS ON WET GRINDING

| Test Number | Per Cent $H_2O$ | 100-Mesh | 200-Mesh |
|---|---|---|---|
| 1 | 0 | 92.0 | 75.0 |
| 2 | 25 | 98.4 | 80.8 |
| 3 | 28 | 99.8 | 87.0 |
| 4 | 30 | 99.2 | 86.8 |
| 5 | 32 | 99.6 | 84.8 |
| 6 | 35 | 96.8 | 80.6 |
| 7 | 37 | 96.8 | .... |
| 8 | 40 | 96.6 | 80.2 |
| 9 | 45 | 96.4 | 80.8 |
| 10 | 50 | 95.2 | 79.6 |

with separate gas meters, giving a complete record of the amount of fuel used in each kiln. Experiments carried on for long periods with a varying fineness of the raw material showed an average of 56 cu. ft. of gas for each per cent of greater fineness between 88 and 96 per cent through the 100-mesh sieve. In other words, each percentage of finer raw material effected a saving of about 47,000 B.t.u. per bbl. of clinker produced. Besides this saving in fuel, it was found that the capacity of the kilns, which were 7 ft. 6 in. by 125 ft., was greatly increased, the output per 24 hours being as follows:

88.5 per cent fineness........................454 bbl. per day
90.0 per cent fineness........................534 bbl. per day
92.5 per cent fineness........................591 bbl. per day
94.0 per cent fineness........................600 bbl. per day
96.0 per cent fineness........................620 bbl. per day

In view of these facts it is a question whether the wet process as it is developed today does not represent the most scientific method of producing Portland cement, where the raw materials are more or less mixed and contain a large percentage of moisture in natural condition.

P. C. Van Zandt (written). The crushing of rock is probably one of the most ancient human industries, and the course of its progress from a crude process into one worthy of scientific regard is interesting and instructive.

In Par. 9, Mr. Mason states that before Mr. Edison constructed his giant rolls the largest rolls in use were those known as Cornish rolls, which were geared together. These rolls were also built at that time for separate belt drives without being geared together, but, with only one or two exceptions for use on rock, the roll shells were smooth-

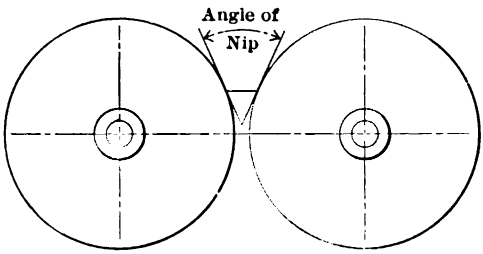


Fig. 17 Angle of Nip on Smooth Rolls

faced. Rolls for crushing coal were then built as they are now with spikes or projections and, as far as the writer can remember, coal rolls were hardly ever built smooth-faced, nor rolls for use on rock other than smooth-faced.

In the crushing of rock the angle of nip as shown in Fig. 17 determined the largest piece of rock that could be fed to a set of smooth rolls, while no such limitation existed in the crushing of coal with spiked rolls, which automatically broke the large pieces of coal into fragments small enough to be nipped. Mr. Edison's rolls, like his rotary kiln, were unquestionably very much larger than anything in use at that time and he alone seems to have foreseen the direction of growth of the industry. The comparison of the kinetic energy stored in the rolls in use at that time and in the rolls built by him shows the magnitude of his step, while other builders of these machines were merely creeping along from one size to the next, Mr. Mason's comparison of the maximum size of rock fed to a gyratory crusher and to a set of rolls is slightly unfair to the former machine. The largest gyratory crusher built at the present time has two openings 48 in. wide by approximately 9 ft. long, this opening being on a curve somewhat the shape of the letter *C*. The writer has seen a piece of rock fed to a gyratory crusher of the 42-in. size whose dimensions were approximately 3 ft. by 5 ft. by 9 ft., this rock being dropped end down and going through the machine as though it were being eaten up. The writer is further of the opinion that the maximum sized piece fed to a set of 6 ft. by 7 ft. rolls would have to be more nearly 7 ft. in diameter than a 7 ft. cube and of spherical shape, to have it turned over by the rolls and new surfaces presented for crushing. However, in the writer's opinion such a set of 6 ft. by 7 ft. crushing rolls, will take a larger piece of rock for crushing than any other machine in existence in the world today.

In Par. 11, Mr. Mason describes the jiggling onto the car or skip by the steam shovel operators of a piece of rock too large to go from the teeth of the dipper through the dipper itself. The writer has seen this done a great many times and judges that in some quarries it is rather difficult to prevent. The limit of size of rock that can be economically handled, and there must be a limit somewhere, is in the writer's opinion, the biggest piece that can be handled *through* the dipper. The steam shovel operators like to make a showing for tonnage and efficiency in the quarry by sending up to the crusher as large pieces as they can handle. Occasionally a piece which is too big for the hopper of a set of rolls or a gyratory crusher is sent up, which has to be broken or blasted or returned, causing considerable delay at the crusher, which together with the expense represents a larger cost than the breaking of a dozen of these pieces in the quarry. Damage to the quarry cars or skips caused by dropping these big pieces of rock is also troublesome. The kinetic energy in the piece of rock striking the car compares favorably with that in the crushing rolls, when in one case the cars are smashed and in the other the rock. By comparison a large piece of rock handled *through* the dipper can be laid in the car very gently.

The writer has examined the tachometer record of test *K* very carefully and does not understand why these records which show the drop in speed of the two rolls so clearly, do not distinguish between the slugging and crushing action. It may be that Mr. Mason has other charts which do show this, and it would be interesting to have his opinion regarding the crushing action of these large rolls upon large pieces of rock. A piece, perhaps the size of a roll top desk, is dropped into the rolls and is first subjected to what may be called a slugging action, in which it is tossed around in the hopper, the corners broken off, and finally shattered into pieces small enough to be caught within the angle of nip of the rolls. The second or crushing operation then takes place and the rock caught in the angle of nip is immediately carried through the rolls and crushed by pressure to a size sufficiently small to pass the available space between the rolls.

It would seem that the maximum tendency to vary the speed of one roll in relation to the other would exist in the slugging action, when first one and then the other roll strikes a large piece of rock; while in the crushing action, as Mr. Mason states in Par. 17, the action of the stone in passing between the rolls would tend to gear the rolls together, in other words, to cause them to rotate at the same speed. The curves plotted from the tachometer charts show an almost simultaneous drop in speed during the slugging action, with a difference in time of a small fraction of a second, while the recovery of speed in the two rolls, probably after the bulk of the crushing action has taken place, shows a much greater difference in speed, the curve giving apparently the reverse of what the writer would suppose the action to be.

In Par. 21, Mr. Mason gives the cost of repairs per ton of rock crushed, which the writer thinks is very good. He has seen records of lower costs of repairs on gyratory crushers, but as a partial offset, it must be remembered that they will not take pieces of rock so large. The horsepower required in the rolls per ton of rock crushed is also greater than the gyratory crushers, but the same partially offsetting advantage also applies here.

The questions raised in Professor Landis' article, Par. 12, namely, how much does it cost in investment, interest, repairs, depreciation, etc., in a rock-crushing plant to provide means for crushing the few larger pieces of rock that come to the crusher in the course of a day's operation, and does the saving affected more than offset the additional cost, must be answered for each individual case, depending upon the cost of installation, location, the desired capacity, the kind of rock and the use to which the rock is put when crushed. We must reach a limit, where Mr. Soper's law of pivotal points or decreasing returns will apply, and in the writer's opinion, this place has been reached and in some cases passed, with equipment in existence today. There are probably a few isolated places where still larger crushers could be used to advantage, but he considers them very few in comparison with those where the larger crushers could not be so employed.

In Par. 23, Mr. Mason refers to the crushing strains being taken up internally because the rolls act as an anvil. As a matter of fact, the enormous crushing strains do not reach the bearing or frame without being greatly absorbed, since if this were not the case neither would withstand the strains that would come upon it. It is a question, however, whether the gyroscopic action of these enormously heavy, rapidly revolving rolls does not do a great deal more to absorb the crushing strains than the inertia due to the weight of the rolls themselves, irrespective of the rotation.

In Par. 27, Mr. Mason estimates the capacity of the rolls at 55,000 tons per hour, if a solid stream of crushed rock were delivered from the rolls. His method of calculation is practically the same as that used in obtaining the capacity of smaller smooth-faced rolls. In his computation the writer has assumed that these smaller rolls were filled with soft plastic clay which would pass between the rolls with no voids, and he has figured the contents of the ribbon of clay that would be wound through the rolls in a minute or an hour in cubic feet. For rock he has assumed that a certain proportion based on actual practice of this theoretical cubic feet content would be voids, and that the balance would be crushed rock, weighing 100 lb. per cu. ft. Thus for the problem in hand, Mr. Mason states that 18,306 cu. ft. would pass the rolls in one minute. Assuming nine-tenths to be voids and one-tenth rock, as would be the maximum in rolls of this character in normal operation, 1830 cu. ft. of rock would actually pass the rolls, which at 100 lb. per cu. ft., would be 91½ tons per minute, or 5490 tons per hour.

In Par. 28, Mr. Mason describes a means of cutting off the current from the motor driving the rolls to avoid the peak loads. I do not exactly understand how this operates, assuming the motor to be an induction motor, as the current consumed by an induction motor varies inversely in speed, that is, the slower the speed, the greater the current consumed and the power output. Thus, assuming that the motor was not disconnected, the rolls would not be slowed down as much in the crushing action, on account of the power supplied by the motor, as if the motor were disconnected during the crushing action. After the crushing had been accomplished, therefore, in the case of disconnecting the motor when the current was turned on again, the motor and rolls would be rotating at a slower speed than if the motor was not disconnected, and the peak load of current used would be greater until the rolls had been brought up to speed again.

Professor Landis' paper gives the impression that mechanical engineers engaged in the cement industry have not done so much toward developing this industry to the highest possible state of efficiency as they should, or as engineers engaged in other industries have done during the same period of time. Thus the figures given in Par. 26 of 16 lb. of coal required theoretically to burn a barrel of clinker, as opposed to 90 lb. of coal actually used, seem especially bad; but upon considering what these figures mean, and comparing them with the efficiency in the use of coal in railway locomotives, steam power plants, etc., they appear on the contrary to be exceptionally good. For example: a locomotive burning 4 lb. of coal per h.p-hr. at 12,000 B.t.u. per lb., uses 48,000 B.t.u. per h.p-hr., while theoretically it should have used approximately 2540 B.t.u.; or where 90 lb. of coal was burned, theoretically the combustion should have been 4¾ lb.

Making the comparison with a gas engine, using 1 lb. of coal per i.h.p. at the same heat value, 12,000 B.t.u. is used, where 2540 should have been used; or where 90 lb. of coal is consumed less than 20 lb. should have been used. When the actual amount of fuel consumed in locomotives and in stationary power plants is compared with that used in the cement industry, the waste by comparison is very much greater in these other industries and the cement engineer as well as the cement chemist, should be congratulated upon making so excellent a showing in comparison with the development of economies in other industries during the same period of time. Greater fuel economies are desirable in the cement industry and I think everyone is working towards this end. Engineers engaged in other industries can unquestionably make themselves valuable, by pointing out methods of economy that have been developed in their own line, with all the details of which those engaged exclusively in the cement industry may not be familiar. The freer the interchange of ideas between engineers engaged in one industry and those engaged in another, the better for both. For example, the question of dust collecting in the cement industry is more or less in its elementary stages, while in the smelting of precious ores it has been carried to a fine point and there are ample data and plenty of examples available.

The point made in Par. 12 of Professor Landis' paper, has already been referred to. Every plant manufacturing cement from rock has a crushing plant in connection with it that is very similar to a great number of commercial crushing plants in existence in this country and the problems are the same in both as regards the size of the largest crusher. There is no question but that it can be overdone, but this does not seem the tendency in the cement industry. There seem to be very few cement plants that can afford to use a smaller crusher than a No. 18 gyratory with two 36 in. by 8 ft. receiving openings, and unless the rock is mined or quarried by the gloryhole process, or lies in ledges so thin that it is blasted into very small pieces, no cement plant should have a crusher smaller than a No. 12, having two openings, 27 in. wide. While it may be true that only a few pieces of rock will come from the quarry more than 36 in. across, it is equally true that a great many are only a little smaller than this.

In Par. 13 Professor Landis states: "It is only recently that attempts have been made to utilize the hot gases from the kilns to perform the drying of the mix." Professor Landis would seem to be mistaken, as several installations made eight or ten years ago are recalled by the writer, as well as a number made at various intervals since then, and he believes this has been tried a number of times in Germany; while he does not know of any recently made and working with great success. The difficulty is not all in the drying of the rock, as in many cases this can be done easily, but in the hampering of the kiln in its primary function of producing Portland cement. Any attempts to save waste heat that hamper the kiln in this function are ultimately a detriment. This has been the greatest drawback to the utilization of the waste gases. Another thing that must not be overlooked is the fact that these waste gases are absolutely inert and do not contain any burnable gases. The only heat value they possess is that due to their temperature alone, and they put out any auxiliary fire with which they may come in contact since they consist of a very great percentage of $CO_2$ and N. It would be interesting to know more of the details of the recent installations referred to by Professor Landis in Par. 13, as the writer believes that a way will be discovered eventually to utilize the waste gases, which carry away most of the heat now lost, without hampering the kiln.

Par. 16 deals with the value of the impalpable powder produced by the grinding machines and the loss of this powder occasioned by air separation. Both air separation and fine screening can be carried too far, but either are advantageous up to a certain point, since by taking out a certain portion of this impalpable powder from a grinding machine, it prevents the cushioning of the blow of the grinding parts which results when the machine is largely filled with this fine powder and prevents the grinding of the coarser particles.

Par. 17 relates to the wet process. Unquestionably a great deal can be learned regarding the efficient use of this process from Germany, since wonderful strides have been made there in the past few years. It is considered at present by some of the eminent engineers to be better than the dry process. While this may be true in Germany, however, this country has made such wonderful strides in the development of the dry process, that it is the full equivalent of and probably a little superior to the modern wet process in Germany.

In Par. 18, Professor Landis refers to 50 or 100 per cent of water in a mass of ground material in the wet process. In Germany at the present time what the thick slurry process is called is running on as little as 25 per cent or less of water.

As regards storage, discussed in Par. 20, the question of shutting down everything but the rotary kilns in a cement mill over Sunday, in order to establish better conditions for the workmen, is just arising. It is becoming more and more difficult to get good operators to work seven days a week all through the season and I believe shutting down the mill on Sundays will ease the labor situation, as well as permit such repairs as are required to be made during the busy season, without loss in time to the kiln.

Par. 22 states that in size these kilns vary from 60 ft. long and 5 ft. in diameter up to 240 ft. long and 12 ft. in diameter. There are kilns in use varying from one size to the other, but the modern cement plant does not install a kiln smaller than 125 ft. by 8 ft., and 150 ft. by 10 ft. would seem to be very much nearer the standard size kiln that will be installed in the next year or so. Kilns smaller than these are now considered obsolete.

In Par. 23 the sizes of kiln stacks are discussed. At least two of the better manufacturers of kilns have now carefully established sizes of kiln stacks and all kilns of any given size have the same size stack, which is properly adapted to the kiln with such minor modifications as might become necessary, depending upon the location of the plant, either in a valley between two hills or upon an open plain.

In Par. 26 reference is made to the saving in heat in the rotary kiln by regeneration in an undercooler. The installation of a rotary cooler immediately under the kiln is an ideal one where it can be made. The writer has, however, been unable to figure out a greater fuel saving than approximately 5 per cent, the amount actually borne out in practice.

Regarding the saving in heat lost by radiation from the kiln shells, without questioning its desirability the writer has found heretofore that the extra investment required to conserve the small amount of heat that can be saved is too great to warrant going very far in this direction, unless the investors are satisfied with a return approximating 7 per cent or less upon the money invested. A great many people have suggested putting a covering on a rotary kiln *outside* the steel shell. This cannot be done, since in order to prevent the steel from becoming overheated and thereby weakened, the heat communicated to it from the brick lining must be radiated. The only place where insulating material can be put is inside the shell. This applies, of course, to the hot end only and this is the only part of the kiln shells where excessive radiation takes place. As a matter of fact, the question of diminishing the returns upon the investment is really what prevents the installation of a great many of the so-called economies.

The cement business cannot be conducted upon a very narrow margin at the present time on account of the fluctuation of the price. Suppose a cement plant has $1,000,000 invested in it, is earning 20 per cent during good seasons, and the investment of $500,000 more would result in the earning of 7 per cent upon the extra investment. The earning upon the entire investment would then be $15\frac{2}{3}$ per cent, and this extra investment therefore appears undesirable in an industry where the earnings may be decreased 15 per cent by a single cut in the price.

In Par. 32 it is stated that the Lehigh region is producing cement as cheaply as any district in the country and cement manufacturers have to strive hard to cut the total cost at the mill below $0.55 to $0.60 per bbl. In spite of the natural advantages in the Lehigh Valley, the average mill cost is not believed to be so low as in some other districts. There are mill costs running under the figures named, but there seems to be no standard method of calculating the mill costs. Furthermore, the publishing of these mill costs, which are very much lower than the ultimate cost is not fair to the industry, since cement sold at $0.80 per bbl., for example, would seem in consequence to carry a good profit. There are very few plants in this country at the present time that can afford to sell cement continuously for $0.80 per bbl. at the mill. The depreciation of the equipment due to the rapid strides in the industry is an item that seldom shows up correctly upon the cost sheet..

Cement manufacturers are more liberal with the interchange of data among themselves, both as regards costs and details of operation, than any other industry. To that fact alone, is due the rapid development and improvement in an industry which has placed the

United States in the front rank of all countries producing Portland cement, while 15 or 20 years ago it was behind all the great Portland cement producing countries of Europe.

## ORAL DISCUSSION

FRANK B. GILBRETH asked if the setting of cement could be delayed in any way without injury. It would be very helpful in connection with building construction to be able to add to the mixture at the time it is mixed wet, something that will keep it from setting for four or five hours without injury.

R. K. MEADE[1] replied that several materials can be added for this purpose, of which gypsum is one of the best. Engineers would probably have to use it in the form of plaster of paris. Great care should be exercised in adding it and the amount to be employed would have to be determined in each case by experiment. Up to a certain percentage plaster slows the set of cement, but after this it has the effect of quickening it.

Cement clinker as it comes from the kiln will set almost immediately. In the manufacture of Portland cement gypsum is added to delay the setting, but if too much is used the cement will set as quickly as if none had been added. Hydrated lime could also be used, but a larger percentage would be necessary, perhaps even as high as 8 or 10 per cent. Calcium chloride can be used, about the same quantity of this as of plaster being required. Sugar added in small quantities would delay the set also, but this is said to be injurious.

W. R. DUNN, in reply to a question, said that the waste heat from the rotary kilns had been used in several cases to heat water for boilers, but that it was more frequently employed to dry raw material.

Mr. Dunn stated that the loss of cement dust from the stacks of the rotary kilns could be largely but not entirely prevented by the use of large dust catchers at the end of the kilns. His practice showed this loss to be in the neighborhood of 2 per cent and at times as low as 1 per cent.

H. STRUCKMANN said that experiments had shown that from 5 to 7 per cent of the material was lost through the stacks, and that it had become necessary to prevent this loss, especially where the cement

[1]General Manager, Tidewater Portland Cement Co., Baltimore, Md.

plants are located in thickly populated districts. A solution of the difficulty was to be found in the adoption of the wet process. He had never seen a plant employing the wet process discharge as much dust from its stacks as the average dry plant.

The problem of making a plant operate under the wet system as efficiently as the dry plants is comparatively simple, and the dust nuisance is here practically eliminated.

The small amount of dust lost in the wet process can be reduced to a minimum by employing proper methods for injecting the slurry into the kiln. At the present time the slurry is delivered to the kiln in a solid stream, permitting the escaping gases to carry part of the raw material, from which the water has been driven off, with it. If spray nozzles are used, similar to the method used for injecting water into jet condensers, the gases on their way to the stack would pass this spray of slurry, which would arrest the dust and very materially lower the temperature of the waste gases, consequently increasing the efficiency of the kiln.

R. K. Meade agreed that a spray nozzle would increase the efficiency greatly, but he thought it would increase the loss of dust. He believed that more careful attention to the design of kilns and stacks would help to eliminate dust with the dry process. The opening from the kiln to the stack is often made too small, and the velocity of the gas is thereby greatly increased just at the point where the raw material is admitted. With lower velocity of gas at this point and larger dust chambers at the base of the stacks, much less would be lost than is now the case. The discharge of the raw material near the bottom of the kiln instead of at the middle should tend to reduce this loss also.

C. J. Reilly[1] stated that he had been connected with both the wet and the dry processes for a number of years, and agreed that the material does not become dry within 15 ft. of the point where it is admitted to the kiln. In the case of one of his plants, located next to a factory where newly varnished furniture was placed close to the windows, it became necessary to eliminate the dust nuisance entirely. After trying many other methods, the problem was solved by putting an ordinary cactus spray into the stack and using a small quantity of water under ordinary pressure. As the gases pass through the

[1]Supt., Sandusky Portland Cement Co., Syracuse, Ind.

spray, the dust is caught and taken to the bottom of the stack as sediment. This method has entirely eliminated the emission of dust from the stacks and the consequent loss of finely ground raw material.

G. P. Hemstreet thought that the inference might be drawn from the paper by Mr. Griffiths that the shaft and wheel drive was to be preferred for a cement plant, or for any similar process which might be described as a chain process, that is, where the material starts at one end and goes through a series of machines, a stoppage of any one of which would hinder the entire process.

About two years ago he was about to design a large stone-crushing plant, and had under consideration both the shaft-driven and the electrically-driven plant. In his visits to a number of cement and stone-crushing plants and installations of coal-handling machinery, he found quite a difference of opinion regarding the relative merits of the two types. The majority of the men in charge of these plants, however, favored the electrically-driven plant, while Mr. Griffiths seemed to believe that this type is not as efficient on the B.t.u. basis as the belt or rope-driven plant.

In a chain process there are other things to consider besides the actual operating efficiency. For example, on a large line-shaft several feet long, containing a number of clutches, pulleys and rope drives, any trouble with one of the drives will necessitate the stopping of the entire shaft or the throwing out of a large clutch. The speaker mentioned the many difficulties experienced with clutches, and and asked the experience of others present regarding the value of such installations as compared with electrically-driven plants.

F. L. Schwenck stated that the manufacture of Portland cement from blast furnace slag had become quite prevalent in Europe, and asked whether American engineers regarded this as equal to Portland cement made from other materials.

Wm. M. Kinney[1] replied that two kinds of cement were being manufactured from granulated blast-furnace slag. One, Puzzolan, or so-called slag cement, which is a mixture of granulated blast-furnace slag and slaked lime; the other, a true Portland cement, in the manufacture of which a definite proportion of granulated blast-furnace slag and limestone is first finely pulverized, then burned at a high

[1]Asst. Inspc. Engr. Universal Portland Cement Co., Pittsburgh, Pa.

temperature (close to 3000 deg.) in rotary kilns. The resultant hard clinker is ground to powder. The process of manufacturing Portland cement from slag and limestone is identical with that manufactured from natural deposits.

Over 7,000,000 bbl. of Portland cement manufactured from blast-furnace slag and limestone were used in the United States last year, being more than 9 per cent of the entire Portland cement output of this country. This material in every way fulfils the standard specifications for Portland cement of the American Society for Testing Materials and those given in professional paper No. 28 of the United States Army Engineers.

W. S. Landis asked whether the power required for grinding wet, plus that required to pump the mixture, plus that required to stir it up in the agitator, is equal to the power required for dry grinding.

H. Struckmann in reply said that a number of tests had shown an average saving of from 30 to 35 per cent in power by grinding wet, besides a much better fineness of the material.

A great many plants in the West use shale, wet clay or chalky limestone for raw material, containing from 15 to 20 per cent of moisture in the natural condition. To drive off this moisture preparatory to grinding the material dry requires as high as 300,000 B.t.u. per bbl. In such cases there is no question but the wet process is the more economical, provided the kilns are long enough to take care of the burning as well as the drying process in one operation.

The relative merits of the wet and dry process may be illustrated by the development which has recently taken place in Europe, when practice has been directed towards fuel economy, the most important item in the cost, and where the gradual gain of the wet process would indicate its merits.

C. J. Reilly referred to the statement in the paper by Professor Landis regarding the abandonment of the air separator in grinding raw materials, agreeing that the old method of separating by air is obsolete and worthless for the purpose there intended, but citing a case in which he had found a new method quite useful. In grinding a hard Trenton rock and silicious clay so that 92 to 94 per cent passed a 200-mesh sieve, it was found impossible in the ordinary way by using screens to get the output with a reasonable amount of power. An experimental plant was installed, and air separation tried in connection with a standard mill, with the result that the grinding was found to be as good as on any modern mill, although the power consumption was 35 per cent less than has yet been accomplished in the cement industry. The new method has improved the quality of the material over that coming from the tube mills, this new device being applied to the Fuller mills and entirely eliminating the tube mills formerly used for the purpose.

W. B. Ruggles said that he had recently designed a 3000-bbl. mill in which all the materials were separated by air. Ten Raymond mills were installed and gave a product of 96 per cent through a 100-mesh sieve and 91 per cent through a 200-mesh sieve. The cost of quarrying, transporting the materials through the mill on an aerial tramway, crushing, storing, removing from storage, drying, grinding with Williams mills, pulverizing with Raymond mills, and delivering to the bins of the rotary kilns is $0.71 cents per ton.

W. R. Dunn announced that a committee had recently been formed at a meeting in New York City to conduct investigations, compile reports, secure professional papers, and conduct meetings in the interests of the cement industry, under the auspices of The American Society of Mechanical Engineers. This committee would later be completed by the addition of representatives of each of the important cement-producing districts in the United States and Canada, the best available man, whether a member of the Society or not, being selected in each case. The Association of American Portland Cement Manufacturers and a large number of individuals and companies have expressed their willingness to coöperate in this work. Through the building of new plants and the rapid extension of old ones to the neglect of the technical side of the industry, this side of the question has not developed as rapidly as it should. Now that the output has caught up with the consumption, new plants will not be built so rapidly, and there will be opportunity to develop the present ones, so that it seems quite possible that a committee representing all parts of the country will be able to do very effective work along this line.

E. D. Meier, in behalf of the Society, assured the cement men present that the resources of the Society would be placed at the disposal of the industry through this committee, and that the Society would coöperate in every way possible.

## CLOSURE[1]

W. S. Landis. The cement industry, like most others of similar widespread activity, does not permit of standardization, that is, a standard mill could not be designed to fit all conditions of raw material supply, and it is thus that the problem of the wet and the dry processes has arisen. In the Lehigh region with the supply of an almost homogeneous raw material, the dry process is used exclusively. In certain other districts of the country the raw material is of such irregular composition that some sort of receiver for adjustment of the mix seems almost a necessity and the wet or semi-wet process with its slurry tanks offers a solution.

The precious metal industry has furnished us with abundant information on the advantages of wet crushing and grinding, and Mr. Struckman has given in his discussion of my paper data of direct application in confirmation of these facts, regarding fuel saving and fine grinding, which I consider to be the most valuable contribution to the industry in many years.

Admitting now that a semi-wet process can operate with approximately 35 per cent water and that the raw materials as received at the mill contain 5 to 10 per cent water, the question arises, is it most advantageous to dry this material and grind it, or to add 20 to 30 per cent more water to it and then dry it in the kiln; or is the total cost of agitating, pumping and drying in the kiln less than that of advancing to the same stage of product in the dry mill, allowing of course for the difference in grinding power? An engineer recognizes as absurd the statement often made that the evaporation of the water in the kiln takes no fuel because the gases leaving the kiln are hot anyway. Any heat used in the kiln for drying could be employed just as advantageously in raising the temperature of the dry material as in evaporating water. I am sure that all would advocate the wet process did the raw material as it is taken from the ground contain the 30 to 35 per cent water demanded by the process, but where water is actually and intentionally added, a different phase is presented. And, to complicate the question still further, we must note that certain successful mills are receiving wet raw material, drying it completely, grinding, adding water and pumping to slurry tanks for further treatment, as in a true wet process.

[1] The closures by Messrs. Mason and Griffiths will appear later.—Editor.

I think Mr. Van Zandt's comparison of fuel economy in the cement industry and in standard power practice is somewhat overdrawn. A good steam boiler will put 75 per cent of the heat value of the coal into steam. The steam engine on the other hand, transforms into work only about 20 per cent of the heat in the steam supplied, the difference, the latent heat of the condensation of the steam not being transformable into work in the steam engine. Thermodynamics teaches us that this latent heat of condensation, amounting to approximately 60 per cent of the calorific power of the coal burned under the boiler, will never be available to the steam engine, no matter to what stages engine design may be developed. If Mr. Van Zandt will leave out of the question this latent heat and examine the work of the mechanical engineer with respect to the transformation of the rest of the heat he will have a different comparison. The latent heat (reaction heat) in the case of the cement kiln amounts to only 18 per cent of the calorific value of the coal burned.

In the case of the gas engine, the comparison is more favorable. A good gas producer will put 85 to 92 per cent of the heat value of the coal burned into gas. The engineer has been too busy, however, perfecting an engine that will run to spend much time on the economical side. I firmly believe that in the next ten years the efficiency of the gas engine and accessories will be very markedly raised.

Mr. Van Zandt in discussing the use of the waste kiln gases for drying the mix has called attention to the failure of the system advocated in the paper. As this question has been brought up so often and the failures have been so pronounced it demands attention. In the installations made years ago an ordinary dryer was connected in series with a kiln. The draft of the kiln was so hindered that fuel could not be burned at the desired rate and the output was thereby greatly reduced. What else could be expected where a 4-ft. dryer is connected to the end of an 8-ft. kiln (figures somewhat exaggerated), the drier being heavily loaded with rock dropping through the free space leaving no room for the great volume of kiln gases? The free space in the drier should be even larger than that in the kiln if the draft is to be preserved. Had a 10-ft drier of suitable length been used instead of the smaller one no trouble would have been experienced. There is such an installation of drier and kiln successfully working in the Lehigh region.

Mr. Van Zandt's reference to the fuel saving by the use of an undercooler opens up an interesting question. The simple undercooler costs, in many cases, less than the elaborate cooling towers so often erected to dispel the heat in the clinker to the surrounding atmosphere. Thus its use, even if it saves only 5 per cent (I have figured it out higher than this) of the fuel is worth consideration. Again, if the cost of the plant is a serious consideration, there is the alternative of doing away with either system and discharging the clinker directly from the kilns into a car fitted with a water spray. This will quickly dissipate the heat, slake the "free" lime and so avoid the necessity of aging, and consequently soften the clinker, saving an enormous amount of power in the finishing grinding. If properly handled the clinker can be made to dry itself. I have never quite understood why more general use of this scheme was not made.

# THE PRESSURE-TEMPERATURE RELATIONS OF SATURATED STEAM

By Lionel S. Marks, Published in The Journal for May

## ABSTRACT OF PAPER

There has been great uncertainty as to the pressure-temperature relations of saturated steam in the range from 400 deg. fahr. to the critical temperature, owing to the considerable differences between the observations of different investigators. The new and authoritative work of Holborn and Baumann appears to have covered this range with great accuracy; their results are consequently presented to the Society.

With this new material the pressure-temperature relations of saturated steam are established satisfactorily from 32 deg. fahr. up to the critical temperature. It is found that these relations can be expressed by an equation of simple form based upon the van der Waals equation of corresponding states. The values of the pressure derived from this equation have a maximum difference from the best experimental values of about $\frac{1}{10}$ of one per cent in the range from 212 deg. fahr. to the critical temperature (706.1 deg. fahr.); below 212 deg. fahr. the maximum difference is 0.196 per cent at 50 deg. fahr. corresponding to a pressure difference of 0.00035 lb. per sq. in.

## DISCUSSION

W. D. Ennis. If in Fig. 2 the lengths of the approximately horizontal portions of the curves are measured, the following is obtained: at 704.1 deg. fahr., 1½ squares; at 705.3 deg. fahr., 3 squares; at 706.3 deg. fahr., ½ square. Since the critical temperature is that at which the horizontal portion becomes zero, the inference is justified that that temperature is not far from 706 deg. The 706.1 deg. assumed in the final formula in Par. 19 has a sufficient basis, and the old value, 689 deg., is certainly too low.

Professor Marks may perhaps be able to state from his examination of the Holborn and Baumann research, whether the abscissae in Fig. 2 are volumes as well as times. If so, the lengths of the hori-

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Presented at the Spring Meeting, Pittsburgh, 1911, of The American Society of Mechanical Engineers.

zontal portions of the curves should steadily decrease as the temperature increases. The measurements given indicate that they do not steadily decrease.

The final equation for pressure-temperature is in a particularly useful form. Numerical values for the derivative $\frac{dp}{dt}$ may be obtained therefrom with a minimum of computation. In this respect the new formula is far superior to that of Thiesen or to the old equations of the form

$$\log\, p = a - bd^n - ce^n$$

where $n$ is a function of the temperature, or even to the Rankine equation in which log $p$ is a function of the $-1$ and $-2$ powers of the temperature. The accuracy of the equation surpasses its convenience, and within the most extreme range of power engineering the agreement with recent tabular values may be regarded as exact.

R. C. H. Heck. Two years ago the writer compared various data as to the pressure of steam at high temperatures, and traced a curve which seemed to show the most probable trend of the true relation. On the appearance of the Holborn-Baumann determination a year later, the assumed curve was found to be well justified up to 1000 lb. pressure, or to 550 deg. fahr., which is about as far as there is any real use in attempting to extend the steam table. The whole comparison, Fig. 6, seems worthy of a place in connection with Professor Marks' paper.

The only satisfactory way to handle such a discussion is to take a mathematical formula, the simpler the better, which follows the general trend of the experimental values, and plot the small departures from that equation. Following Henning,[1] the formula of Thiesen was used, with some modification. It is preferably written in the general form

$$\log \frac{p}{p_a} = A\,\frac{t - t_a}{T} - B\,\frac{(t_c - t)^4 - (t_c - t_a)^4}{T} \qquad [1]$$

in which $p_a$ is the pressure of the atmosphere, $t_a$ the corresponding temperature, $t_c$ the critical temperature, taken as 365 deg. cent., or 689 deg. fahr., and $T$ is absolute temperature at $t$. The coefficient $A$ is the same with either thermometric scale, but the centigrade value of $B$ must be divided by $1.8^3$ when changing to fahrenheit temperatures.

[1] Annalen der Physik, 1907, vol. 22, pp. 609–630.

The original Thiesen coefficients were

$$A=5.3807,\ B=0.508\times10^{-8}\ (0.87106\times10^{-9})\ \ldots\ldots\ldots [2]$$

The writer found that by changing these to

$$A=5.3807,\ B=0.540\times10^{-8}\ (0.92593\times10^{-9})\ \ldots\ldots\ldots [3]$$

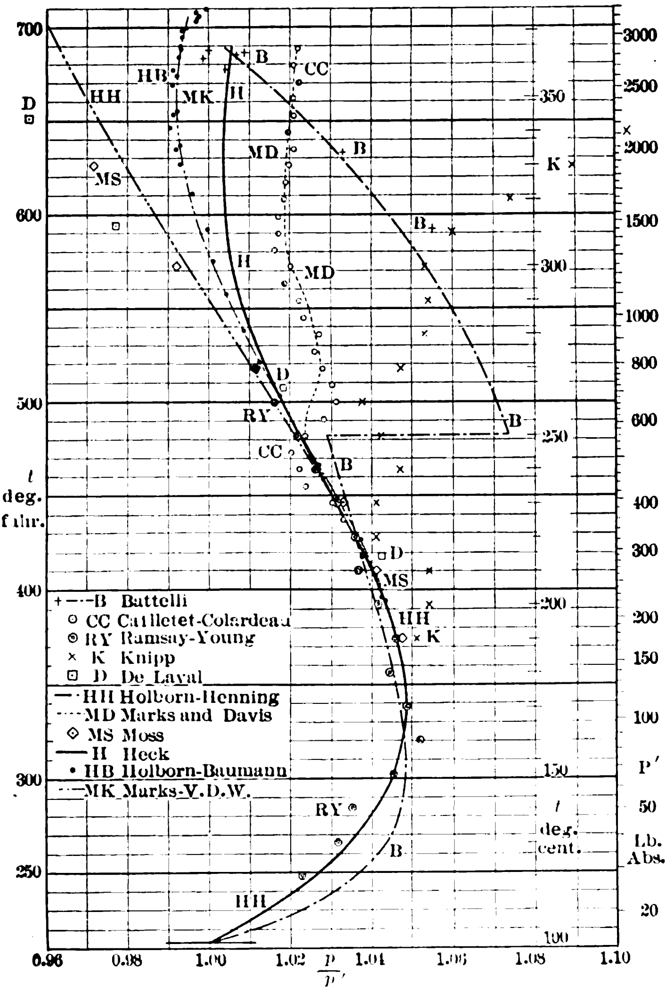


FIG. 6 COMPARISON OF DATA RELATING TO THE PRESSURE OF STEAM AT HIGH TEMPERATURES

an almost perfect agreement with the Holborn-Henning[1] determination from 100 to 200 deg. cent. was secured, as appears in Table 5.

[1] Annalen der Physik, 1908, vol. 26, pp. 833-883.

In what follows, equation [1] with these constants will be called Formula $A$.

As noted in the paper, Holborn and Baumann[1] used the values

$$A=5.3867,\ B=0.5262\times10^{-8} \qquad [4]$$

and obtained excellent agreement with the experiments below 200 deg.

TABLE 5 TRIAL OF FORMULA $A$

Pressure $p$, in Mm. of Mercury; Column $HH$, from Holborn-Henning Table; Column Form. by Formula

| $t$ Deg. Cent. | $p$ $HH$ | $p$ Form. | $t$ Deg. Cent. | $p$ $HH$ | $p$ Form. |
|---|---|---|---|---|---|
| 110 | 1074.5 | 1074.53 | 160 | 4633 | 4633.2 |
| 120 | 1488.9 | 1489.00 | 170 | 5937 | 5936.4 |
| 130 | 2025.6 | 2025.71 | 180 | 7514 | 7513.8 |
| 140 | 2709.5 | 2709.67 | 190 | 9404 | 9404.1 |
| 150 | 3568.7 | 3568.77 | 200 | 11647 | 11647.2 |

As a foundation for the comparison in Fig. 1, the first or principal term of the second member of Thiesen's equation was used to calculate a reference pressure $p'$. The coefficient $A$ was changed, by trial, with the purpose of keeping the range of data near to the reference line, and was fixed at 5.52. From the formula

$$\log\frac{p'}{p_a} = 5.52\frac{t-t_a}{T} \qquad [5]$$

were computed values of $p'$. Then at any temperature $t$ and pressure $p$, the ratio $\frac{p}{p'}$ is plotted to the scale at the bottom of Fig. 1; or, in effect, the difference, $p-p'$, is laid off as a fraction or percentage of $p'$, the latter just reaching to, or being represented by, the vertical line $AA$. Thus to plot differences as percentages makes the scheme of comparison equally sensitive over the whole range of temperature. The scale of $p'$ will give an approximate idea of the variation of pressure with temperature, obviating the need of referring to some table when examining the diagram. Naturally, Formula $A$ would have given a preferable reference line, but the work was largely completed before that formula was established.

[1] Annalen der Physik, 1910, vol. 31, p. 945.

The various data are named on Fig. 1 in chronological order, and may be briefly described as follows:

Battelli[1] fixed two sets of constants for the Biot formula (the one which Regnault preferred)

$$\log p = a + b\alpha^t + c\beta^t \quad \text{[6]}$$

These change at 250 deg. cent., but the plot shows that the two sections decidedly fail of continuity. With the upper section are given the experimental points on which it was based.

The Cailletet-Colardeau[2] measurements, from 225 deg. cent. upward, show a sudden jog of about 1.5 per cent near 250 deg., then proceed very regularly. With these points is traced a broken line from the high-temperature end of the Marks and Davis tables.

The Ramsay-Young[3] experiments run only to 270 deg. cent., but are entirely consistent. In the fixing of the writer's curve they were given predominant weight, as against any tendency to make the curve rise to the Cailletet-Colardeau plot.

The experiments of Knipp[4] do not deserve a place among data worthy of serious consideration.

A few observations reported from the original De Laval turbine works at Stockholm[5] run below Formula *A*, or the extended *HH* curve. With these are given some points computed from the Roche formula (Regnault's *K*), recommended by Moss[6]

$$\log p - A \frac{1}{B - \frac{C}{T}} \quad \text{[7]}$$

where *A*, *B* and *C* are constants and *T* is absolute temperature. This evidently runs low.

The writer's extended curve *H* was based upon the modified Thiesen equation, Formula *A*. The latter gives the dotted curve marked *HH*. The character of the deflection was determined by adopting a smooth and gradually increasing departure of the derivative $\frac{dp}{dt}$ from the range of values computed by Formula *A*, then working back

[1] Memorie d. reale Accad. d. Scienze di Torino, 1891, vol. 41 and 1893, vol. 43.

[2] Annales de Chimie et de Physique, 1892, series 6, vol. 25, pp. 519–534.

[3] Phil. Trans. Roy. Soc., 1892, vol. 193A, pp. 107–130.

[4] Physical Review, 1900, vol. 11, pp. 129–154.

[5] Engineering, 1907, vol. 83, p. 1.

[6] Physical Review, 1908, vol. 26, pp. 439–447.

to the primitive. The general idea was to parallel the trend of the *CC* points, and to aim at the middle of the group of *B* points near the critical temperature.

The Holborn-Baumann experiments are plotted as points, and with them is drawn the curve of Marks' adapted van der Waals equation, from Table 3, column 4. Of course, this last determination supercedes all others, as a statement of scientific fact. The writer, having made out a smooth and consistent extension of the steam table up to 550 deg. fahr., is gratified to find that the absolute error at this upper limit of usefulness does not exceed 0.25 per cent. A difference of 1.25 per cent at the critical temperature and the raising of the latter by 17 deg. fahr. can be viewed with equanimity.

It is of interest to note that Holborn and Baumann measured pressures with a weighted plunger. The earlier experiments were made with a closed mercury manometer; at very high pressures, the compression of the air above the mercury column becomes very much the major component, and the difficulty of precise determination increases rapidly.

THE AUTHOR. The author is glad that Professors Ennis and Heck concur in his opinion that the pressure-temperature relations of saturated steam may now be regarded as practically settled for all purposes of the engineer by the investigations reported in this paper. It is now possible to eliminate from the steam tables one of the most considerable of the hitherto existing uncertainties.

In reply to the question of Professor Ennis, the abscissae in Fig. 2 do not accurately represent volumes. They represent times, and the times depend primarily upon the rate of leakage past the weighted plunger which was used for measuring pressures. It is not possible to base any quantitative deductions upon measurements of the abscissae of Fig. 2.

It is interesting to see that the conclusions to which Professor Heck has come, as a result of his careful examination of the earlier investigations, are in such close accord with the latest investigations, and that they are a demonstration of the value of such analysis.

# RECIPROCATING BLAST-FURNACE BLOWING ENGINES

By W. Trinks, Published in The Journal for July

## ABSTRACT OF PAPER

The causes for the gradual change and progress in reciprocating blowing-engine practice are set forth. An elementary study of valve motion is given and the valve gears of present standard American practice are described. It is shown that these engines are very successful at the speeds for which they were designed, but that at higher speeds they cannot be used successfully, so that new designs had to be brought out in order to meet the pressing demand for higher speeds and lower first cost. Two American designs are described. It is shown that these valve systems, although much superior to the so-called standard gears when used for high speeds, have not yet broken with the idea that smallness of clearance is required for economy, whereas German builders have demonstrated that by the use of multi-ported plate valves large valve areas and economy at high-speed operation can be obtained in spite of large clearance. The foremost European types of plate valves are described and the results of tests are given.

It is pointed out that the bringing up of the piston speed of the blowing engine to the standard piston speed of the power gas engine or the power steam engine reduces the first cost of the reciprocating blower and that the combination of the high-speed blast-furnace gas engine with a high-speed blower constitutes the most economical method for the production of furnace blast.

## DISCUSSION

E. T. Child (written). In Par. 7, Professor Trinks refers to the difficulty which exists with all poppet valves; namely, the fluttering of the valves and the impossibility of bringing them promptly and quietly against their seats at high speeds. The last sentence of this paragraph, which states that in ordinary American blowing-engine practice poppet valves close so near the dead center that for all practical purposes they may be considered as closing on time, without slipping back of air, is true only when poppet valve engines are run at very slow speeds.

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Presented at the Spring Meeting, Pittsburgh, 1911, of The American Society of Mechanical Engineers.

In the many cases in which we have taken off heads equipped with poppet valves and replaced them with heads fitted with the Southwark sliding valves, the delivery of the engine has been increased from 50 to 100 per cent, through eliminating the loss due partly to leakage and slip, and partly to the fact that the engines could run efficiently at much higher speeds than they had been used to running with the poppet valves.

In Par. 14 and in several subsequent places, Professor Trinks speaks of obtaining pressures in the air cylinder within ½ lb. of the atmosphere. With Southwark valves, we do much better than this. We assisted some years ago at a series of tests of blowing engines with Southwark valves at the Lackawanna Steel Company in Buffalo. The report on these tests was as follows: At mid-stroke the suction varies from 3 oz. per sq. in. at 45 r.p.m.

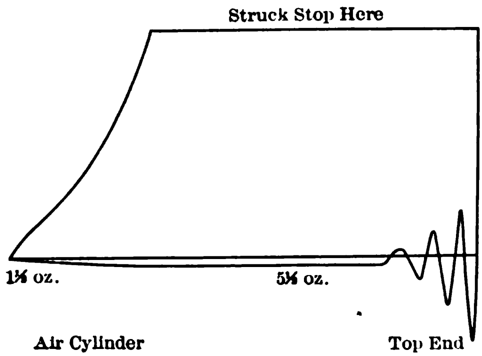


FIG. 34 TYPICAL INDICATOR CARD WITH SOUTHWARK VALVES

to 5½ oz. per sq. in. at 80 r.p.m., but at the end of the admission stroke the blowing cylinder is filled with air which is always within 1½ oz. of atmospheric pressure.

Fig. 34, shows a typical card taken during these tests. The amount given, 1½ oz., is looking at the matter from the worst point of view. It seems probable that the pressure in the cylinder at the end of the suction stroke is actually equal to atmospheric pressure, owing to the fact that the inertia of the column of air rushing through the inlet valve is enough to make up for the friction loss. This is the more likely from the fact that the Southwark inlet valve does not have harmonic motion, but remains wide open until almost the end of the stroke, when it is closed very rapidly by a cam. We are informed by Mr. Longacre, chief engineer of the

Ingersoll-Rand Company, that he has frequently found that the inertia of the air entering through well designed inlet valves is more than sufficient to overcome the friction.

It will be noticed that in Fig. 34 a very light spring was used, which does not show the top of the card at all, since the indicator struck the stop before reaching the pressure at which the blowing engine was delivering air. This light spring also accounts for the vibration at the beginning of the inlet stroke, which was doubtless due to the large inertia of the indicator parts as compared with the strength of the spring.

In connection with these tests at Buffalo, measurements were made by two methods to find out how much the air was superheated at the beginning of the compression stroke. This was found to be 4 deg. fahr. in the worst case and appeared to be due mainly to the contact of the air with the hot cylinder walls. The heating was a trifle less at high speeds than at low speeds, which shows that it was not due to friction through the inlet valve.

In Par. 20, the action of the Southwark valve gear is described and it is stated that the actuating cylinder is so proportioned that, for a given speed of engine, for a given blast of pressure and for a given method of lubrication, the valve opens at the correct instant. In modern Southwark gears, however, there is a check valve in the pipe leading air to the actuating cylinder, and this check valve is held shut by the pressure in the blast main. Air is therefore not admitted to the actuating cylinder until the pressure in the air cylinder becomes almost equal to that in the blast main. This arrangement overcomes the defect which Professor Trinks speaks of, of having the outlet valves open too soon. Also, our modern valves give considerably greater areas than those mentioned. They provide 20 per cent for the inlet and 15 per cent for the outlet whenever these large amounts appear to be desirable. If required, these amounts can be made 30 per cent and 20 per cent, respectively. We have not noted any falling off in the popularity of this valve gear. On the contrary, we have been busily engaged taking off heads of other design and substituting Southwark heads at many furnace plants in this and other countries.

The Southwark gear operates as satisfactorily at 600 ft. speed as at 300 ft. and avoids the losses due to tortuous passages mentioned by the author. Regarding the wear of the Southwark gear it will be noted that the valves do not move under pressure, but that at the moment when they are opened and shut, the pressure inside and outside the cylinder is balanced, causing the valves to float when moving. This doubtless accounts for the small amount of wear. It would not be possible to move the valves under these balanced conditions if they moved with harmonic motion, since they would then be moving practically all the time.

The performance of these valves is indicated by the record of 16 engines installed at the plant of the Lackawanna Steel Company, Buffalo, which have been running about eight years at 60 r.p.m. On horizontal gas engines in Europe, many engines run 80 revolutions continuously, night and day, and any speed less than 65 r.p.m. is abnormally slow. Of two engines 96 in. in diameter by 44 in. stroke, running 70 revolutions, one ran a total of 4475 hours out of a possible total of 4525; the other ran 4358 out of a possible total of 4452, after which one of the engines made a non-stop day and night run of over five months. Such results speak for themselves, and are not possible with engines having a large number of lifting valves, some of which are sure to need frequent attention.

We do not agree with Professor Trinks as to the quietness of the small poppet valves, since the impression we have received from all of the engines so equipped is that they were making a great deal of noise.

F. E. Cardullo thought that builders of blowing engines could follow the lead of the pumping engine manufacturers by using a large number of small valves of about 3 in. in diameter instead of large ones of 18 to 20 in. in diameter, which must be mechanically operated and are subject to unusual mechanical stresses and high temperatures. These large valves are more satisfactory with air than they would be with water, but objections are of the same character, and with high speeds are of the same validity as the objections to similar valves in water pumps. Suitable material should be used, perhaps steel plates, and with a very small rise almost no fluttering or vibration would be found. On account of the great simplicity of construction, such valves would give no trouble, and shutdowns from defective valves would be reduced to a minimum.

The Author. Professor Cardullo recommends a great number of small valves, but there would be no novelty in such a design. Fourteen years ago the writer saw a blowing engine with an almost countless number of small aluminum valves about 2½ in. in diameter, all in strict compliance with the ideal of Professor Cardullo. Yet that type of engine did not survive, partly because the failure of even one valve of that size demands a shutdown for repair, just as it does with larger valves. The frequency of shutdowns is thereby increased and since it is impossible to tell definitely which valve has let go, hunting for the location of the broken valve is aggravating.

The comparison with the water pumping engine is weak, since the great number of small valves is inseparable from excessive clearance space, a condition not harmful in water pumps, but impossible for blowing engines. Finally, the question of frictionless guiding is much more difficult for small valves than for large ones, because flexible members for small valves become too delicate to be practical. The suggestion must therefore be dismissed as impractical.

The first paragraph of Mr. Child's discussion is rather misleading because (without saying so) he refers only to the high-lift, non-mechanical closed poppet valve, found in very few American blowing engines. Mr. Child's remarks do not apply to the low-lift plate valves with frictionless guides.

The second paragraph is also ambiguous. It is true that poppet-valve cylinder heads have been replaced by Southwark heads and that great economies have been obtained by the change, but the poppet valves in these cylinders were of antiquated design. The writer does not know of a single instance of replacing modern low-lift multi-ported poppet valves by a Southwark gear. It should also be noted that in any case of replacement the old engine is usually worn out and in need of repair, whereas the new engine which takes its place is in first-class condition. As a proof of this statement the writer wishes to offer personal knowledge of two Southwark engines which, when new, furnished the wind for a furnace at 40 r.p.m. After a few years of operation these same engines had to run at 55 r.p.m. to furnish the same amount of wind.

While the writer values the receipt of the information that Southwark engineers have made an attempt to correct the harmful pre-opening of the discharge valve at slow speeds by the interposition of a check valve, he feels that it would have been of greater value to the engineering profession if it had been available at the time of preparing the paper.

Another point in Mr. Child's discussion needs attention. He states that Southwark valves do not move under pressure. If this were true they would have to move through the lap at an infinite velocity and no valve gear can be designed which is strong enough to accomplish this feat. Cam diagrams will show the untenability of his statement. It will be recognized that time for motion must be allowed and that a considerable amount of valve wear is unavoidable in order to save the operating cams from excessive wear or breaks.

# TOPICAL DISCUSSION ON INTER-CHANGEABLE PARTS

## THE ASSEMBLY OF SMALL INTERCHANGE-ABLE PARTS

BY JOHN CALDER, PUBLISHED IN THE JOURNAL FOR JANUARY

### ABSTRACT OF PAPER

The direct labor cost of assembling small interchangeable parts is a comparatively large item in light mechanical engineering and repetition work.

Economical production demands that easy assembly be kept in view at all stages from the design of a mechanism and through the tooling and shop processes to the delivery of the unit parts to the assembler.

The paper analyzes and illustrates all the elements which should enter into the producer's calculations and outlines the works organization necessary to secure the rapid and economical production of suitable unit pieces. It describes the results obtained in the assembly of given pieces and illustrates the simple apparatus used and the place that preliminary time and motion study have in assuring that the shop shall, from the first, begin operating upon the assembly of the mechanism under the most economical conditions.

## THE PROCESS OF ASSEMBLING A SMALL AND INTRICATE MACHINE

BY HALCOLM ELLIS, PUBLISHED IN THE JOURNAL FOR MAY

### ABSTRACT OF PAPER

The Ellis adding-typewriter is a combination typewriter and adding machine composed of about 3400 pieces. To secure rapid and economical assembling of such a large number of parts a very elaborate system is necessary. Not only is the machine designed to be assembled in sections, but these sections are divided into sub-sections, small groups of assembled parts, assembled parts and individual pieces, all of which are numbered. All the parts are produced by means of carefully made dies, jigs and fixtures so as to be interchangeable without special fitting. During the manufacture of the various parts a record is kept of the successive operations on each one, so that it is possible to tell at a

Presented at the Spring Meeting, Pittsburgh, 1911, of THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS.

glance what stage each piece has reached at a given time. The sheet on which these records are kept is called the operation docket. When a stock of parts has been produced, each section and sub-section is assembled independently by means of assembling charts and photographs of the parts required for each section. Numerous illustrations show the method employed and various stages of the work from the production of the parts to the completed machine.

# QUANTITY MANUFACTURE OF SMALL DEVICES

By F. P. Cox,[1] Published in The Journal for June

## ABSTRACT OF PAPER

This paper deals with the production of small but not particularly complicated devices. It assumes that the apparatus has been properly designed for economical manufacture, and discusses the organization of the shop.

The author considers it essential that change of design, except at stated periods, should be avoided; that the responsibilities of the different assistants should be sharply defined, and should not overlap; that stock handling is of the greatest importance in order to avoid interference with the labor cost, and that the chief function of an organization is to assist the workman to perform a maximum of work with a minimum of effort. Recognizing and fully believing in scientific management, he contends that an organization should be sufficiently flexible that ability in whatever form it may be found may be used to advantage, and in no case should the man be sacrificed to the system.

## DISCUSSION

Hugo Diemer said that while on a visit to the plant of the Western Electric Company several years ago, he was shown an interesting feature of their system of assembling. In connection with the scheduling of stock orders, each foreman estimated the time of completion, and after the work was done he was given a percentage rating each month based on the accuracy with which he predetermined the time of completion. Certain foremen with a percentage of 40 at the beginning of this practice were able to reach a standard of nearly 90 per cent. He wished to ask Mr. Puchta, as a representative of the company, whether this was merely a temporary effort, or if it had been continued, and whether an inducement was offered to these foremen to acquire greater efficiency.

[1] Meter Dept.. General Electric Co., West Lynn, Mass.

Edward Puchta replied that the plan of making a promise for the completion of each special order was still in effect, but the regular shop schedules were placed monthly, and it was expected that they be completed in the standard time. A record is kept of the estimates on special orders, and at the end of the month a statement is prepared showing how many of these promises each foreman has kept. No especial inducement is offered, except that the placing of one foreman's record against another's brings about competition.

C. W. Ripsch agreed with the methods stated in the papers for the division and outline of the work for the proper assembling of such machines and discussed the proper methods of fastening punchings of rolled steel made on the screw machine and the fastening of this combination to a shaft. The present method of ring staking and pinning the punchings to hubs is quite often a failure in parts which receive much pound, as the pieces loosen after continued operation. Furthermore, the cost of ring staking, drilling, pinning and lapping off the resulting surface is great whether done in the punching and hub separately or in a locating fixture. To remedy this difficulty he had experimented with the method of electrically spot-welding such parts, which serves to fasten the pieces quite securely. A chisel is required to chip apart the weld. The condition of the metal is the same except for the slight blueing and ridge thrown up around the welded point which can easily be lapped off. The main difficulty is to secure a point small enough to withstand the heat for the smaller pieces.

The next operation, fastening this assembled piece to the shaft, is usually done by a dowel pin located either centrally or to one side, or by two pins, one on each side. Owing to the running of the drill and spring due to driving dowels, the pieces will not be interchangeable and will in some cases require broaching or filing. Mr. Ripsch stated that he had failed to find a satisfactory method for this operation which would permit the elimination of the file from the assembler's set of tools, as advocated by Mr. Calder in Par. 17.

A. C. Jackson believed that it would be very helpful if Mr. Calder would supplement his paper by giving data regarding the percentage allowances on different classes of work between what is considered maximum by the rate-setter and the output of the average day worker.

CHAS. W. JOHNSON asked about the methods used by Mr. Calder in paying the demonstrators who did the preliminary work in the rate-setting department before turning the work over to the manufacturing department. He wished to know how their earnings compared with those of regular workers, and whether they really worked at their maximum capacity.

W. J. KAUP asked whether it was not true that the best men were chosen as rate-setters and if there should not be some discount made for the average workman.

N. W. PERKINS,[1] JR., representing Mr. Ellis, stated that they had found no better way of doing this work than the methods mentioned by Mr. Ripsch.

E. PUCHTA (written). Mr. Calder's paper is one of exceptional interest, especially to those engaged in the manufacture of apparatus composed of small interchangeable parts, where the assembling is a considerable item of the total cost. This, of course, would vary directly with the simplicity of the design and the requirements placed upon the apparatus to insure its satisfactory operation.

About twelve years ago the Western Electric Company, which manufactures a large number of types of telephone apparatus comprising some 75,000 separate parts, started to analyze manufacturing problems along the lines advanced in this paper. The first step was to produce interchangeable parts, which involved a very careful study of design, as well as of manufacturing methods. Later, attention was directed to the assembly of apparatus, and studies were made to determine the most efficient divisions of labor in assembly and to develop tools and fixtures which would enable the operations to be performed with the greatest facility. Since that time the work has been highly developed and all the elements involved in introducing new designs are thoroughly analyzed and standardized before work is started commercially. The adoption of these methods brought up many interesting organization problems ultimately resulting in radical changes in the organization and some changes in personnel.

It is of interest to note that the organization developed in our shops is very similar to that shown in Mr. Calder's paper. There are, however, a few points which we have worked out differently in our

[1] Engr., Ellis Adding-Typewriter Co., Newark, N. J.

study of the problem. For instance, the supplying of raw material is entirely under the control of the purchasing department. Inasmuch as the interchangeability of parts is directly dependent upon the quality of the raw material, the organization should be so laid out that the shop can control the quality of the raw material by furnishing specifications and by inspecting the product when it is received, to make sure that all manufacturing requirements are fulfilled.

No provision is made in the organization shown for raw material inspection nor for the inspection of tools, which we have found is also of great consequence. Both tool inspection and raw material inspection should be closely associated with the inspection of parts, so that the inspectors in these divisions may be kept well informed in regard to shop conditions. These two departments, as well as the departments inspecting parts and finished apparatus, should come under a common head, who, in turn, should report to the superintendent.

The chart provides that the tool designing department and the testing rates and methods department report to the head of one of the branches of the manufacturing department. Inasmuch as these departments supervise the work in their respective lines in both branches of the manufacturing organization, it would appear that they should report directly to the man to whom these two branches report.

With an efficient organization for conducting the work there is but little doubt that the fulfilment of the ten conditions outlined in the paper will place the manufacture of apparatus on a highly efficient basis.

In our shops we consider the design of a part with reference to its economical manufacture as well as quick assembly, referred to in condition *D*, of such great importance that we have adopted the practice of analyzing completely and discussing each design with the heads of all departments interested. The design is then modified, if necessary, and the particular features which have been found to be objectionable, from a manufacturing standpoint, eliminated. After the designs are finally determined upon and working drawings completed, each part and each stage of assembly are carefully analyzed by the tool designing and methods department. After the various methods are balanced against each other, the most efficient are chosen and the general design of the tools which will enable the operations to be performed with the greatest facility is decided upon. Upon the completion of the tools, and after they have been inspected and approved for quality of work, they are carefully studied to make sure that they will permit of the operation being performed with the greatest dispatch. If satisfactory in this respect a complete time study is made and the operators are informed of the exact method to be followed in performing each step of the work.

The principal difference between our method and that proposed by Mr. Calder is that our department which corresponds to his testing rates and methods department does not actually run the job in the shop to determine upon time allowances. Our practice is to have the tools turned over to the operators who are to use them commercially, and after they have been instructed and have become familiar with them, the testing rates and methods department make a careful time study of the job. At this stage the final time allowances or piece-work rates are decided upon, after having carefully compared the rates observed with those previously estimated and with established rates for similar operations.

In Tables 2 to 5 showing the assembly work, operations seem to be included which do not properly belong in such a department. For example, Stage No. 1 in Table 2 calls for a reaming operation on a unit part, which apparently could be better done in some manufacturing department, since it is not in reality a part of the assembly work. A number of similar instances occur in these tables, including tapping, reaming and bending operations.

The point made in Par. 17 that files should not be used in assembly, is a very good one, since in prohibiting the use of them the quality of workmanship on the parts has been greatly improved.

## CLOSURES[1]

F. P. Cox in reply to a question, said that in the conferences mentioned in his paper it was possible to get honest opinions from leading hands quite as well as in personal conversation. The leading hand is solely responsible for his own operations and will frankly discuss them, although as a rule he is more reticent about operations other than his own.

John Calder. Referring to Mr. Puchta's remarks, which touch in part details somewhat outside the scope of the paper, the purchasing, storing and issuing of raw material are entirely under the control of the purchasing department in the organization illustrated, but the specifications and quality are not.

[1] Mr. Ellis did not desire to present a closure.—Editor.

The chart has been necessarily curtailed in the paper and illustrates especially the general relation of other departments to parts assembly. In particular, the general and departmental inspection system, under the chief inspector and his staff, and the reporting to the superintendent and the tool engineer on the condition of parts and of tools respectively, is not exhibited.

The difference between the system described and that mentioned by Mr. Puchta, where the rate and method department does not actually run the job in the shop, or in its own section of the shop, is a vital one. It is, of course, the author's practice to watch for comparison the performance of ordinary piece-work operatives, but it is the very essence of the system described to have at all times an independent set of facts and figures obtained by a reliable staff. This practically eliminates the delays and the tedious process of guessing involved in turning over untested equipment to see what the shop will do with it.

Even the best of shops will make much greater progress in capacity and arrive quickly at more economical production if it does not start to manufacture a new piece in the dark, with only tradition and custom for guides. The best results actually demonstrated by experts, who are far more critical and resourceful than the average employee, should be used from the beginning.

Mr. Puchta's definition of assembly, embracing only work wholly performed by manual operations, is rather a narrow one. Power aids to the assembler have long been used by the author. The compounding of unit pieces, as distinct from the subsequent process of assembling machines described by Mr. Ellis in his paper, should not be restricted purely to hand work.

Many slight reaming, tapping and final setting operations can be performed properly to gage only when the finished and related unit pieces are in contact. The latter are often finished in a different manufacturing department from that in which they originated and the provision of some light machine tools in the parts assembly room is not only a desirable, but very economical proceeding. Other handling and transmission delays are thus eliminated and the responsibility for the assembled parts placed solely on the foreman and inspector of that department.

Referring to the request of Mr. Jackson for further details of the time and study system, the main effort is directed towards finding a sure basis on which to determine correct methods and fair piece rates for various classes of task and ability. Each class is rated on a percentage allowance of the study time, based on experience but usually 10 per cent less than the maximum performance. Thus all can make a fair wage and the exceptional men get all their surplus. The latter, however, does not compare with the variations under premium systems.

In the case of fast assembly on very light work by male demonstrators it is sometimes necessary in rating to raise instead of lower the standard performance, as in the case of the greater dexterity of females in work of a light fingering character involving no mechanical skill.

Answering the question of Mr. Kaup, it is not easy to get men to fulfil the functions required from a time and method study department. In fact, there is nothing easy about the task of management, but the author believes that the outside expert is not always the inevitable or the best solution of the matter. Most plants already contain enough men suitable for this work if trouble is taken to locate and develop them. Such men when organized for study work are paid a high daily rate, without reference to what task they may be engaged upon and are really retained for their potentialities. It is possible to determine from the records beyond any doubt whether the demonstrators are giving efficient and consistent service.

The effect of such time and method study work and advance criticism is that, if a body of operatives be given an entirely new job, they know the management is well aware of what can be done and that the employer has carried independent criticism of his own plans as far as practicable. If there is any doubt in their minds as to whether the rated performance can be accomplished, a demonstration is at once offered and the matter settled. This method is absolutely fair to all concerned and under these conditions the test is seldom demanded.

Confidence in the work of the demonstrators is based on the integrity and reliability of the men selected and on the ability of their supervisor to see that the work done on test is of the prescribed quality and a full measure of their powers.

The author desires to express his agreement with Mr. Cox in placing as much stress upon the development, full use and recognition of able assistants as upon the system which is employed, for the human element is half the problem. At the present time there is a tendency towards too great rigidity in some of the shop systems offered for general application. It is not a recommendation for any system, but rather the reverse, that absolute conformity to type in details without regard to the problem in hand and the great amount of experience already acquired from it are insisted upon. The best shop management is that which will draw out and adequately reward the best effort of everyone concerned, not forgetting the employer, and the best systems for so doing will never be alike in any two cases though the principles may be identical.

# POWER FORGING, WITH SPECIAL REFERENCE TO STEAM-HYDRAULIC FORGING PRESSES

By Barthold Gerdau and George Mesta, Published in The Journal for July

## ABSTRACT OF PAPER

**Various methods of producing forgings by power are discussed. Comparison is made between forgings produced by hammers and by presses with regard to quality. The particular fields for power hammers and presses are outlined. The effect of the blow of a hammer and the consumption of steam per working stroke are computed. The various types of presses are discussed with a view of determining their steam consumption under equal conditions. The computation of the steam consumption is carried out. The most interesting features of various steam-hydraulic presses are illustrated.**

## DISCUSSION

J. I. Rogers.[1] With regard to the assertion in Pars. 7 and 8, that hammer forgings have concave ends and that press forgings have convex ends, the shape of the ends really depends more on whether the hammer is heavy enough rather than whether it is or is not a hammer. There are plenty of forgings made with heavy hammers that have convex ends. In the same way there are press forgings which are apt to have concave ends if the press is not powerful enough.

In Par. 18 direct-acting presses are referred to, which, acting directly from pumping engines using fly-wheels and expanding the steam, have been in very successful operation in this country in the making of guns and armor plate. They have given very satisfactory service, the only objection being the great cost of first installation.

In Par. 22, having figured that there is about 240,000 ft-lb. of work to be done on the forging by the hammer, Mr. Gerdau compares the press with the hammer on the basis of the work necessary to accom-

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Presented at the Spring Meeting, Pittsburgh, 1911, of The American Society of Mechanical Engineers. All discussion is subject to revision.

[1] Consulting Engineer, 165 Broadway, New York.

plish equal physical results on the forging being the same with both hammer and press. I believe from actual experience that this assumption is incorrect. The amount of work to be done on a forging depends upon the speed with which it is done. That is, a hammer does not need to be quite so large as a press because it works at a different speed. On the same forging the actual force necessary to overcome the resistance of the metal will depend on the speed of the hammer or the press.

In some experiments on two 10,000-ton presses (two of the largest forging presses in the country) one of the direct-acting type and the

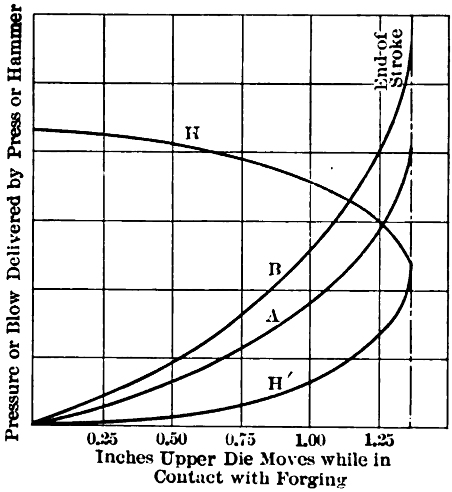


Fig. 5 Comparison of Blows Delivered by Press and by Hammer

other of the intensifier type, all conditions were made as nearly alike as possible in the different tests, only the speed at which the press ran being changed. When the work was done in 50 seconds it required 10,000 tons; when in 32 seconds, only 6500 tons; and when in 17 seconds, only 4000 tons, in each case this being the total pressure. Therefore to do the same physical work on the hot forging, the force necessary depends upon the speed; that is, the speed with which the forging is compressed after the die first touches it.

Fig. 5 shows graphically the amount of the pressure or the force of the blow delivered by the pressure of the press or by the hammer. The ordinates represent the pressure of the press or the force of the blow of the hammer and the abscissae the distance the die moves in accomplishing the work. Taking this distance constant for means of comparison, the hammer will deliver the greatest blow at the beginning of the compression of the forging and have a curve like *H*. The press, on the other hand, will exert its greatest pressure at the end of the compression of the forging, starting with zero and gradually building it up as more is required like curve *A*. With a more slowly moving press it will run like curve *B*, and so on.

In the case of the press, the resistance offered by the metal is at all times equal to the pressure exerted by the die; thus the areas under the curves *A* and *B* represent the work done in the two cases. In the case of the hammer the resistance offered by the metal is not equal to the force of the blow delivered until the end of the stroke. Thus the area under curve *H* does not represent the work done by the hammer, this being represented by the area under a curve $H'$ which represents the resistance offered by the metal to the blow of the hammer. Accordingly, we cannot say that the amount of work to accomplish the same result on a forging is the same in all cases. In addition to the speed of forging, the force necessary to overcome the resistance of the metal depends upon so many things, such as the temperature of the forging, the composition of the metal, the shape of the dies and the condition of their faces, that it is a very difficult quantity to figure accurately.

I believe that the press and the hammer has each its own field. In the selection of a press or a hammer the question of steam consumption should be one of the minor factors, the most important requisite being to select the tool that will make the best forging in the most efficient way, taking into consideration the speed of production, the facilities for changing dies, etc., and one that will not be out of service under repairs. Each case must stand upon its own requirements for the particular work in hand.

W. E. Hall. Referring to the computation of steam consumption of steam hammers, this type of hammer has the reputation of being a steam eater, but the method used by the authors gives results which seem excessive. Efforts have been made for several years, but without success, to have placed before the Society some comprehensive information relative to their steam consumption, etc. The only record available, so far as we know, are some indicator cards (Figs. 6 and 7) taken by the writer some 21 years ago, which are quite incomplete, but do throw some light upon the steam consumption.

The hammer was built by William Sellers and Company, and the nominal rating was 2 tons; the stroke 35¾ in. and the indicator spring 40 lb. The hammer was not available for measuring the cylinder diameter until some weeks after the cards were taken. This dimension (the cylinder having been rebored one or more times after instalation) was subsequently accidently lost. This and other matters prevented a completion of the investigation. The steam for the hammers was obtained from boilers located over the smith shop heating furnaces and the variation of the work in the furnaces produced

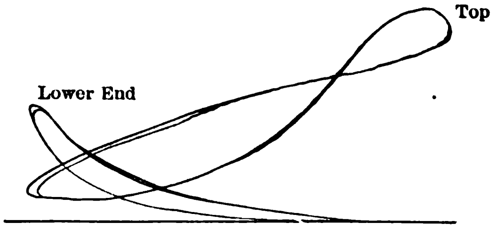


Fig. 6 Effect of Short Stroke not Striking

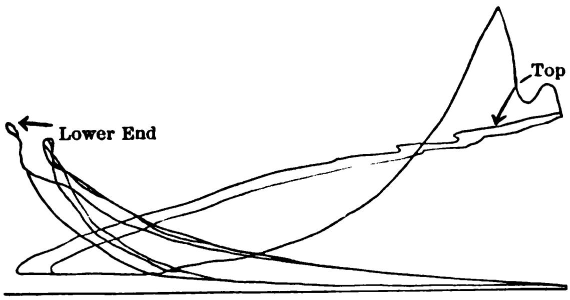


Fig. 7 Effect of Long Stroke Striking Hard

rather abnormal differences in the boiler pressures for the different cards. The hammer was located about 50 ft. from the boilers and was operated in the usual way by a hammer man under the guidance of the foreman.

The cards are presented because they show from the cut-off, etc., that the basis used by the author for computing the steam consumption would seem to give an abnormal result. They contain some rather interesting features such as the effect of cushioning, etc., and it is rather unfortunate that there seems to be no record showing the most economical method of distribution and the most efficient way of operating such a widely used shop appliance.

The Author. Mr. Rogers' contention that hammers which are very heavy in proportion to the size of the forging will produce convex ends, is correct. The size of hammers, however, has kept pace with that of forgings, which fact accounts for the concave ends on large forgings made by hammers. The vibrations of the ground from hammers large enough for heavy forgings are so serious that the use of a press is imperative. A heavy hammer is better than a light one because the former owes its power more to its mass and less to its velocity. The action during contact is slower than that of the light hammer and therefore approaches the action of the press.

I do not understand the inference made by Mr. Rogers in the second paragraph of his discussion. I have never denied that presses operated by crank and fly-wheel pumps are in successful operation, but I have stated over and over again, that the direct-steam hydraulic press is for certain processes not only cheaper, but also more economical.

I agree with Mr. Rogers that the work required to shape a forging depends upon the time consumed, but I cannot assent to the statement that a hammer works faster than a press. To the casual observer it might appear that the hammer moves faster, but while it does so, most of its fast motion is used for getting ready to do work. The press consumes practically no time in getting ready, and does work all the time. It may be interesting to note that the forge shop of the Mesta Machine Company has been able to cut the time on forgings considerably since the hammer was replaced by the press.

I do not wish to discuss the correctness or incorrectness of Fig. 5, because that would involve a theory of plasticity, coupled with dynamics of the anvil and ground or soil. While my own experience leads me to believe that these curves are not right, I cannot disprove them for want of tangible proof.

Referring to Mr. Hall's discussion, it appears to me that the cut-off like shape of the indicator cards misleads him. Both cards show a great deal of negative work, and when this is substracted from the positive work the high steam consumption per unit of work becomes apparent.

# GAS POWER SECTION

## TOPICAL DISCUSSION ON LARGE BLAST-FURNACE GAS-POWER PLANTS

A. E. Maccoun.[1] As is well known, the cost of a gas engine is very much higher and the space required very much larger than that for a steam engine of the same power. Some have tried to overcome this great difference by running the engines at excessively high speeds, but this practice cannot be recommended. With large gas engines, for instance an engine with a cylinder 48 in. in diameter, it becomes nearly impossible to design the working parts, such as cylinders, piston rods, pistons, frames, crank pins, etc., sufficiently large and strong and to find material good enough to withstand the enormous strains to which they are subjected. Everyone who has operated these large engines knows that their parts are continually subjected to fatigue on account of the high temperature and pressure conditions, that many cracked pistons, rods, heads and cylinders have resulted, and that much of the economy gained in the use of fuel has been lost in the enormous repairs required on many of these engines.

So far as reliability is concerned, although they may require more skilled supervision, excellent results are being obtained at many plants. At the Edgar Thomson furnaces of the Carnegie Steel Company during 1910, the record of operation with the percentage of time operated during the year was as follows:

| | Per Cent |
|---|---|
| No. 1 blower, horizontal, twin-tandem, Westinghouse, 38 in. x 54 in. ... | 90.3 |
| No. 2 blower, horizontal, twin-tandem, Westinghouse, 38 in. x 54 in..... | 90.0 |
| No. 1 electric, horizontal, twin-tandem, Westinghouse, 40 in. x 54 in.. .. | 75.87 |

[1] Supt. of Furnaces, Edgar Thomson Steel Works, Carnegie Steel Co., Braddock, Pa.

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Presented at the Spring Meeting, Pittsburgh, 1911, of The American Society of Mechanical Engineers. All discussion is subject to revision.

In what follows some important points are dwelt upon relating to the design of gas engines and some of the changes are mentioned which have been made in the design of the Westinghouse gas engine at the Edgar Thomson works.

*Cylinder Design.* The most important part of a gas engine is the cylinder and the troubles from this have not yet been completely overcome. The greatest difficulty is due to cylinders cracking, thus allowing the water to leak into them, seriously interfering with the operation of the engines. To prevent this great care must be taken to provide for the extreme temperature and pressure conditions and the cylinders necessarily have to be very carefully water-jacketed to prevent unequal expansion.

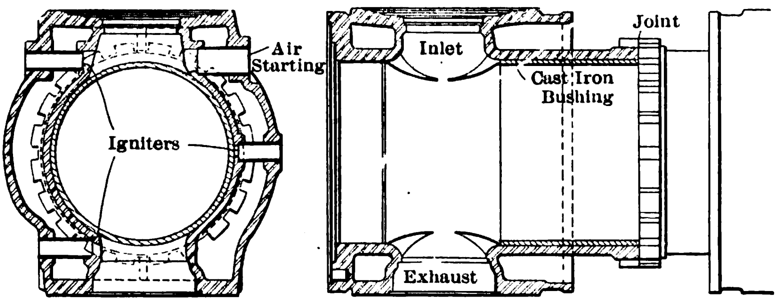


FIG. 1 LONGITUDINAL AND CROSS-SECTION OF CYLINDER

Iron and steel castings have been used for these cylinders and there is still a difference of opinion as to which is preferable. I greatly favor the steel casting on account of its greater strength, together with its thinner walls; thus permitting the cooling to penetrate closer into the cylinder walls and reduce the temperature of the walls and also help to prevent the fatigue of the metal. But even this does not eliminate cracking. Large gas-engine cylinder castings should be made as plain and simple as possible, and preferably in halves and bushed. The bushing renders a new cylinder wall available at a cost much less than boring and fitting new pistons, from time to time. The bushing should be easily removable and not require the removal of the cylinder from the engine. Both cast-iron and cast-steel bushings have given satisfaction.

As large a space as possible should be allowed for circulating water and special attention should be given to the bu hings connecting the inner and outer walls of cylinders for igniters, air valves, etc., so they will remain tight and allow for the difference in expansion between the inner and outer walls of cylinders. Fig. 1 shows a cast-steel cylinder we have had in use for two years and Figs. 2 and 3 sections through the exhaust valve.

The limit of size of gas-engine cylinders is very uncertain and it looks as if 44 in. in diameter should be about the maximum until further results are obtained from the numerous designs now being tried out.

*Gas-Engine Pistons.* The design of the piston is also of great importance but it can now be relied on for any size to which the cylinder can be carried. Nearly all the builders are using cast steel for large

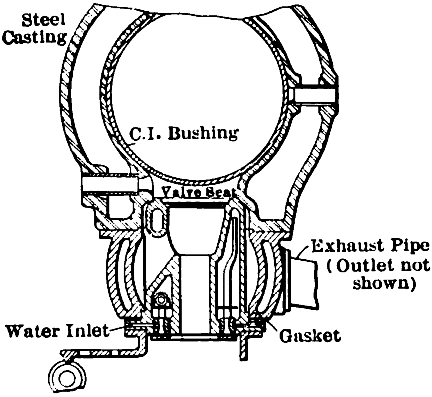


Fig. 2 Cross-Section of Cylinder through Igniter Holes

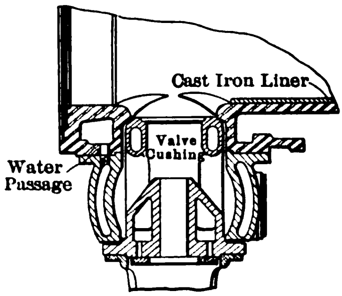


Fig. 3 Section through Exhaust Valve

pistons. They should be made in one piece and should be free from all parts that may become loose. Fig. 4 shows the type of piston in present use, made from cast steel, one with which we have never had any trouble. It can be seen that it approaches a sphere, as nearly as is possible, which gives enormous strength and also allows for expansion.

The number of rings used in various gas-engine pistons shows that there is no agreement among builders regarding this feature of design. They vary from three to eight, from snap rings to the more elaborate sectional rings with keepers. We prefer not to exceed four rings, of the latter type, with good depth and wearing surfaces. The rings should not be dowelled in place so that the dowels can come out and cut the cylinders.

It is unnecessary to state that the pistons should never bear on the working bore of the cylinder; all this weight should be carried by the rod on the cross-heads and slippers, and nothing but the pressure due to the rings should be on the cylinder walls.

*Piston Rods.* It is a most difficult problem to design piston rods strong enough to stand the constant stresses and strains to which they are subjected on large gas engines. The maximum stress on a section of rod, due to the explosion pressure, varies from about 6000 to 11,000 lb. per sq. in., on the various American types of large gas engines, and still many of these rods have failed and it is nearly impossible to increase the size to any great extent. Some are as large as 13 in. in diameter, but changes that have helped to strengthen them to some extent have been made in the design and material.

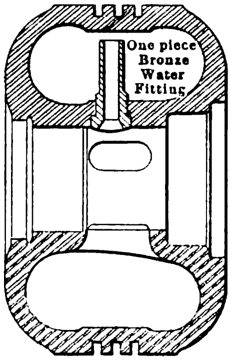


FIG. 4 SECTION OF GAS-ENGINE PISTON; RINGS 1 IN. BY 1¾ IN.

There are two general methods of fastening the rods to the cross-heads: by keys through rod and by thread and nut, or clamp over the threads. Both keys and nuts have given considerable trouble and it is hard to say which is the better type to use. The clamp over a thread, or other recess, seems to be preferable, as it does not interfere with the passage of the water from the end of the rod.

The material from which our rods were first made was nickel steel, as this was thought to be the best, but we found it very unreliable for this particular class of work and numerous failures developed. We find open-hearth steel of the following composition more satisfactory:

| | Per Cent |
|---|---|
| Carbon | 0.45 to 0.60 |
| Manganese | 0.45 to 0.60 |
| Phosphorus | under 0.04 |
| Sulphur | under 0.04 |
| Silicon | 0.10 to 0.20 |

The steel is heat treated and has the following physical properties: 50,000 lb. per sq. in. elastic limit; 95,000 lb. per sq. in. ultimate

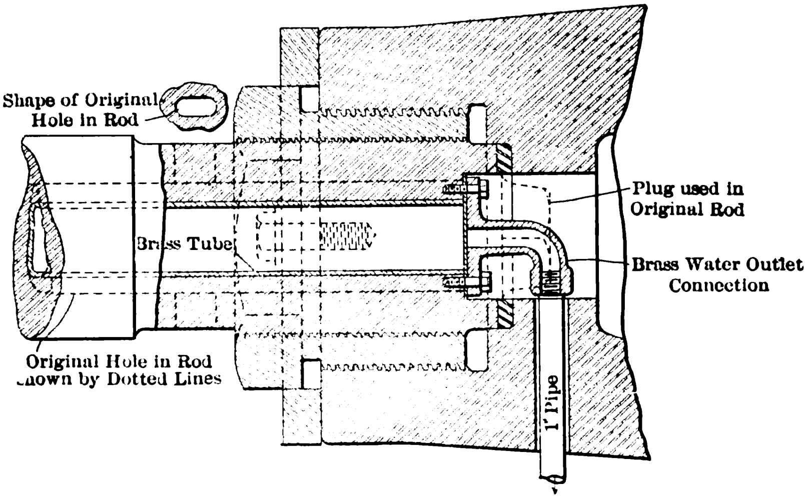


FIG. 5 SECTION SHOWING PISTON WATER OUTLET AND MAIN CROSS-HEAD CONNECTION

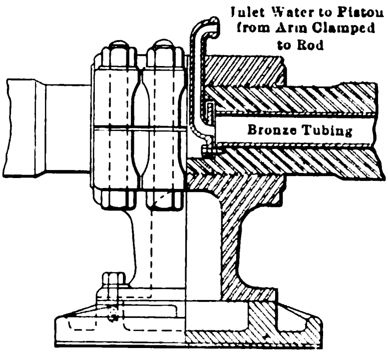


FIG. 6 SECTION SHOWING WATER INLET TO PISTON

strength; 12 per cent elongation in 2 in. No trouble has been experienced by the wearing of piston rods made from this material, on account of their softness.

At the Edgar Thomson works we were compelled to line the inside of all our piston rods with brass tubing, on account of the acid in the river water, and we have had excellent results from this practice. In fact, nothing but cast iron, cast steel or brass should come in contact with Monongahela River water, as it frequently runs very high in acid.

We were compelled to abandon all holes for the entry or outlet of water through the walls of piston rods, as they were found to be very convenient places for cracks to start. The water is now brought into and taken out of the ends of the piston rods.

Figs. 5, 6 and 7 show the detail construction of the rods and connections at present in use, which seem to be satisfactory.

*Piston-Rod Packing.* Very little trouble has been experienced from our piston-rod packing. The most important points to be watched are the fire rings; they should be solid and there should be a sufficient number to reduce the explosion pressure before it reaches

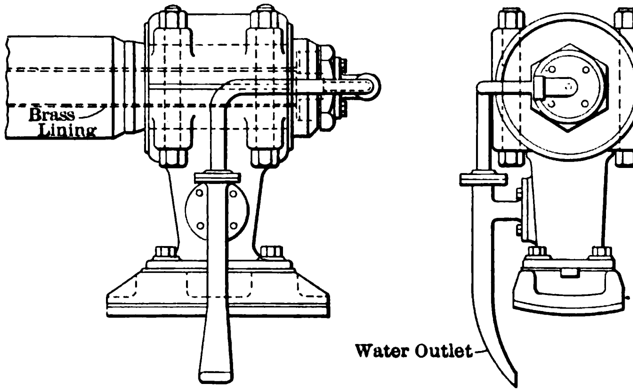


FIG. 7 VIEW SHOWING WATER CONNECTION TO TAIL ROD

the packing rings, and care should be taken to have a sufficient number of packing rings to prevent trouble, as the increased length of stuffing box is very small compared with the trouble that will certainly occur if the number of rings is reduced.

It is necessary to have sufficient side clearance so the rings can float. For this 0.005 in. is a fair allowance. The rings should also be fairly deep to allow wear. From present indications, our piston-rod packing should last a good many years.

*Cylinder Heads.* At first we experienced some trouble from cylinder heads but by changing the design we found it possible to make perfectly satisfactory cylinder heads from cast iron. Figs. 8 and 9 show the construction of the cylinder heads on our Westinghouse engines.

*Inlet Valve Gear.* There are still many improvements that can be made on the inlet valve gears of all blast-furnace gas engines. The essentials are as follows:

*a* A reasonable percentage of dirt in the gas should not affect their operation.

*b* The wear on all parts, cams, valves, seats, etc., should be easily compensated for in their method of adjustment.

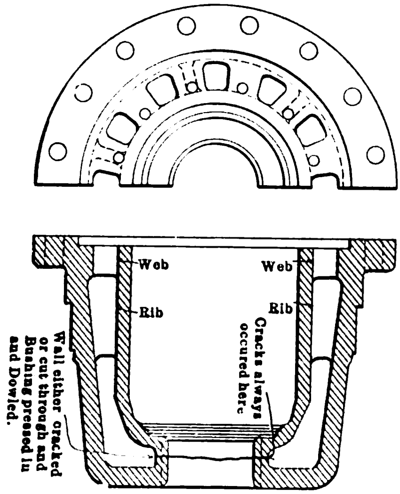


FIG. 8 SECTION OF ORIGINAL CYLINDER HEAD

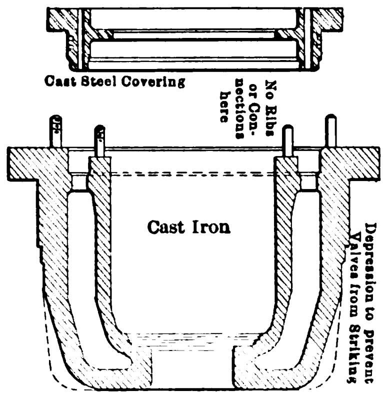


FIG. 9 SECTION OF CYLINDER HEAD OF NEW DESIGN

c Ample surfaces should be allowed for all wearing parts, to prevent wear and distortion of the valve setting.

*d* The adjustment of each valve on the engine should be made so as to be independent of the others.

*e* The valve gear should also be arranged so that the relative ratio of the air and gas ports can be changed either individually or collectively and very quickly to suit sudden changes in the composition of the gas.

A great many of the gears in use fulfil most of these conditions, but none of them, so far as I am aware, satisfy the last, which is a most important one. By meeting this condition, many of the experiences from backfiring, due to the sudden changes in the quality of blast-furnace gas, would be avoided.

There are two general systems in use in designing valve gears, namely, the constant-mixture and constant-compression systems. We have found the former the better for all load conditions, but these two systems have already been very thoroughly discussed. In a discussion upon a paper by H. J. Freyn,[1] I gave examples of cards from an experimental gas engine, using these two systems of governing. We have found the oil relay governor most satisfactory for operating inlet valves, on account of the large amount of work to be done and nearly all builders are adopting some modification of this system.

*Exhaust Valves.* Our exhaust valves have given very little trouble and do not have to be ground in very frequently. We at first expected a great deal of trouble from this source and all kinds of methods

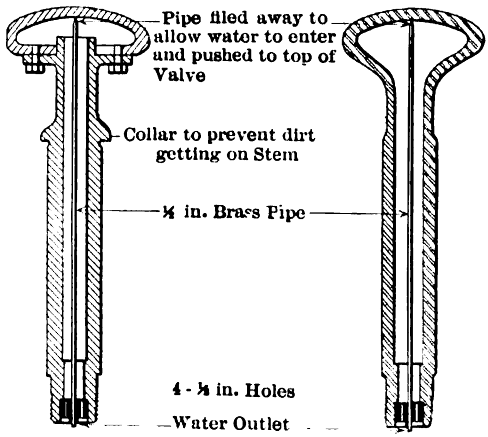


FIG. 10 EXHAUST VALVES

were arranged for changing them quickly. Fig. 10 shows the type in use, which has proved itself to be entirely satisfactory.

R. H. STEVENS[2] had not prepared a paper, but said that at the Carrie furnaces they had four blowers of the Allis-Chalmers make, and five gas-electric units, three of the Allis-Chalmers make and two of the Bethlehem, all in operation. There is also a cleaning plant in connection with them. The gas first goes through an impinging washer, then in series through a baffle, a fan, a screen, and a Theisen, and finally into the engine-house. A total efficiency is secured in the cleaning of over 99 per cent, the dust contents being

[1] Trans.Am.Soc.M.E., vol. 32, p. 462.

[2] Mechanical Engineer, Homestead Steel Works, Homestead, Pa.

as low as 0.003 of a grain per cu. ft. The engines are running along about 110 to 120 cu. ft. of gas per i.h.p., the gas running from 85 to 90 B.t.u. The fans are not operated in connection with the cleaning system, the gas merely passing through them.

The operation of the gas engine has been fairly successful. The gas-electric engines have been in shape to operate 95 to 98 per cent of the time but the demands have required only about 90 per cent. Two furnaces have been operating at the Carrie furnaces almost continuously for two years with gas blowers without any assistance from the steam units in the station, other than when cleaning the gas engines, as there is no spare gas engine.

The troubles with the gas engine have been mostly with the gears driving the lay shaft, with piston packing, rod packing, soft cast-iron cylinders, governors and inlet valves. These troubles have been met and overcome as they occurred.

A. N. Diehl.[1] A blast furnace may be considered as a producer in which some of the carbon monoxide, produced near the tuyeres, is oxidized to carbon dioxide, thereby robbing the original gas of some of its power. The low hydrogen value of the furnace gas allows an explosive mixture capable of high compression, and with a slow propagating flame makes an ideal fuel for power production. At the Duquesne plant of the Carnegie Steel Company, we consume 1 lb. of coke for about every 60 cu. ft. of air blown in actual practice, and produce approximately 150,000 cu. ft. of gas per ton of pig-iron produced, of which a loss of 10 per cent can be allowed for leaks. About 50,000 cu. ft. is used to heat the blast, and the remaining 85,000 can be used to produce steam or drive the blowing engines; any excess is available for other uses.

The gas from the top of the furnace varies considerably in thermal value, as well as in temperature, moisture, and dust content. The normal H is about 2 to 5 per cent and CO from 18 to 27 per cent. These figures are only normal; very often we have higher H and either higher or lower CO. The dust will vary from 1 grain per cu. ft. to 25 or 30 grains in gas from a slipping furnace, and the moisture from 15 to 35 or 40 grains per cu. ft. The temperature of the top gas will vary from 250 deg. fahr. in a good working furnace, to 1000 deg. fahr. in a furnace working irregularly. The normal top temperature is about 500 deg. fahr. The gas after leaving the furnace first passes

[1] Supt. of Furnaces, Duquesne Steel Works, Carnegie Steel Co., Duquesne, Pa.

through the dust catcher, where the heavy particles are deposited by their own weight, and also by the reason of the chamber being large enough to slow down the gas, thereby allowing some dirt to fall out.

A number of systems of gas cleaning have been proposed from this point. The gas may be caused to enter a chamber so designed that the velocity is greatly increased, and the gas and dust whirled rapidly to the circumference, where vertical Z-bars are located to catch the dust and keep it from getting back into the gas. The dust falls into a pocket below, where it can be drawn off. The system referred to is the Brassert-Whitting type, as used in the South Chicago plant of the Illinois Steel Company. It is desirable to get the dust out dry if possible, as it is saved for other purposes, while removing just that much material and heat from the scrubbers through which the gas will have to go.

There are different systems of preliminary or partial wet washing. In some cases the gas is passed through impinging washers, where it is rapidly thrown on surfaces of water; in others the gas is sprayed, etc. None of these systems are very efficient unless used as an auxiliary to a cooling apparatus for the removal of the moisture, because even though the gas should be more or less purified regarding dust, its temperature is so high that the gas would pick up moisture, and the good effect of the clean gas be destroyed by the excessive moisture absorbed.

In case the gas is to be cleaned, the scrubbers will do all that these cleaners will do, and will in addition almost completely remove the dust, as well as considerable moisture. In some installations, the gas is passed through baffle towers. The gas enters at the bottom of the tower and finds a tortuous way to the top. Water is run over these baffles and drawn off below. From the baffles the gas is passed through Zschocke tower washers, which have stationary sprays, located at the top of the tower, and a succession of wooden grids over which the water flows, falling from one to the other.

A number of installations use baffles and one or two Zschockes in series, then pass to Theisen horizontal washers for final cleaning. At Duquesne we have departed somewhat from this system and have obtained the best results by positive and repeated spraying, with a tower 76 ft. high, 12 ft. in diameter, having two main supplies for the water, one about 10 ft., the other about 40 ft., from the bottom of the scrubber. The water is fed in each case into a valve having a motor-driven revolving core. One 5-h.p. motor is required to drive four valves, that is, two scrubbers. The valves are located outside the scrubber, and have 12 openings which can be used. At present we are using only six, each having a 1¼-in. pipe connected to the discharge opening in the valve. These pipes run into the scrubber and are so located as to spray the entire area. The nozzles on the end of the pipes are turned vertically and a screen is placed about 6 ft. above the nozzles, which breaks up the water into a fine rain or mist, thus exposing an enormous surface to the gas and allowing better contact and cooling.

The revolving core is so designed as to blank one opening, allowing the water to flow through the remaining five. It is evident that, by its revolution, each hole will be blanked in succession, causing a momentary suspension in the flow of water from this nozzle, the other five delivering their usual flow. The result of this water suspension will momentarily cause an area of lesser resistance to the gas, approximately equal to one-sixth of the area of the scrubber, which will naturally be the point toward which the gas will surge. After the gas has surged over the dead nozzle, and is traveling upward through the scrubber at the rate of 4 ft. per second, the core passes the opening, allowing the water to flow once more at a velocity of about 60 ft. per second. The water sprays through the volume of gas above, at the same time tending to drive the gas from its path by means of the higher pressure and positively driven water. The gas, being under control of this spraying, and continually rising toward the top of the scrubber, is repeatedly sprayed and tends toward a spiral course, by which channeling is avoided. We have found that 15 r.p.m. is about the proper speed for the core.

The upper and lower valves, which operate on the same principle, are driven from one shaft and so arranged that the sprays overlap. We were led to this scheme of washing gas by the results obtained in our scrubbers as originally operated with a revolving spraying device located at the top. The water after leaving the top of the scrubber was deflected by the different velocities of the gas, so that a continuous varying regulation of the quantity of water and speed of rotation was required to maintain a uniform rain. In spite of the most careful regulation, however, the column of gas surged from one side of the scrubber to the other, the column practically deflecting the drops of water. The water distribution was verified by numerous distribution tests, at different points in the scrubber, 4 in. apart, covering the entire diameter, by means of a movable funnel.

Drain pipes from the bottom of the funnel were brought to the outside of the scrubber, where the water was collected in a standard measuring vessel, and the time taken for the water to fill the same. The channeling was determined by putting powerful incandescent lights and reflectors inside the scrubbers to note the action. The lights were so arranged that the inside of the scrubber could be seen through a corresponding door placed over one of the man-holes. This channeling would tend to keep the gas and water from coming in close contact. This is further borne out by the tests in Tables 1 and 2, showing the difference in temperature of 18.1 deg. between

TABLE 1 COMPARISON OF DUST DETERMINATIONS

Grains of Dust per Cu. Ft. at 62 Deg. Fahr. and 30 In. Heating on a No. 4 Scrubber, Equipped with Motor-Driven Positive Spraying Valve, Compared with Similar Determinations on a No. 8 Scrubber Equipped with Spray Pipe and Screens at Top

| Test No. | No. 4 Scrubber | No. 8 Scrubber |
|---|---|---|
| 121 | 0.21716 | ....... |
| 122 | 0.19695 | ....... |
| 123 | 0.26964 | ....... |
| 124 | 0.26312 | ....... |
| 116A | ....... | 0.34640 |
| 117A | ....... | 0.33208 |
| 118A | ....... | 0.27540 |
| 119A | ....... | 0.35895 |
| Average........................ | 0.2367 | 0.3282 |

TABLE 2 COMPARISON OF COOLING WATER TEMPERATURES AND TEMPERATURE OF GAS LEAVING SCRUBBER (TESTS IN TABLE 1)

| | No. 4 Scrubber | | No. 8 Scrubber | |
|---|---|---|---|---|
| | Inlet Water | Outlet Gas | Inlet Water | Outlet Gas |
| | 76 | 78.6 | 79.0 | 98.7 |
| | 76 | 81.4 | 78.5 | 99.0 |
| | 74 | 79.4 | 79.0 | 96.4 |
| | 74 | 78.5 | 78.9 | 97.8 |
| | 74 | 77.1 | 79.0 | 93.4 |
| Average...... | 74.8 | 79.0 | 78.9 | 97.0 |

Average difference, scrubber No. 4, 4.2 deg. fahr.; scrubber No. 8, 18.1 deg. fahr.
Average gas per min. through scrubber No. 4, 25,704 cu. ft.; scrubber No. 8, 22,701 cu. ft.

the inlet water and the outlet gas, against 4.2 deg. on positive spraying under the same conditions, except that 3000 cu. ft. more gas per minute passed through the latter scrubber.

Our object was to establish a condition of intimate contact between the water and gas, and this is shown by the gas entering at a temperature of 350 to 400 deg. and coming out at the top, at about 4 to

5 deg. above the temperature of the cooling water. The upper part of the scrubber is sufficiently large to allow any mechanically carried water to fall out before going farther. Our moisture tests, taken on the connecting line from the scrubbers to the clean gas main, show the moisture in the gas to be on an average of ½ grain per cu. ft. above the saturation point at the temperature of the gas. Each scrubber will handle 25,000 cu. ft. of gas per minute, with a water consumption of about 815 gal. for the same period.

This will give 30.6 cu. ft. of gas per gal. of water used. The gas enters, from an average of a large number of tests, with 3 grains of dust per cu. ft., at an average temperature of 350 to 400 deg. The gas in the main delivering to the stoves and also to the Theisens, contains 0.19708 grains per cu. ft. This figure covers an average of 150 tests during the past year. We have noticed that the gas delivered to the stoves will show traces of moisture when the temperature of the air is less than 5 deg. higher than the temperature of the gas. If the temperature rise is greater, we have no deposition, showing that the gas is comparatively dry.

The gas, after leaving the Theisen, contains an average dust content of 0.00902. This is an average of about the same number of tests mentioned before. The capacity of a Theisen is 14,000 cu. ft., although more can be put through. The engine builder's specification, as regards dust in the gas, is 0.025. The Theisens consumed 1 gal. of water per 56.1 cu. ft. of gas cleaned. As an average for the past year, our present practice, however, is as high as 70 cu. ft. per gal.

The gas-cleaning plant consists of nine tower washers for the rough cleaning. This makes a scrubbing capacity of from 250,000 to 275,000 cu. ft. of gas per minute, when the entire plant is in operation. The gas from this plant is divided so that clean gas is provided for the stoves for four furnaces, and also for 2000 b.h.p. besides the gas sent through the Theisen for six gas engines. The gas is delivered to the scrubbers, in a brick-lined gas main, 8 ft. 6 in. in diameter, and afterward goes through a 10 ft. 6 in. unlined, riveted and calked main, extending to the fans. The gas is passed only through one scrubber, then taken through a fan which had been provided, but is not in use at present. From the fan it is passed through a spiral dryer, or separator, which will tend to remove the mechanically carried moisture picked up in the fan, and any dirt which might be thrown out in its path through this spiral.

There are four fans rated at 84,000 cu. ft. of gas per minute capacity and driven by a 200-h.p. motor. The reason for not using the fans is that by backing up the pressure in the dirty gas main, sufficient pressure can be obtained to drive the gas to the point of combustion.

The gas is taken from the clean gas main, which is 8 ft. in diameter, by the Theisens, each running 375 r.p.m., and driven by a 150-h.p. motor. It then passes through another spiral dryer, into a 7 ft. 6 in. refined gas main, leading to the gas engines.

The water for the scrubbers is taken from the main pressure system and increased 10 lb. by means of two DeLaval centrifugal lifting pumps. The dirt and water from the scrubbers is collected in a central sewer and run into a settling basin, provided with baffles which will allow the dirt to settle so that it can be recovered. The water will be sufficiently clean to go into the river. We catch an average of 0.65 per cent of a car load of dirt in the settling basin per day. The settling basin is divided into two parts, so that when one side is filled, the water can be diverted to the other, allowing the first compartment to be cleaned.

The gas, after leaving the Theisens, passes into the engines through a small gasometer. The object of this gasometer is to reduce the pressure to about 2 in. before delivering it to the mixing chambers of the engines. The gasometers are about 4 ft. in diameter and about 4 to 5 ft. high. We have not a large gasometer such as has been used in a number of the plants.

The gas-engine equipment consists of two power engines and four blowers. The engines drive 2000-kw. Crocker-Wheeler generators, delivering alternating current at 6600 volts. The blowing engines operate Slick blowing tubs, and are guaranteed to deliver 33,000 cu. ft. of air at 62 revolutions, against 22½ lb. pressure.

The cylinders are 42 by 60, with inlet and outlet valves on the side, the total horsepower of the engine being given by the builders as 3600, using furnace gas containing 80 B.t.u. per cu. ft. and calculated on a mean effective pressure of from 55 to 60 lb. This mean effective pressure is far lower than we have obtained in some tests, but in most of them the thermal value of our gas has been between 90 and 100 B.t.u. The outlet and inlet valves are operated by noiseless cams, the inlet valve being closed by a heavy spring, and the outlet valve by compressed air at about 25 to 30 lb. The engines are of a constant-mixture and variable-compression, twin-tandem, 4-cycle type.

The ignition is of the mechanical make-and-break type, with current supplied from storage batteries, two spark plugs being placed in the combustion chamber of each cylinder. We have a forced feed lubricating system operated by means of Richardson oil pumps. The oil is forced into the cylinder and packing cases. The packing requires a feed of one drop of oil for every other revolution of the camshaft while the feed of the cylinder requires one drop every four or five revolutions of the camshaft.

The engines require about 6 to 8 gal. of oil every 24 hours. The engines are cooled by means of water circulation, and require about 6 to 7 gal. of water per horsepower. The temperature of the ingoing water is from 50 to 75 deg., the outgoing from 120 to 160 deg. About 20,000 gal. of water per hour is being used. A governor of the Lombard design controls the engine, the top of which actuates a small pilot valve admitting oil, under a pressure of from 175 to 200 lb. per sq. in. to a cylinder, against either one or the other end of the piston or plunger, about 3½ in. in diameter.

The plunger is connected by means of an arm and lever to a floating gear, the main drive of which is taken from the main camshaft, the upper part of the floating gear in turn driving a small shaft from which a cut-off shaft, running the entire length of the engine, is operated. This cut-off shaft carries a cam at each mixing valve, disengaging a hook lifting the mixing valve and allowing it to drop, depending on the quantity of gas required to keep the speed constant. By means of the operation of this plunger, and the floating or rolling gears, this small camshaft is either advanced or retarded in its relation to the operation of the main camshaft, allowing the cylinders to take either a larger or smaller quantity of the mixture as demanded by the load of the engine.

The speed variation on the power engines is from 1½ to 2 per cent from no load to full load, while the variation on the blowers is from 6 to 8 per cent under the same conditions. The governor of this engine has been extremely gratifying, the engine responding very quickly to its action. Our revolution recorders on the blowing engines show very few variations. The compression pressure at full load is about 200 lb., the release pressure about 15 lb. The temperature observed in the exhaust line is about 850 deg. on full load.

The average thermal efficiency for the last six months of 1910 was 24.15 per cent on an average load of 1372 kw., and gave an average B.t.u. per i.h.p. of 10,529. This was only 55 per cent of the rated full load. At a nearer rated full load the gas power engine showed the following as an average: Average load 3030 b.h.p.; percentage of rated full load 84 per cent B.t.u. per i.h.p. 8244, or a thermal efficiency per i.h.p., of 30.9; rated full load 3600 b.h.p. The maximum load noted on the engine, lasting continuously for a period of three minutes, was 3300 kw., no drop in speed being noted at this load. This load would correspond to 4807 b.h.p. or 5741 i.h.p., giving an apparent overload of 33 per cent above the builder's rating and a mechanical efficiency of 83.7 per cent at this total load. This, however, was all due to the increase in B.t.u. value of the gas, but shows the engine to be capable of more power if the conditions are favorable. Unfortunately, we have no records of the thermal value of gas at this time, but from periods before and after, the value was quite high, which evidently accounts for the increased power.

The engines are cleaned only about once every two months, and about 4 or 5 lb. of dirt scraped off the cylinder and piston heads. We have not as yet had to stop an engine especially to clean the cylinders and pistons, but do so when we stop to clean the cooling jackets, which become clogged up with mud and leaves, due to the poor condition of our river water. The dirt removed from the cylinders and piston heads is a whitish deposit which seems to be held in position by carbonized oil. The cylinders are blown off about once every six hours, allowing two exhaust charges to pass through a blowing-off port, located at the bottom of the cylinder.

An analysis of the whitish deposit formed on the cylinder and piston heads is as follows:

| | | | |
|---|---|---|---|
| $SiO_2$ | 18.40 | MgO | 1.68 |
| $Mn_3O_4$ | 2.40 | $Fe_2O_3$ | 4.71 |
| $Al_2O_3$ | 15.55 | Ignition loss | 2.17 |
| CaO | 12.20 | Alkalis | 42.89 |

The engines are started by means of compressed air. At the end of each camshaft is located a four-way valve. A 3½-in. pipe leads to the end of each cylinder and admits air through a check valve in the side. The plunger of this valve has one port, a key being provided on the end of the plunger corresponding to the keyway in the end of the camshaft. The plunger is held away from the camshaft ordinarily, by means of a spiral spring in the body of the valve. Before starting the plungers are turned until the key corresponds to the keyways in the camshaft. Air is then admitted from one hand-operated valve along the side of the throttle valve, at from 60 to 100 lb. pressure, this pressure overcoming the tension of the spiral spring and engaging the plungers with the end of the camshafts. The pressure is then admitted to the proper cylinder at the proper time on the explosion stroke, the plunger turning in the four-way valve as the camshaft turns. The throttle valve operated by the air plunger is then open and the ignition circuit closed, the engine soon acquiring sufficient momentum to give an explosion, this pressure preventing any air from the starting arrangement entering the cylinder, the engine continuing to operate on gas at the desired speed. The air is then shut off, the spiral spring disengages the plungers of the air starting valve from the camshaft, the valves thus remaining stationary while the engine is operating. These operations can all be performed very easily by one man, in less time than it takes to explain it.

In the power house, for operating two engines, the governor pumps and oil tank pumps, and attending to the water screens and oil filters, five men on each turn are required. On day turn one additional man is provided for cleaning up. In the blowing room, for operating three engines, and attending to the same auxiliary machinery as in the power house, eight men are required on each turn, with one clean up on day turn only.

The record of the past six months shows that the gas engines were required for 14,580 hr., of which they operated 14,395 hr., or 98.8 per cent, losing only 185 hr., or 1.2 per cent. Of this amount 94 hr., 40 min., is charged to the blowing tub drive, the design of which has been changed, leaving only 90 hr. and 20 min. chargeable against the engines proper, or less than ½ per cent delay. During this time also two new engines have been put into service, the delay record covering every shutdown after the engine is first put under load. The No. 5 engine, which was started in November, operated during that month 648 hr., with only 4 hr. 20 min. delay, and this was caused by a hot cross-head guide. The No. 6 engine, started in March, operated the balance of the month, or 526 hr. without any shut-down whatever. Of the total delays of 185 hr. before referred to, 54 were on the two power engines and 131 hr. on the three blowers.

The engines have been quite free from premature fires and back-firing, except when a variation in gas occurred, due to an irregular furnace working, and other similar occasions. One instance might be mentioned where it was noticed that after the heavy slipping of one furnace, the gas power engine back-fired quite violently. Provision was made to take an analysis of the gas at another similar slip to determine what change, if any, occurred in it. Following are the gas analyses:

| | | | |
|---|---|---|---|
| CO | 19.8 | $H_2$ | 38.8 |
| $CO_2$ | 12.9 | $N_2$ | 26.8 |
| $O_2$ | 0.1 | B.t.u | 209.5 |
| $CH_4$ | 1.6 | | |

Another sample was taken immediately after this which showed the following analysis:

| | | | |
|---|---|---|---|
| CO | 23.8 | $H_2$ | 9.2 |
| $CO_2$ | 16.8 | $N_2$ | 50.0 |
| $CH_4$ | 0.2 | B.t.u | 110.8 |

The dust coming from the scrubbers and collecting on the sampling pipe is generally of a steel gray color, shading to red. The weight of dust per cubic foot seems higher in the gray, than it does in the red samples. This deposit seems to carry through the entire system and is seen at the top of the stoves and at the top of the boiler stacks. A determination was made to find what quantity passed through the system without being deposited, and it was found to be 25 per cent of the dust recorded at the gas-cleaning plant. In the bottoms of the stoves and in the combustion chambers of the boilers, this white deposit, which appears as an impalpable powder, collects, and has the following analysis:

| | | | |
|---|---|---|---|
| $SiO_2$ | 22.80 | $Al_2O_3$ | 15.73 |
| Fe | 6.00 | CaO | 21.42 |
| $Fe_2O_3$ | 8.57 | MgO | 2.50 |
| Mn | 1.50 | $K_2O$ | 20.90 |
| $Mn_3O_4$ | 2.09 | Ignition loss | 6.08 |

The question of installing gas engines is a problem to be determined by the consumers whose fuel is expensive. They should be located so that the value of the furnace gas saved can be recovered through electric power by replacing steam, or supply other facilities.

In case there is no coal consumed, and the operation is conducted wholly from power supplied by blast-furnace gas through steam, a gas-engine installation might not be advisable, nor would it be advisable to install gas-blowing engines thereby getting better fuel economy, if no provision is made to use this additional fuel saved. The price of coal is also a great factor in the entire problem, as under most favorable conditions it might be supplied at such a price per ton as to make its use less expensive than a gas-engine operation. A blast furnace will supply sufficient fuel to operate itself, besides having some excess gas, and unless a market is found for this excess besides the additional gas obtained by the installation of gas-blowing engines, it would not be considered advisable to install gas engines. On the other hand if a blast-furnace plant is so located in connection with steel works where large quantities of coal are being fired, it becomes an economic proposition to replace this coal, provided its cost will so warrant. After all it is for the engineer to solve the problem himself after taking all his resources into consideration.

ALEX. L. HOEHR.[1] The plant of the National Tube Company at McKeesport contains two Allis-Chalmers twin-tandem, four-cycle gas engines, with cylinders of 32 in. diameter and 42 in. stroke. Each engine drives a 1000-kw. Crocker-Wheeler direct-current generator, 250 volts at 110 r.p.m. The first engine was started with the load on October 27, 1907, and the second on September 23, 1908. They operate in parallel with four Allis-Chalmers steam units driving 624-kw. Crocker-Wheeler generators. Many difficulties were encountered in starting the plant, which interfered with the successful operation of the engines, and for a time the situation was somewhat discouraging. Many changes were made, most of them comparatively slight, and many experiments with different methods of operation. The result is that today and for many months past the gas engines have operated as regularly as any other unit in the plant. Some of the details which gave trouble and which were changed at this plant are operating successfully at other plants. This may be due to the difference in service or slight differences in material. The following are the principal changes made:

*a* Piston cooling water system changed from swing joint to telescope.

*b* Spark plugs changed, vertical instead of rotary motion, resulting in a simpler plug, which can be used, however, only on top of cylinders.

*c* Gearing driving lay shafts changed from worm to spur gears.

*d* Connections between exhaust valves and mufflers provided with expansion joints.

*e* Pistons changed from cast iron to steel. Also changed slightly in shape on the ends.

*f* Design of piston rings changed to eliminate the keeper which held the rings in place. The cylinder cutting which resulted in the bushing of three cylinders is attributed in every case to trouble with these keepers.

*g* Piston rod packing rings have been changed from cast iron to babbitt except the first, or "firing" ring.

[1] Steam and Hydraulic Engineer, National Tube Works, McKeesport, Pa.

*h* A slight change made in design of exhaust valve chambers to prevent internal strains in casting.

It is believed that engine No. 1 was the first of its size to be turned out by the builders and some such changes are to be expected in any new machine. As indicating the manner in which the engines operated after the various changes had been made, figures will be quoted from the operating records for the year 1910.

## OPERATING RECORDS OF ENGINES

The total number of hours per year is 8760 and of this possible number the No. 1 engine ran 7851.5 hr. or 89 per cent. There were four months when no delays were charged to the engines. The maximum charge was 40 hr. 45 min. in February and the minimum 40 min. in January.

The load factor is known for seven months of this year, beginning with June. It was found that the meters were not correct and the figures for the first five months are not used. The load factor for the seven months averaged 81.6 per cent. The maximum was 86.06 per cent in November and the minimum was 77.23 per cent in July.

The No. 2 engine ran 8015.5 hr. out of a possible 8760 hr., or 91 per cent. The load factor for this unit averages 79 per cent for the the twelve months. The maximum was 86.06 per cent in November and the minimum 67.89 per cent in August. There were six months when no delays were charged to the engine.

The gas engines are operated on Sunday in preference to the steam units, which are supplied by coal-fired boilers, and this helps to hold up the load factor.

The two engines use about 15,000,000 gal. of water per month which amounts to 12.4 gal. per kw-hr., or 61.9 gal. per 1000 cu. ft. of gas used. The jacket water is discharged at temperatures ranging from 120 to 140 deg. fahr. and no use is made of it at present except in winter, when a part is further heated by passing through a coil in the exhaust muffler and is used to heat the shops.

## GAS-CLEANING PLANT

The blast-furnace plant at McKeesport consists of four 500-ton furnaces producing bessemer pig iron for the manufacture of tubular goods. The gas mains from these furnaces are all connected into one system. To this system is connected the main leading to the gas-cleaning plant so that the surplus from any or all of the furnaces can pass to the gas engines. The arrangement of the dust catchers differs at each of the four furnaces, but includes in all cases a large dry dust catcher into the top of which the downcomer passes and from the sides of which, at various angles, pass gas mains to the stoves, boilers, etc. These branches are equipped with water seal valves so that they can be cut off from the system for repairs or other purposes.

Dry dust catcher No. 1, on the gas cleaning system, is 35 ft. in diameter inside the plates and about 32 ft. total height. It has a 4½-in. brick lining throughout. Two 6-ft. diameter gas flues, which form the connection between the general gas system and the gas-cleaning system, enter the dust catcher tangentially near the top, giving to the entering gas a rotary motion which lengthens the distance to be traveled between the inlet and outlet and also causes some centrifugal effect which aids in separating out the dust which falls to the conical bottom and is kept out of the outgoing gas current by a series of baffle plates. A short distance above the tops of these plates and at the center of the dust catcher is the lower end of the 8-ft. diameter outlet flue which is supported by a series of diagonal rods running to the upper edge of the dust catcher. This flue passes up and out at the top, where it makes a 90-deg. bend and crosses the mill yard to dry dust catcher No. 2, entering it tangentially near the top. It is reduced to 6 ft. in diameter at the point of attachment for convenience of construction. This flue is not lined.

Dust catcher No. 2 is the same size and construction as No. 1 except that it is not lined and has but one inlet connection. These two 35-ft. diameter dry dust catchers and the connecting flue, 8 ft. in diameter, were made large not only to reduce velocities so that the dust would settle out, but also to provide large radiating surfaces for the dissipation of heat which otherwise would have to be carried off by additional water supplied to the Zchocke washers. As the temperature of the gas leaving the top of the furnace will average about 550 deg. fahr. and the temperature of the gas leaving dust catcher No. 2 will run about 365 deg. fahr., it is evident that this dissipation has been accomplished. With two engines at full load the velocity of the gas in the 8-ft. connecting flue will not exceed 135 ft. per min. It should be explained here that this connection was designed for twice the engine capacity now in use but even with this increase the velocity would be very low.

From the top of dust catcher No. 2 the gas passes into a horizontal overhead flue 8 ft. in diameter from which two vertical branches are taken, which act as supports and also as downcomers to deliver the gas into the lower portion of two Zchocke spray towers. These towers are each 14 ft. in diameter, 42 ft. high and are water-sealed at the base. They consist of a cylindrical steel shell with circumferential angles at intervals, which support a series of wooden baffles, the function of which is to break up into small streams and thoroughly mix the gas which is rising from the bottom and the water which is falling from the top. The water is supplied to each tower through 30 stationary spray nozzles, so arranged as to deliver a fairly uniform rain over the entire area of the top baffle. These two towers were designed to work in parallel, but it has been found possible to operate with only one in service. The gas enters the base of the tower at a temperature of about 365 deg. fahr. and with a dust content of 33.5 mg. per cu. ft. (0.517 grains per cu. ft.), and leaves the top at a temperature of 75 deg. fahr. with a dust content of 4 mg. per cu. ft. (0.062 grains per cu. ft.). The downcomers from the tops of the towers connect at ground level with a water-sealed U-tube, which conducts the gas to a third Zchocke tower or, through a by-pass, direct to the Theisen rotary washer. The plant is operating at present through this by-pass with the third spray tower not in use.

The rotary washer is of the usual Theisen construction, the rotating part being about 8 ft. mean diameter and 10 ft. long. It is driven by a 111-D Crocker-Wheeler motor, 150 h.p. at 300 r.p.m. By measurement when washing gas for two engines the power required was found to be 300 amperes at 220 volts.

The gas leaving the Theisen washer is practically free from dust, a 100-cu. ft. sample containing 0.15 mg. (0.0023 grains per cu. ft.).

From the Theisen washer the gas passes through a water separator, 4 ft. 6 in. in diameter and 13 ft. 1 in. high to a 50-ft. diameter gas holder, of 50,000 cu. ft. capacity. The gas holder is by-passed so that the engines can be operated with the holder out of commission for painting or repairs. From the holder the gas enters the 42-in. diameter clean gas main which conveys the gas a distance of about 1100 ft. to the gas engines.

The water for the gas-cleaning plant averages 105.7 gal. per 1000 cu. ft. of gas washed. This includes the water used in all parts of the cleaning plant.

It is very evident from the experience at this plant that it is quite possible to have a large gas engine operating on blast-furnace gas give perfectly satisfactory service, carrying its full share of the load about as regularly as any of the steam units.

Satisfactory as this service has been it does not prove that the gas engine is necessarily the best type of prime mover for such locations. At the time these engines were installed, the low-pressure turbine was only faintly visible on the horizon and no question was raised as to the advisability of installing the gas engine. At the present time the conditions are very different. The turbine has been developed until it is a very efficient and reliable prime mover, and the engineer cannot ignore it in figuring on new installations.

Without being able to present figures at this time to support his position, the writer believes that in the Pittsburg district under existing conditions as to prices for coal, turbines, gas engines and labor, a complete steam plant from gas-fired boilers to low-pressure turbines can be installed and operated to produce a given amount of power for less money than would be required through a gas-engine plant. This would be due to lower first cost, lower attendance charges and lower repair charges on the steam plant. It is assumed that proper interest and depreciation charges are made to both plants.

H. J. Freyn had not prepared a written discussion, but spoke at length in advocacy of the large gas engine, indicating the remarkable performance of large gas power plants in this country at this present time and calling attention to the fact that in Europe, where the development is several years ahead of that in this country, many of the difficulties which we are now encountering have been entirely done away with. He considered that figures like 95 to 99 per cent for running time, such as have been given by previous speakers, were highly creditable and that they compared favorably with figures for continuous operation in any type of plant, either steam or gas.

He referred to an inspection visit to Europe of an official of the Illinois Steel Company who found the most surprising development to be that of the gas engine and Mr. Freyn himself had made a trip last year for the first time in four years and was surprised to see how well large gas-engine installations were operating. The blast-furnace gas engine was started in Europe about 1898 and five or six years ago at a meeting like that at which he spoke there would have been exactly the same complaints about cylinders cracking, piston rods breaking and all kinds of troubles; but over there today there is practically nothing heard about these troubles for the reason that they have been overcome. The gas engine in America cannot be as far advanced as in Europe because only four or five years have elapsed since the first large 4-cycle engines were installed and operated.

Nevertheless, these engines are today operating at 95 per cent of their running time.

Mr. Maccoun appeared to think that gas-engine cylinders were successful only in the smaller sizes. Mr. Freyn called attention to the fact that abroad cylinders are used 48 in. in diameter by 55-in. stroke, these engines running from 80 to 90 r.p.m.; and he had himself seen a twin-tandem double-acting 4-cycle engine of 4000 h.p. in operation with blast-furnace gas. As to piston rods, he took issue with Mr. Maccoun regarding the difficulty of designing rods strong enough to withstand the terrific strain. The diameter of our rods is made from 30 to 33 per cent of the diameter of the cylinder; that is, engines have recently been built with 44-in. cylinders and 15-in. rods. In Germany, with similar engines of about the same size, the diameter of the rods would not be more than 26 or 28 per cent of the diameter of the cylinders. He had found nickel steel rods over there containing as much as 5 per cent nickel which would be considered a prohibitive amount in this country as breakages would be feared.

Then in the matter of workmanship he believed America was not up to the European quality as he had found engines working satisfactorily abroad upon which there were details of construction exactly like those which had given trouble in this country.

As to cast-steel or cast-iron cylinders, there are many troubles encountered in this country with cylinders cracking. The solution here seems to be sought in cast-steel cylinders. Abroad not a single cylinder of that kind can be found, even in the 48-in. diameter size. The reason so far as he could judge is that foundry practice over there is a little bit different and better than here, including the selection of the iron and the method of casting. It is held over there that while the modulus of elasticity of steel castings is much higher than of cast iron, the coefficient of elongation by temperature is not much higher, so that the product of these two valves, which Professor Langer calls the "Material-Ziffer," is about four times as high for cast steel as for cast iron, whereas the strength of the former material is hardly three times that of the latter. The lower this "Material-Ziffer," however, the better the casting and the less danger of cracking of the cylinder. The same is true of cast-steel pistons. He had found 48-in. cast-iron pistons in use abroad without cracking. Mr. Freyn believed that the packing for piston rods as designed in America was superior because European packings are very complicated.

While the speaker used to be a stanch adherent of the constant-compression stratification principle for governing, he did not now advocate it and referred to the perfect running of engines under variable compression, such as the Snow engines at Duquesne which Mr. Diehl had described. In Europe the prominent builders are using nothing but butterfly valves for throttling the gas and air and are getting remarkable results. The valve gear is so simple and cheap that no relais-governor is required because it has but little work to do. They are able to run 50-cycle generators in parallel without cross-currents or other difficulties.

Mr. Freyn believed that remarks which had been made on the cost of installation were in error. He and Chas. J. Bacon, steam engineer of the Illinois Steel Company, had taken up the question of the relative cost of gas power and steam power plants, and while their conclusions were reserved for the report to their company, he could say that figures such as had been quoted of $125 per kw. were not found at all in actual installation in steel plants. While the cost of installation is unquestionably higher than for the steam turbine or for a steam engine, the result would compare very favorably when taken in connection with the high commercial efficiency of a gas engine. He appreciated that coal was low in price in American steel works districts but believed the price was bound to increase as it had in the past, as for example in Chicago, where it could be had for $1 a ton a few years ago and today costs 60 per cent more. This increase would come on gas engines, steam engines or steam turbines alike, but if the gas engine is able to use only one-half the quantity of fuel of the steam turbine, the increased fuel cost would not affect it as much as the steam turbine.

It was interesting to note in connection with the cost of repairs that abroad this charge is materially lower, not on account of cheaper labor alone, but because of lack of repairs, and that the troubles we have had here are none of them such as it would not be possible to overcome by proper design, workmanship and material. He was pleased to state that so far as gas cleaning was concerned, we are ahead of European practice.

Referring to operative conditions at the South Chicago plant of the Illinois Steel Company, upon which he had presented a paper before the Society in 1910,[1] he said the Theisen washers had kept their excellent efficiency of 98 and 99 per cent, regardless of the quantity of dirt or quality of gas. Recently one of their furnaces had been mak-

[1] Trans. Am. Soc. M. E., vol. 32, p. 369.

ing ferro-silicon which produced a great amount of dust in the gas of a quality almost impossible to remove by the washing process. The efficiency of the wet scrubbers dropped from 85 to about 50 per cent, while the efficiency of the Theisen washers kept at approximately 98 or 99 per cent. There is no trouble with dirt in the gas. Their engines had not been cleaned even once a year. The other day he had pulled out a cylinder head on one of their oldest blowing engines and found it to be polished like glass. Almost no carbon was to be seen and the dirt deposited in the cylinder head, on the piston and in the counter bore, was all-told not a handful. The gas of the American blast-furnace plants is now cleaned so that it contains only about one-half the amount of dust allowed by the requirements of gas-engine builders.

The question of oil consumption was brought up in connection with cost of operation and he instanced a case where the Horton oiler, designed by the engineer on plant efficiency at Homestead, and which operates on the principle of injecting oil onto the piston and into the cylinder, by means of compressed air, had made a remarkable saving in the quantity of oil.

Mr. Diehl had mentioned the danger of gas-blowing engines failing suddenly on account of the failure of the ignition. When the Gary plant was started no provision was made for a proper ignition system. The ignition current came from the general lighting system and a motor-generator set transformed the regular current in the plant to whatever voltage was necessary for ignition. Soon, however, a very reliable, independent storage-battery ignition system was installed and shutdowns due to failure of ignition current have since that time been withdrawn. He would advocate an independent storage battery for any gas installation to insure reliable operation. With such an installation there is no possibility of the ignition system of the whole station failing. In the plants of his company they always run three blowing engines to supply two furnaces, by splitting the supply from one engine. If local ignition troubles arise, there is still one-half of the other engine running to keep the gas out of the blowing cylinders. Also, by connecting the cold blast pipes of the various furnaces by a small pipe 6 in. in diameter and having 6-in. valves inserted in these connections, it is always possible to get pressure from the other furnace onto the one on which the blowing engine went down. By this small pipe line one is able to by-pass air from the other furnaces and keep the gas out. This is being done abroad and the speaker considered the gas-blowing engines today so safe that he would not hesitate to have a large engine of 40,000 cu. ft. capacity blow one furnace by itself.

In connection with the question of efficiency he had found that the subject of utilization of waste heat from gas engines had made much headway in Europe. If the heat from the exhaust and the cooling water could be recovered, as in fact is now being done, the amount of energy saved would be considerable. Tests on a plant in Belgium showed that 13 per cent could be obtained from the waste heat in the exhaust and cooling water, generating low-pressure steam with this waste heat and using it in low-pressure turbines.

E. Friedlander.[1] The discussion has brought out the fact that the application of modern American steam-engine practice to the blast-furnace gas engine has finally made it a reliable prime mover. Up to this time, however, a large part of the saving in cost of fuel which it accomplishes has been consumed in the operation and maintenance of these engines. That the recent improvements in the details of these engines which Mr. Maccoun has described will greatly reduce this factor, is borne out by the fact that maintenance last year was but one-half of the previous year, and it is reasonably to be expected that such improvements will continue.

A periodical inspection, cleaning and overhauling will be necessary so long as there is excessive dirt in the water, air or gas, which may cause deposits to accumulate on the cylinders. If this is not done at least twice a year, operation will probably become very unsatisfactory and the damage that may finally result will far exceed the expense of timely inspection.

The blast-furnace gas engine has a strong rival in the low-pressure steam turbine working in combination with the reciprocating engine. The low-pressure turbine may be considered as also belonging to the class of prime movers giving us power for nothing, so to say. This places under comparison reciprocating steam engines, high, low, or mixed-pressure steam turbines and blast-furnace gas engines. Therefore, in comparing these different prime movers from the operators' point of view, I would like to bring out some special features which are under discussion.

The present largest gas-power unit of about 3000 k.v.a. capacity is not large enough for power stations of any magnitude. In order

[1] Supt. Elec. Dept., Edgar Thomson Steel Works, Carnegie Steel Co., Braddock, Pa.

to reduce cost of installation, operation and up-keep, units should be as large as possible. A number of 5000-kw. turbine units are being replaced today by 20,000-kw. units, and the resultant economy in fuel and operating costs will pay for such an investment in a short time.

The very large floor space taken up by these gas engines is also a serious objection raised by central station men where they must contend with a high cost of real estate and consequently the buildings to contain them. This should induce the engine builders to make their engines of as large capacity as possible. I do not see any objections to running them faster than Corliss engines of the same size. It is not the inertia of a flywheel, shaft, piston and rod, which limits the speed of such large engines, but the wear and tear of the valve gearing which in the case of gas engines is much lighter in weight and moves only at half the speed of steam engine gears.

In order to facilitate the periodical inspection, cleaning and overhauling, the engine must be constructed with this point in view. Each part should be above the floor, and easily accessible, and it should not be necessary to remove a mass of machinery to get at certain parts.

The arrangement of main and cross-head housings, cylinders, etc., should make them self-contained and perfectly aligned; male and female fits of large diameters should be provided, so that all parts when separated will go back exactly in line without depending upon bed plate, foundations, or reamed and fitted bolts.

The overload capacity of prime movers in electric central stations, especially of turbines, is always taken into consideration in figuring on the station capacity, and plays an important part in reducing the cost of the current generated on account of the small investment necessary for steam stations to deliver a given maximum load, whereas an internal-combustion engine may be looked upon as not possessing any overload capacity whatsoever. Again it has been observed that gas engines are very slow in taking their proportionate amount of load under fluctuating load conditions, and always lag behind the other prime movers, especially turbines. This is partly caused by the extra time required to take in the charge, compress and explode it. A powerful relay governor should be arranged to reduce this lag as much as possible.

I strongly recommend using steam turbines in connection with gas engines in large central gas-power plants. These turbines can furnish overload or peak current, together with all the necessary wattless current.

Where an abundant supply of clean and pure water is available, no trouble should be encountered. In the Pittsburgh district, however, more shutdowns and delays are chargeable to inadequate cooling than to any other cause, due to the local conditions rather than to faults in materials or design. The water available for circulating through the engine jackets is mostly muddy and gritty and contains from 1 to 8 grains per gal. of free sulphuric acid and iron sulphate. This mixture will attack any material, especially steel forgings and piping. Therefore, all the water piping should be made of brass or copper, or the larger sizes of cast iron. Malleable iron fittings should not be used. All forgings, such as piston rods, valve stems, etc., should be lined with non-corrosive tubing. The abrasive matter in the water will wear out any metal if speed of travel is high. It is necessary to make all water passages large to allow mud to settle and to avoid high rates of flow. The sediment in our circulating systems has to be removed at regular intervals by means of hydraulic or steam pressure. If this is neglected, the engine will overheat and cause trouble in the operation and finally serious delay.

Ignition has given very little cause for complaint. If wiring is properly installed in sealed steel tubing with standard porcelain-lined outlet boxes and if all grounds are avoided by installing separate generators and batteries for this work, so that one will automatically take the place of the other whenever necessary, not a single shutdown need occur on account of igniters. There should always be three igniters evenly spaced at each end of a large cylinder, so that the failure of one or even two of these igniters will not affect the operation of the engine. The mechanical make-and-break system with forged steel contact points requires the least attention and excels the electromagnetically actuated igniters. Each igniter should be wired up independently of the others with its own fuse of at least four times the normal current capacity. A main fuse of four times larger capacity than the individual fuse and a tell-tale to indicate the working of each igniter should be provided.

The igniter plugs can act as safety valves for regulating the permissible maximum pressures in cylinders by holding them to their seats by means of heavy compression springs. Such an arrangement would probably prevent a serious break when water fills up the clearance space in a cylinder.

The lubrication of gas-engine cylinders has not been generally satisfactory. The manner of admitting the oil into the cylinders is just as important as the quality and quantity used for lubrication.

The oil cannot be vaporized with the charge, as in steam engines, but must be spread over the cylinder walls. This is preferably accomplished by pumping it in with the charge, or as soon as possible after the scavenging of cylinders, and spreading it during the compression stroke, so that the cylinder will be ready for the power stroke. In no case should oil be admitted during the explosion stroke and it should not drop on the piston as soon as it enters the cylinder, but be given time to run down on each side before it is spread over the walls by the piston rings.

It has been found very satisfactory to provide two holes in each end of a cylinder, located in the top half about 40 to 60 deg. apart. This location does not permit oil to drop off to the bottom nor does it leave a dry spot on top between oil holes. This method of oiling has been adopted in our 40 in. by 54 in. Westinghouse twin-tandem double-acting engines, running at 78 r.p.m., and at no time during its service of over three years has any cutting of the cylinder walls been observed. In fact, the original tool marks have not even been worn away.

It is not always an easy matter to locate the cause of misfiring and requires some experience in the handling of internal-combustion engines. It is quite important that the engineer should be familiar with the different causes for misfiring, so he may prevent them if possible.

The calorific value of blast-furnace gas changes often and requires a different amount of air to be added to the charge. Every possible means should be provided to enable the operator to detect in time any radical change in the gas, so he can change the ratio of gas and air, if the valve gearing is designed to make such a change easily and quickly. Otherwise he can only reduce the load on the engine until the supply of gas is normal again. Poor gas will burn slowly and is liable to ignite the successive charge, causing a backfire, that is, an explosion on the suction stroke back into the air and gas passage. This will seldom cause any other harm, but tends to slow down the engine. Too rich gas, dirty explosion chambers, leaky valves, too much oil, etc., can cause backfiring. It is easily detected by the loud report and large volume of smoke produced.

Pre-ignition of charges, or so-called prematures, are much more serious and should never be allowed to occur for any length of time. They cause excessive strains in cylinders, overheated pistons and cylinder walls, and are liable to loosen joints. An excessive amount of hydrogen in the gas, igniting at lower temperatures, is often the cause of prematures; but leaky piston rings, hot cylinders, etc., may also cause them. If they occur repeatedly, the cylinders should immediately be cut out alternately until the trouble is located. These prematures are explosions during the compression stroke after inlet and exhaust valves are enclosed, without the aid of igniters, and are not to be confused with backfires.

If all valves are tight, the prematures should produce no visible effect except the rapid slowing down of the engine and heavy pounding.

Such actions as described tend to show that the successful operation of blast-furnace gas engines is dependent upon the gas. Any appreciable change in the calorific value, temperature or amount of moisture or dirt, will directly affect the operation.

It is of great importance to keep gas uniform and to do this all furnaces should feed their gas into a common line, as far as possible. The analysis of average furnace gas shows about 24 per cent CO, 12 per cent $CO_2$, 2 to 3 per cent H, 60 per cent N.

In concluding, I wish to emphasize the fact that I have purposely spoken rather pointedly of some of the imperfections from which the large gas engine has previously suffered in order that this experience may contribute to the successful future of the gas engine. Mr. Maccoun has also very frankly discussed certain necessary improvements in the design of the large gas engine, and I have attempted to dwell upon many of the important facts which must be observed in order that successful operation may be insured. Such a development has not been peculiar to any one make of engine, but it has been more or less common to all of them. Some of the engines most recently installed have obviously had the benefit of experience obtained in the operation of preceding installations. But in spite of what has just been said, we have every reason to believe our plant records are fully comparable, on the average, with any other large blast-furnace gas-engine installations, and that they are possibly much better than some of them. No special periods where unusually good records were made have been selected in this case, nor any special consideration taken into account. It is, on the other hand, the actual result over the entire period of the year.

## CONTRIBUTED DISCUSSION

W. Trinks. Referring to Mr. Maccoun's discussion, I cannot agree with one of his remarks, namely, that the practice of increasing the horsepower of gas engines by increasing their rotative speed should not be recommended. I disagree with him in this respect for several reasons. First, it is argued that slow rotative speed is conducive to economy. Of course, it is possible to chase after the last amount of economy in the gas engine by avoiding the throttling losses through the inlet and outlet valves, and by reducing friction work to a minimum by the adoption of long stroke and slow rotative speed. By this means we obtain an ideal engine but one upon which the price is prohibitive. The gas engine would then be in the same position as the triple and quadruple expansion steam engines are today. These latter engines are more economical than the compound engine but they are not built except under very exceptional circumstances, namely, when highest economy is of paramount importance.

As already mentioned by Mr. Freyn, the slow-speed blast-furnace gas engine is two and one-half times as economical as the steam engine or the steam turbine, and we can well afford to sacrifice some of this, if by so doing we can reduce the first cost of the engine considerably.

I believe that Mr. Arthur West has been the foremost fighter for higher piston and rotative speeds, but there are others following very closely on his heels.

After it has thus become evident that these speeds will make it possible for the gas engine to compete successfully, even in places where coal is cheap, a word should be said about the supposedly detrimental features of high speeds.

I disagree with the engineers from the various plants of the Carnegie Steel Company and the National Tube Company who have mentioned the trouble of up-keep and maintenance in gas engines and have made that a key-note for advocating lower rotative speed or for abandoning the gas engine altogether. High speed in itself is not detrimental unless the machinery is so designed as to be unfit for such speeds. I recollect with pleasure looking at engines of 2000-kw. capacity built by Bellis and Morcum of Birmingham, England, which ran at 200 r.p.m. The fact that they were steam engines does not alter my point. They were taken apart after three years of operation and the tool marks were still visible in the bearings, crank and cross-head pins and on the guides. The wear of the piston rings also had been exceedingly small. Now if such behavior is possible in England, why not here? The engines which I speak of had forced lubrication; oil was pumped through the bearings automatically and kept the surfaces from touching. We all know there is absolutely no wear if the so-called rubbing surfaces are kept apart by a sufficiently thick film of clean oil. The whole question of design then comes down to doing away with the method of lubrication which requires attention on the part of the operating crew, and of making it all automatic; of providing a continuous stream, not a few occasional drops, preferably under pressure. So far as the valve gear is concerned, there should be no trouble, as one of the other speakers mentioned, because it runs only at half the speed of the engine.

I expect some will raise the objections that at higher speeds the economy will decrease and there will not be much gain in power because the cylinder cannot be filled with gas and air. I recommend that such critics draw a curve between percentage of brake horsepower and average pressure of air and gas in the engine cylinder during the suction stroke. This curve will be a revelation to them.

With regard to piston rods, it has been said that although they are now almost of prohibitive size, they are one of the principal trouble makers in gas engines. Mr. Freyn has refuted this statement, but has not gone far enough. It should be stated exactly what has caused these troubles and I should like to draw your attention to one design and point out how it is wrong. In this, which I believe it is the one to which the speaker referred, there was a hole drilled through the top of the piston rod for the purpose of admitting the cooling water to the interior of the rod. This was drilled in the place where the full tensile stress and the maximum bending stress occur in the rod. Of course this is wrong for the reason that wherever there is a hole drilled in a tension member, the stresses at its edge are three times the regular stresses in the solid material, no matter how small the hole is. If the hole is large, even greater stresses are produced on account of the smaller cross-section remaining. This drilling of the hole in the rod in a place of great stress is, therefore, a mistake of engineering; and if, on top of that, a hole is drilled in the shop by a mistake at right angles to the first one and afterwards plugged, we have not only a mistake of engineering but almost criminal recklessness in the shop. This should not be charged against the gas engine in general. A gas engine correctly designed and well inspected in the shop will not show this error.

Turning now to the alleged complication of gas-engine valve gears with their troubles of maintenance and attendance, I wish to say, in addition to the remarks by Mr. Freyn, that we do not have to go to Europe to see the builders throw all useless stuff away and simplify the engine. In fact, the Westinghouse Machine Company was the first to build a simplified valve gear of the constant-mixture type and the design has been still further simplified by Mr. Ottesen of the Mesta Machine Company, who introduced the simple butterfly valves which Mr. Freyn praises so strongly in the European engine.

I am looking forward to higher rotative speeds and simple engines without ginger-bread work, but with careful methods of lubrication, and I feel that after a couple of years we will look with a sort of astonishment on the enormously large and ponderously moving big engines which we now have in the steel works of this section and will wonder why we did not build them smaller and of higher speed in the first place.

A. E. Maccoun. Mr. Freyn, like a great many others, in discussing the future of large blast-furnace gas engines in America is very optimistic and seems to be inclined to give only the bright side of this subject. I have tried rather to give a true history of the actual conditions met with in this type of prime mover and even though our experience, as Mr. Freyn states, was obtained from the first large 4-cycle blast-furnace gas engines built in this country, still so far as records show, these engines have at least given as good, if not a better account of themselves than most of the later engines of this type. In the gas power plant operated by Mr. Freyn, I know that most, if not all, of the experiences have been encountered which are covered by my discussion. In fact, so far as I know there is no large blast-furnace gas-engine plant in this country that has not, and therefore I do not think Mr. Freyn is quite as frank in treating this subject as he should be. I have perfect confidence, however, that most of them will be overcome by changes in material and design and my object has been merely to present this matter before the Society in its true light and to look at the subject from both sides.

The blast-furnace gas engine unquestionably has a great advantage over the steam engine, on account of its greater economy in transforming heat into useful work, and this advantage is manifestly greater when the cost of fuel is high. Mr. Freyn suggests that the price of fuel in the Pittsburg district may be increased. If this should be the case it will make the gas engine more desirable in this district.

To compensate for the advantages of the gas engine, any fair-minded person must grant there are some disadvantages, such as high first cost; large sizes for comparatively small powers; harder duties to perform by its different parts on account of the enormous pressure and temperature conditions, due to the explosion principle of the gas engine cycle; and necessarily more careful attention and a greater amount of repairs are required than for a steam engine of the same type.

I stated that with the larger size gas engines, for instance cylinders of 48-in. diameter, it becomes nearly impossible to design the working parts, such as cylinders, piston rods, etc., strong enough to stand the strains. Mr. Freyn states this is quite common practice abroad and that they make cylinders, pistons, etc. for engines of this size very successfully, on account of the better foundry practice. I am sure we would all appreciate seeing the drawings of a cylinder of this size, made from cast iron, that had proven by time that it was satisfactory, and also hearing about the differences in foundry practice here and abroad, as these are some of the most vital parts of a gas engine.

Mr. Freyn states that abroad 5 per cent nickel is used in their piston rods and that in this country we would not think of making such an expensive piston rod. I think he is entirely mistaken, as we would be perfectly willing to use any percentage of nickel in a piston rod if we thought anything was to be gained by its use.

The analysis of the nickel steel rods we originally had was approximately as follows: carbon 0.32 per cent; manganese 0.54 per cent; phosphorus 0.048 per cent; sulphur 0.024 per cent; nickel 3.11 per cent; silicon 0.215 per cent. If Mr. Freyn could give us the analyses of the rods he refers to I am sure it would be appreciated. He states that abroad they do not have to make their piston rods nearly as large as ours, and still get the required strength. In going over many German designs, I find just the opposite and very few of their rods have a maximum stress on a section of the rod, due to explosion pressure, of over 5000 lb. per sq. in.

Regarding the fastening of rods to cross-heads with differential nuts, Mr. Freyn also states that they have no trouble from this source, and we would also like to know how this trouble is avoided, as all these details are of great interest and value.

I am glad to hear Mr. Freyn has changed his views in favor of the constant-mixture system and it would also have been of great interest to have heard more from him regarding the simple valve gear, consisting of a light governor operating butterfly valves.

I fully agree with Mr. Freyn regarding the Snow gas engine; it is a splendid machine and Mr. Scott, its designer, deserves the greatest credit. But even Mr. Scott was compelled from experience to adopt cast-steel cylinders and pistons, and some difficulties have been experienced even on this engine with piston rods and other details.

I am fully satisfied that we can make as good material, and build and design as good a blast-furnace gas engine in this country as can be done abroad. It may be that abroad they do not tell us all their troubles, or that the duty imposed on their engines is not so severe.

Jos. Morgan. The fact of the heat economy of the gas engine over the best steam results is established, but as in previous discussion, attention must be directed to the whole problem which includes relative first cost and interest on plant as part of the total cost of operation.

When it comes to electrical generators the difference in first cost of the small 2000 to 3000 gas-driven units and the much larger modern turbine units cannot be ignored. It is asserted that the gas engine costs less than is popularly supposed, and that it is being cheapened by simpler gas-valve and cut-off gear and by much higher speed in blowing engines due to the use of light sheet steel in valves. The latter will certainly help the gas engine by increasing its capacity, but the gas valve gear is a trifling part of the gas engine. Its great cost is in its massiveness, due to the high explosive pressures it has to endure, affecting the heavy parts, the bed, the shaft, the cylinders, piston, connecting rod and crosshead. Most of the cost is in these.

Gas engine driving generators cannot be helped much by increase of speed as this has never been limited. Operating superintendents will agree with Mr. Friedlander that a 3000-kw. unit is too small for plants intended to generate 20,000 to 50,000 kw. and upward. All the economies of operation are in favor of the larger units up to 10,000 or 15,000 kw. There is a tendency on the part of the gas-engine advocates to ignore the recent developments in steam plants, the greater steam productiveness of the boiler units, with lessened unit cost. Most of all do they ignore the great emergency reserve capacity of the steam turbine, in which it is greatly the superior of the gas engine. This reserve capacity of the turbine is important in lessening the necessary power investment.

For the last half century the quantity of coal mined has increased 100 per cent every ten years, and its price is gradually going upward, as Mr. Freyn points out. This is recognized in our use of by-product coke ovens which save about 10 per cent of the coal burned to waste in the beehive oven, saving also large amounts of gas, tar and ammonia heretofore wasted. Mr. Parker in his report to the U. S. Geological Survey for 1909, says: "1,350,000 h.p. is going to waste in the coking region of the United States every day in the year. In the Connellsville region the energy from 38,000 ovens exceeds 570,000 h.p. The total value lost in the United States by wasteful coking methods is

$38,000,000 per annum and the value now recovered is $8,000,000 per annum." Notwithstanding these facts, works managers have had to take into consideration the large amount of capital required to replace beehive by by-product ovens, and have conservatively awaited their development with the proof of their capacity and durability.

This also is the present attitude of many managers toward costly gas-engine installations. For generating electricity, disregarding first cost, no cheaper prime mover can be found than the water turbine, but many hydro-electric plants have been built, bankrupting the building corporations because their first cost was too great and a paying load was not to be found.

It is to the paying load that attention must be directed. Electric current is worth nothing if it cannot be sold and blast furnace gas is of no value when blown to waste. There is much exaggeration of the possible gain by gas engines. One prominent gas engine building concern has been industriously circulating a theoretical calculation upon the value of power from a blast furnace plant about as follows:

"For two blast furnaces making 500 tons of pig each daily, coke ton per ton, 60 cu. ft. of air per lb. coke, the surplus power available is as follows: Power available over furnace requirements and the coal equivalent of same based on a load factor of 75 per cent, (*a*) with compound steam blowing engines and steam turbo-electric generators, 10,225 h.p. = 60,600 tons coal yearly; (*b*) with gas blowing gas generator drive, 26,350 h.p. = 85,400 tons coal yearly."

The accountant not satisfied with this showing proceeds to double the coal to 156,000 tons of coal as saved by using a gas engine instead of steam engines and coal under boilers to generate an equal amount of current. The real saving assuming all the current used is only the difference, 85,400 − 60,600 = 25,800 tons of coal, which may be largely or entirely offset by the greater operating cost of the gas-engine plant.

Managers of electric plants are well aware how much the load factor influences the cost of production, and that the most difficult part of the business is to keep the paying load fairly full at all times. Practically few plants average over 30 to 50 per cent of their full capacity. Mr. Hoff, Chief Engineer, of Duedelingen, Germany at meeting of German iron workers, in May 1911, is quoted as saying: "In twenty-nine German electrical generating plants in steel works an average of 38 per cent of the power of the gas plants is utilized." In a plant depending upon the output of furnace gas, for the power developed, at times much of the gas is blown to waste and lost, for the gas power must be at all times equal to carrying the maximum load and therefore much of the time when there is no such load, there will be a gas surplus wasted.

The actual kilowatt capacity of the Gary plant, as published, shows probably not over one-half the furnace capacity of gas used. The load has not yet been built up to full furnace capacity nor can it ever be so large unless there shall be a steam turbo-electric generating reserve.

This leads to the suggestion that what we need to utilize all this by-product power is a general public system of transmission lines or a sort of electrical power clearing house to take all surplus current produced as a by-product by blast-furnace and coke-oven plants, and to supply all users of power, whether railroads, manufacturers or towns, makers to be credited and users to be charged with current. This system would have at some convenient place near fuel and condensing water large reserve generating stations to make up all deficiencies, which would result in great economies of operation and reduce the total cost of installation to the community. In no other way can so much of the by-product gas be used to generate power.

E. D. Dreyfus. It is indeed very fortunate to have operators express themselves so frankly on both the good and unsatisfactory features developed by the large gas engine in service, and the methods undertaken to correct the latter. Mr. Maccoun has typified the important changes which have been essential in the designs of the large gas engines, and while apparently it has not been expressed in the same way for all other plants, it is well known, of course, that they have had the same degree of trouble, which may or may not have been so completely overcome, or else their final solution is still in the future and not available at present. The exposition of troubles of the more or less transient nature described may create a feeling of apprehension in the minds of some power users, when on the other hand it should really prove reassuring to them on account of their successful correction, as pointed out by Mr. Maccoun.

It seems in truth that the experience of many with the gas engine has been that the difficulties met varied, it may be said, as some power greater than unity in proportion to their dimensions. This may be explained by the greater magnitude of forces and bulk of material existing in the larger engines. Smaller units for electric and industrial purposes, therefore have not been attended with anything like the same "woes", relatively, and in consequence, with the ratio of heat efficiency of the steam and gas plants increasing in favor of the latter with diminishing size of units, there is no question about the small and moderate sized gas engine becoming a greater economic factor in our industries.

The preceding remarks obviously exempt engines not well designed or accurately built. The large gas engine under the present conditions has been properly limited mainly to the blast-furnace plant where there is a gaseous by-product fuel and particularly where most installations have not required a large number of units. In the large plant burning coal at prices obtaining in this country, it is impossible to show an advantage with the gas engine in spite its high thermal efficiency due to the greater economy in labor, operating supplies and investment realized with the steam turbine. As mentioned before this does not hold with moderate and small capacities and in this range we will probably find the gas engine will forge ahead rapidly.

# REPORT OF THE PLANT OPERATIONS COMMITTEE

The Plant Operations Committee has been actively engaged during the past year in soliciting operating costs from various gas power plants, only a few of which have responded with available data. At the present time, one prominent manufacturer is coöperating to secure other data, which will probably be submitted later.

The Committee's correspondence indicates that during the past few years various engineering bodies have devoted considerable time to investigating similar data, sending numerous requests for information all over the country, to answer which requires both time and expense. They recommend that such investigations shall in future be made in conjunction with such other societies as may be interested, thus reducing the number of inquiries.

The following data were submitted by the Plant Operations Committee, consisting of I. E. Moultrop, Chairman, J. D. Andrew, C. J. Davidson, C. N. Duffy, H. J. K. Freyn, W. S. Twining, C. W. Whiting, with the recommendation that the committee be discharged:

The plants upon which the Committee is able to make a report are described in some detail in the following pages and, following each description is a summation of their operating costs. In some instances, these cost records cover a few months and, in one instance, a considerably longer period of operation.

For the purpose of identification, but without disclosing the name or location, the plants are designated by letters.

It should be distinctly understood that the cost figures are presented as they are furnished by the operators. The Committee has not been in a position to verify or question any of the operating costs which are herein presented.

## PLANT *A*

### DETAILS OF PLANT

*Producers.* There are two 250-h.p. pressure producers, 7 ft. 0 in. inside diameter, with water seal bottoms and 9 in. fire-brick linings, also two wet scrubbers, 7 ft. 6 in. in diameter by 18 ft. 0 in. high, filled with wooden lattice work. There are two dry scrubbers, 7 ft. 0 in. square by 3 ft. 6 in. high, filled with coarse shavings.

Presented at the Spring Meeting, Pittsburgh, 1911, of The American Society of Mechanical Engineers.

*Gas Engines.* There is one 500-h.p. horizontal, double-acting, 4-stroke-cycle engine with two cylinders, 23½ in. by 33 in., arranged tandem. The engine has three bearings rigidly in line. It runs at 150 r.p.m. and is direct connected to an electric generator. It is started by compressed air at 100 lb. pressure and has an electric ignition of the make-and-break type, the source of supply being a 110-volt direct-current lighting circuit and a motor generator set.

### AUXILIARIES

There are two tar extractors and one blower.

*Details of Operation.* The data received covered two complete months. The plant is run 24 hours per day from 6 a.m. Monday until 12 p.m. Saturday night, and the current generated is utilized for light and power. During the two months, a total of 308,410 kw-hr. was generated and 35,190 kw-hr. was used in the plant, leaving a net output of 273,220 kw-hr. The fuel used is bituminous coal. The cooling water from the engine is utilized for other purposes and is not, therefore, charged to the plant. The cooling and cleaning water for the scrubbers is not given.

### COST OF OPERATION

| | | |
|---|---|---|
| Fuel | | $0.2576 per net kw-hr. |
| Water | | 0.0000 per net kw-hr. |
| Supplies, oil | $0.0141 | |
| waste, etc | 0.0024 | |
| Total | | 0.0165 per net kw-hr. |
| Superintendence | | 0.0000 per net kw-hr. |
| Labor, producer room | 0.1585 | |
| engine room | 0.0555 | |
| electrical | 0.0000 | |
| Total | | 0.2140 per net kw-hr. |
| Repairs, producer | 0.0127 | |
| engines | 0.0040 | |
| electrical | 0.0000 | |
| Total | | 0.0167 per net kw-hr. |
| Total cost | | 0.5048 per net kw-hr. |

## PLANT *B*

### DETAILS OF PLANT

*Producers.* There is one set of producers of the Loomis-Pettibone type.

*Gas Engines.* There is one 500-h.p. horizontal, double-acting, 4-stroke-cycle engine with two cylinders, 23½ in. by 33 in., arranged tandem. The engine has two bearings rigidly in line. It runs at 150 r.p.m. and is direct connected to an electric generator. It is started by compressed air at 240 lb. pressure, and has an electric ignition of the make-and-break type, the source of supply being a 110-volt lighting circuit.

### DETAILS OF OPERATION

The data received are for fifteen complete months. The plant is run ten hours per day.

### COST OF OPERATION

| | | |
|---|---|---|
| Fuel | | $0.4460 per net kw-hr. |
| Water | | 0.0879 per net kw-hr. |
| Supplies, oil | $0.0465 | |
| waste, etc | 0.0335 | |
| Total | | 0.0800 per net kw-hr. |
| Superintendence | | 0.0000 per net kw-hr. |
| Labor, producer room | 0.1603 | |
| engine room | 0.2050 | |
| electrical | 0.0000 | |
| Total | | 0.3653 per net kw-hr. |
| Repairs, produced | 0.0243 | |
| engines | 0.2375 | |
| electrical | 0.0000 | |
| Total | | 0.2618 per net kw-hr. |
| Total cost | | 1.2410 per net kw-hr. |

## PLANT *C*

### DETAILS OF PLANT

*Producers*. There are two sets of producers of the Loomis-Pettibone type and of 2000-h.p. capacity each.

*Gas Engines*. There are two 1500-h.p. horizontal, double-acting, 4-stroke-cycle engines each with four cylinders, 32 in. by 42 in., arranged twin tandem. Each engine has two bearings rigidly in line. They run at 107 r.p.m. and are direct connected to electric generators. They are started by compressed air and have an electric ignition of the make-and-break type, the source of supply being a motor generator set supplying current at 60 volts.

The information following is taken from the plant's own forms, as due to the supervision of a State Commission they could not use our forms without duplicating the work.

## COST OF OPERATION

### For the Year 1908

| | | | | |
|---|---|---|---|---|
| Fuel | | $0.566 | per | kw-hr |
| Water | | 0.000 | per | kw-hr. |
| Supplies, oil and waste | $0.044 | | | |
| miscellaneous | 0.013 | | | |
| Total | | 0.057 | per | kw-hr. |
| Superintendence | | 0.031 | per | kw-hr. |
| Labor, producer room and engine room | 0.173 | | | |
| electrical | 0.000 | | | |
| Total | | 0.173 | per | kw-hr. |
| Repairs, producer | 0.006 | | | |
| engine | 0.000 | | | |
| electrical | 0.004 | | | |
| Total | | 0.010 | per | kw-hr. |
| Total cost | | 0.837 | per | kw-hr. |

### For the Year 1909

| | | | | |
|---|---|---|---|---|
| Fuel | | $0.439 | per | kw-hr. |
| Water | | 0.000 | per | kw-hr. |
| Supplies, oil and waste | 0.029 | | | |
| miscellaneous | 0.016 | | | |
| Total | | 0.045 | per | kw-hr. |
| Superintendence | | 0.023 | per | kw-hr. |
| Labor, producer room | 0.109 | | | |
| engine room | 0.066 | | | |
| electrical | 0.000 | | | |
| Total | | 0.175 | per | kw-hr. |
| Repairs, producer | 0.020 | | | |
| engine | 0.006 | | | |
| electrical | 0.002 | | | |
| Total | | 0.028 | per | kw-hr. |
| Total cost | | 0.710 | per | kw-hr. |

### For the Year 1910

| | | | | |
|---|---|---|---|---|
| Fuel | | $0.422 | per | kw-hr. |
| Water | | 0.003 | per | kw-hr. |
| Supplies, oil and waste | $0.024 | | | |
| miscellaneous | 0.015 | | | |
| Total | | 0.039 | per | kw-hr. |

| | | | |
|---|---|---|---|
| Superintendence | | 0.026 | per kw-hr. |
| Labor, producer room | 0.102 | | |
| engine room | 0.063 | | |
| electrical | 0.000 | | |
| Total | | 0.165 | per kw-hr. |
| Repairs, producer | 0.024 | | |
| engine | 0.004 | | |
| electrical | 0.005 | | |
| Total | | 0.033 | per kw-hr. |
| Total cost | | 0.688 | per kw-hr. |

## PLANT *D*

### DETAILS OF PLANT

*Producers.* There are two 400-h.p. pressure producers, 8 ft. 0 in. inside diameter with water seal bottoms and with 9 in. fire-brick linings, and two wet scrubbers, 8 ft. 0 in. in diameter by 20 ft. 0 in. high, filled with coke. There are two dry scrubbers, 6 ft. 0 in. square by 3 ft. 6 in. high.

*Gas Engines.* There are three 250-h.p. vertical, single-acting, 4-stroke-cycle engines each with three cylinders, 20 in. by 19 in. arranged side by side. Each engine has five bearings rigidly in line. They run at 230 r.p.m. and are direct connected to electric generators. They are started by compressed air at 200 lb. pressure and have an electric ignition of the make-and-break type, the sources of supply being a primary battery and a direct-driven magneto.

### DETAILS OF OPERATION

The data received are for three complete months. The plant was in operation 1439 hr. during the three months and generated a total of 309,300 kw-hr. The fuel used was No. 1 anthracite buckwheat.

### COST OF OPERATION

| | | | |
|---|---|---|---|
| Fuel | | $0.2828 | per net kw-hr. |
| Water | | 0.0000 | per net kw-hr. |
| Supplies, oil, waste, etc | | 0.0572 | per net kw-hr. |
| Superintendence | | 0.0000 | per net kw-hr. |
| Labor, producer room | 0.1135 | | |
| engine room | 0.2640 | | |
| electrical | 0.0000 | | |
| Total | | 0.3775 | per net kw-hr. |
| Repairs, producer | 0.0249 | | |
| Repairs, engines, electrical | | 0.1745 | per net kw-hr. |
| Total cost | | 0.8920 | per net kw-hr. |

The cost of coal at the plant given was $2.55 per ton at Plant *A*; $4.53 per ton at Plant *B*; unknown at Plant *C*; and $2.33 per ton at Plant *D*. Reducing the cost of coal at Plant *B* to $2.50 per ton, the costs of operation compare as follows:

| | | |
|---|---|---|
| Plant *A* | $0.505 | per kw-hr. |
| Plant *B* | 1.041 | per kw-hr. |
| Plant *C* | 0.745 | per kw-hr. |
| Plant *D* | 0.892 | per kw-hr. |
| Average | 0.796 | per kw-hr. |

# PRELIMINARY REPORT OF LITERATURE COMMITTEE

## (IX)

### ARTICLES IN PERIODICALS[1]

BITUMINOUS COAL, SUCTION PRODUCER FOR. *The Engineer* (*London*), *July 21, 1911.* 1½ pp., 3 figs., 1 table. *bfA.*

**Invented and built by R. V. Farnham of Farnham's Patents, Ltd., Glasgow, Engineers.**

ENGINE, 1350-B.H.P. GAS. *The Engineer* (*London*), *July 21, 1911.* 1½ pp., 2 figs. *bfA.* Also *London Engineering, July 21, 1911.* 2 pp., 3 figs., 1 table. *b.*

**Describes in detail engine made by Galloways, Ltd., Manchester, Eng., of the Ehrhardt and Sehmer horizontal tandem, double-acting four-cycle type, and is intended to drive an 800-kw. Mather and Platt alternator continuously day and night, seven days per week.**

ENGINES, MODERN DIESEL OIL, F. Schubeler. *London Engineering, July 28, 1911.* 2 pp., 1 fig. *bf.*

**Description and possibilities of operation.**

FIAT MARINE OIL ENGINE. *The Engineer* (*London*), *July 28, 1911.* 1 p., 1 fig. *bf.*

**Describes a 600-h.p. marine oil engine, Diesel type.**

FUEL OIL, THE HEATING VALUE OF. *Cassier's Magazine, August 1911.* 1 p. *f.*

**Extract of Bureau of Mines, Technical Paper No. 3, Specifications for the Purchase of Fuel Oil for the Government, by Irving C. Allen.**

KRAFTGAS GENERATOREN, Braunkohlen, H. L. *Braunkohle, March 31, May 19, June 2, 1911.* 31 pp., 17 figs., 6 tables. *abfB.*

LIGNITE GAS PRODUCER IN TEXAS, THE PRESENT STATUS OF THE. *Electrical World, August 5, 1911.*

[1] Opinions expressed are those of the reviewer not of the Society. Articles are classified as *a* comparative; *b* descriptive; *c* experimental; *d* historical; *e* mathematical; *f* practical. A rating is occasionally given by the reviewer, as *A*, *B*, *C*. The first installment was given in The Journal for May 1910.

MARINE OIL ENGINE, THE WEAK POINTS OF THE. *The Engineer* (*London*), *July 21, 1911*. 1 p. *afA*.

The lack of ability to run at very low speeds without undue loss in efficiency and means of working the winches, stearing gear, blowing of the whistle, heating of the ship, etc.

MOTEURS À COMBUSTION INTERNE ET ENPARTICULIER LES MOTEURS DIESEL. *L'Industrie Electrique, June 10, 1911*. ½ p. *acf*.

Describes former and later costs, etc., of internal-combustion engines; in particular the Diesel engine.

MOTOR, NEW FRENCH HIGH-COMPRESSION. *The Engineer* (*London*), *July 14, 1911*. 3 pp., 9 figs. *abfB*.

Describes oil engines of six-cylinder reversing, marine type, built by Société des Moteurs Sabathe, St. Étienne, Engineers.

PRODUCER PLANT EXPERIENCE AT HURON, S. D., GAS. *Electrical World, August 5, 1911*. 1½ pp., 3 figs.

TRACTION IN EUROPE, GASOLINE, Francis E. Drake. *Electrical World, July 22, 1911*. 2 pp., 5 figs.

## PERSONALS

Edward E. Ashley, Jr., formerly mechanical engineer in charge of the electrical department of W. G. Cornell Co., has opened an office of his own in New York.

Henry L. Barton, vice-president of the Metals Product Co., Detroit, Mich., has accepted a position with the General Motors Co., of the same city.

Andrew C. Campbell has severed his connection with the E. J. Manville Machine Co., Waterbury, Conn., with which firm he was identified for the past 16 years, in the capacities of chief engineer, mechanical executive, secretary and superintendent. Mr. Campbell is at present maintaining an office in Waterbury, as consulting engineer.

William L. Dearborn, secretary and treasurer of the Eastwick Engineering Company, New York, is representing the firm of Barclay, Parsons and Klapp, Consulting Engineers, New York, in Cuba, and is resident engineer for the Port of Havana Docks Co. in the construction of the new reinforced concrete docks and warehouses.

George T. Frankenburg has been appointed superintendent of The Columbus Brass Co., Columbus, Ohio. He was formerly outside foreman of The Cambria Steel Co., of Johnstown, Pa.

Herman Gamper, until recently superintendent of the Municipal Electric Light Plant, Columbus, Ohio, has become general manager of the Erie Company, Erie, Pa.

Wm. Paul Gerhard, consulting engineer and author of some standard works on Household Sanitation and on Sanitary Engineering has received the honorary degree of Doctor of Engineering from the German Imperial Technical University of Darmstadt.

Lucian L. Haas, formerly associated with the E. R. Thomas Motor Car Company of Buffalo, N. Y., is now chief tool designer with the Alden Sampson Manufacturing Company, Division of the United States Motor Company, Detroit, Mich.

Robert E. Hall has resigned his position as assistant manager of Francis Bros. & Jellett, Inc., Philadelphia, Pa., to become vice-president and treasurer of The Goulds Manufacturing Co. of New England, Boston, Mass.

Carleton W. Hubbard, formerly engineer with the Mianus Works, Greenwich, Conn., has taken a position with the Sayles Bleacheries, Saylesville, R. I.

E. P. Larkin has become associated with the United States Metal Products Company, College Point, N. Y.

Leo Loeb has recently been made assistant steam engineer in the steam engineering department of The Cambria Steel Co., Johnstown, Pa. He was formerly assistant professor of mechanical engineering at the Rensselaer Polytechnic Institute, Troy, N. Y.

H. H. Maxfield has recently been transferred to the Pittsburg Shops of the Pennsylvania Railroad. He was formerly master mechanic with the same company, Trenton, N. J.

H. F. J. Porter has been appointed secretary of the Organizing Committee of the Sixth Congress of the International Association for Testing Materials, which will be held in Washington and New York in September 1912.

William J. Reilly, formerly manager of the Cleveland office of Babcock & Wilcox Co., has been transferred to their Denver branch.

Arthur D. Shaw has been appointed manager of Francis Bros. & Jellett, Philadelphia, Pa. He was formerly associated with the Sagax Wood Co., Baltimore, Md.

Everett W. Swartwout has been appointed manager of the Chicago office of the Nordberg Manufacturing Company of Milwaukee, Wis.

Edward G. Thomas, until recently engineer with the Choralcelo Mfg. Co., Boston, has become mechanical engineer of The Boss Mfg. Co., Kewanee, Ill.

O. C. Thompson has accepted a position as mechanical engineer with the Healy Box Corporation, New York, N. Y. He was formerly works manager of the National Wire Box Co., South Bend, Ind.

Arthur P. Truette has become identified with the Goodyear Tire & Rubber Co., Akron, O. He was formerly assistant in mechanical engineering, Massachusetts Institute of Technology, Boston, Mass.

Lewis Wehner has severed his connection with the Bucyrus Company, South Milwaukee, Wis., to become chief engineer of the Vulcan Steam Shovel Co., Toledo, Ohio.

# ACCESSIONS TO THE LIBRARY

This list includes only accessions to the library of this Society. Lists of accessions to the libraries of the A. I. E. E. and A. I. M. E. can be secured on request from Calvin W. Rice, Secretary, Am. Soc. M. E.

Annalen für Gewerbe und Bauwesen. By F. C. Glaser. Vols. 1–15. *Berlin, 1877–1884.*

Army List and Directory. Officers of the Army of the United States. July 20, 1911. *Washington, 1911.* Gift of U. S. Superintendent of Documents.

Ausbildungs und Prüfungsstellen für den deutschen Kraftfahrzeugverkehr. Mitteleuropaischer Motorwagen Verein, No. 15. *Berlin, 1911.* Gift of the society.

Boston Society of Civil Engineers. Constitution and By-Laws and List of Members, June 1911. *Boston, 1911.* Gift of the society.

Collapsing Pressures of the National Tube Company's Bessemer Steel Lap-Welded Tubes. (Report). By R. T. Stewart. *Alleghany, 1906.*

Congreso Cientifico (1° Pan Americano). Ciencias Economicas y sociales. Vol. 2. *Santiago de Chile, 1911.* Gift of the congress.

Cost-Keeping and Scientific Management. By H. A. Evans. *New York, McGraw-Hill Book Co., 1911.*

Directory of Boiler Shop Equipment and Supplies, 1911. *New York, 1911.* Gift of the Boiler Maker.

Fighting Ships. By F. T. Jane. 1911. *Huddersfield.*

Fortschritte der Technik. 2d Year, 1910, 7 vols. *Berlin, 1910.*

Furnace Slags in Concrete. *Pittsburg, 1911.* Gift of Carnegie Steel Co.

Indiana Engineering Society. Proceedings of 13th, 20th, 25th, 28th Annual Meetings, 1893, 1900, 1905, 1908. *1893, 1900, 1905, 1908.* Gift of the society.

The Institution of Mechanical Engineers—Calcutta and District Section. Proceedings, 1910–1911. *Calcutta, 1911.* Gift of honorary secretary of the Calcutta section.

Lloyd's Register of British and Foreign Shipping. Vols. 1–2, 1911–1912. *London, 1911.*

———Rules and Regulations for the Construction and Classification of Steel Vessels. 1911–1912. *London, 1911.*

Massachusetts Railroad Commissioners. 40th–42d annual report. 1908–1910. *Boston, 1909–11.* Gift of the commissioner.

Michigan College of Mines. Year Book, 1910–1911. *Houghton, 1911.* Gift of the college.

Milwaukee Bureau of Economy and Efficiency. Bulletin No. 5. *Milwaukee, 1911.* Gift of the bureau.

National Machine Tool Builders' Association. Official Report, May 18, 19, 1911. *Atlantic City, 1911.* Gift of the association.

NATIONAL SOCIETY FOR THE PROMOTION OF INDUSTRIAL EDUCATION. Trade Continuation Schools of Munich. Bulletin No. 14. *New York, 1911.* Gift of the society.

NEW YORK STATE ADVISORY BOARD OF CONSULTING ENGINEERS. Report to the Governor, 1910. *Albany, 1911.* Gift of the board.

PNEUMATIC CAISSONS. By T. K. Thomson. Reprint from Construction, November–December 1908. Gift of the author.

POOR'S MANUAL OF RAILROADS, 1911. 44th annual number. *New York, 1911.*

PREVENTION OF INDUSTRIAL ACCIDENTS. No. 1—General. *New York, 1909.* Gift of Fidelity & Casualty Co. of New York.

RHODE ISLAND SCHOOL OF DESIGN. Year Book, 1911. *Providence, 1911.* Gift of the school.

STEAM TURBINES. Short treatise on theory, design and field of operation. By J. W. Roe. *New York, McGraw-Hill Book Co., 1911.*

STEEL WORKERS. By J. A. Fitch. *New York, Charities Publication Committee, 1910.*

TEXTILE EDUCATION AMONG THE PURITANS. By C. J. H. Woodbury. Read before Bostonian Society, April 18, 1911. *Boston, 1911.* Gift of the author.

U. S. ORDNANCE DEPARTMENT. Report of the Tests of Metals and Other Materials, 1910. *Washington, 1911.* Gift of the Ordnance Dept.

UNIVERSITY OF NEBRASKA. General Catalogue, 1910–1911. *Lincoln.* Gift of the university.

UNIVERSITY OF NEVADA. Register 1910–1911. *Reno, 1911.* Gift of the university.

VICTORIAN INSTITUTE OF ENGINEERS. Proceedings. Vol. 10, *Melbourne, 1910.* Gift of the institute.

WORK ACCIDENTS AND THE LAW. By C. Eastman. *New York, Charities Publication Committee. 1910.*

WORKINGMEN'S INSURANCE IN EUROPE. By L. K. Frankel and M. M. Dawson. *New York, Charities Publication Committee, 1910.*

## EXCHANGES

AMERICAN INSTITUTE OF ARCHITECTS. Proceedings of 44th Annual Convention, 1910. *Washington, 1910.*

NEW ENGLAND WATER WORKS ASSOCIATION. Constitution and List of Members. July 1911. *Boston, 1911.*

SOCIETY OF NAVAL ARCHITECTS AND MARINE ENGINEERS. Transactions. Vol. 18, 1910. *New York, 1910.*

U. S. NAVAL OBSERVATORY. Publications. 2d series. Vols. 6–7. *Washington, 1911.*

U. S. PATENT OFFICE. Annual Report of the Commissioner of Patents. 1910. *Washington. 1911.*

## UNITED ENGINEERING SOCIETY

Decimal Classification and Relative Index. By M. Dewey. Ed. 7, 1911. *Lake Placid Club, New York, 1911.*

Moody's Manual of Railroads and Corporation Securities. 12th annual number, 1911. *New York, 1911.*

Oklahoma Geological Survey. Bull. No. 3. *Norman, 1910.* Gift of the survey.

### TRADE CATALOGUES

Wm. Bailey Co., *Springfield, O.* Bailey-Springfield steel and iron window sash, 18 pp.

Bristol Co., *Waterbury, Conn.* Catalogue No. 160, Recording instruments for pressure, temperature, electricity, speed, time, etc., 64 pp.; Bull. No. 142, Recording water level gages, 23 pp.

Flannery Bolt Co., *Pittsburg, Pa.* The Tate flexible staybolt and information on the breakage of staybolts, 34 pp.

Hess-Bright Mfg. Co., *Philadelphia, Pa.* DWF adapter and the method of assembling it with bearings on a straight shaft, 1 p.; Application of floating bushes to grinding machine spindles, 1 p.; Method of assembling an adapter with mountings, 1 p.; Ball bearings in horizontal molding machines, 1 p.

Ingersoll Milling Machine Co., *Rockford, Ill.* Heavy duty knee type millers, 8 pp.; Examples of rapid milling done on an Ingersoll miller, 14 pp.; Milling machines, 102 pp.

Michigan Wire Cloth Co., *Detroit, Mich.* Catalogue on wire cloth of all types, 189 pp.

Model Stoker Co., *Dayton, O.* Model automatic smokeless furnace, 48 pp.

Sherwood Mfg. Co., *Buffalo, N. Y.* Injectors and ejectors, oil pumps, oil cups, flue scrapers and blowers, engine appliances, 62 pp.

Sims Co., *Erie, Pa.* Hot water generators and converters, laundry heaters, live steam and water mixers, 27 pp.

Westinghouse Electric & Mfg. Co., *Pittsburg, Pa.* Circular 1104, Portable meters for alternating current, 31 pp.

# EMPLOYMENT BULLETIN

The Society has always considered it a special obligation and pleasant duty to be the medium of securing better ositions for its members. The Secretary gives this his personal attention and is most anxious to receive requests both for positions and for men available. Notices are not repeated except upon special request. Copy for notices in this Bulletin should be received before the 15th of the month. The list of men available is made up of members of the Society and these are on file, with the names of other good men not members of the Society, who are capable of filling responsible positions. Information will be sent upon application.

## POSITIONS AVAILABLE

0112 Responsible salesmen wanted by established manufacturers of steam specialties. Unusual possibilities to a live wire. Give experience and state age.

0113 Works manager of an agricultural implement factory employing from five hundred to one thousand men. Prefer a man who has already proven successful and is at present employed in a similar capacity with some representive manufacturer. Applicant must be of highest order of engineer. Address c/o Am.Soc.M.E.

0114 Thoroughly competent engineer, technical education, who has had five or more years' experience in practical engineering. Must be thoroughly fitted in refrigerating and steam engineering, capable of being a licensed engineer; also require some knowledge of buildings, to look after alterations, changes and improvements both in steam and power, ammonia and general packing house work. Location Middle West.

0115 Young engineer to take charge of manufacturing end of micanite company, for concern engaged in development of mica mine in West. Experience in this particular line of manufacture essential. Address c/o Am.Soc.M.E.

0116 Mechanical engineer, first class draftsman and practical tool maker, competent to take charge of department manufacturing water meters. Prefer man who has had experience in above line of work. Only man of the highest ability will be considered.

## MEN AVAILABLE

262 Associate, age 33, desires responsible position; experienced in design and erection of mining, milling and smelting machinery, mills, etc., gas producers and gas plants, miscellaneous machinery. Location unimportant. Excellent references.

263 Member, having basic patent on method of governing gas engines, desires to interest capital to take out and finance foreign patents on same; and form company to collect royalties and control situation in this country. Only individuals or corporations controlling unlimited means will be considered.

264 Associate, fifteen years' experience as draftsman, squad foreman and checker, on blast furnaces, steel, rolling, pipe and tube mills, coke ovens and chemical apparatus, desires to locate in the East, preferably near Philadelphia or New York.

265 Member, graduate Massachusetts Institute of Technology, practical manufacturing and selling experience, competent to fill position as manager or superintendent, would accept good position as assistant or in sales department or branch where technical or mechanical knowledge is required.

266 Member, experienced as marine engineer, also designing, building and equipping manufacturing plants of all kinds, including design of special machinery, railroad and bridge construction, and as manager of a large business. Will be open for engagement November.

267 Mechanical engineer desires position as manager or operating engineer; for twelve years with large industrial plant as operating engineer. Best of references.

268 Member desires position as superintendent of foundry or works, engaged mostly in foundry work; can prove ability to manage and make money for anyone wanting such a man. Best of references.

269 Junior Member, technical graduate, wishes to advance with a construction or manufacturing concern. One year's experience in a plate glass plant.

270 Junior Member, graduate mechanical engineer, age 30; eight years' experience with contracting engineer and manufacturer, designing, estimating costs, inspecting; in charge of work, selling, heating and ventilating. At present, executive with contracting company; best references from previous and present connections. Desires to hear of opening for branch manager, assistant engineer, sales engineer. Salary $2000.

271 Junior Member, five years' experience in locomotive and car department of large railroad, three years' experience in automobile selling company; portion of time spent on railroad given to developing scientific management.

272 Mechanical engineer, Cornell graduate, ten years' practical experience, covering factory superintendence and maintenance, building construction, including reinforced concrete, and the installation and operation of power plant and factory machinery. Desires position with consulting or contracting engineers or as executive engineer in manufacturing concern.

273 Factory manager, extensive experience in management of large properties, and design, equipment and organization of new plants, wishes to make a change.

274 Mechanical engineer, technical graduate, present position factory manager; previous experience in general engineering as mechanical engineer, sales engineer and construction superintendent. Desires position as factory manager or mechanical engineer.

275 Technical graduate, thoroughly accustomed to handling men and working on own responsibility; now employed. Experienced in all phases of plant engineering, cost reduction, accounting, tool systems, power plant operations, construction and maintenance, with extensive study of scientific management and accounting.

276 Technical graduate, experienced in the design and construction of power plants, industrial plants and mill buildings, wants position which will not confine him to drafting board or office, while not objecting to some office work or drawing.

277 Member A.S.M.E. and A.I.E.E., at present employed with large manufacturing corporation, desires to become associated with smaller company or to take partnership in an established engineering firm. Wide experience in both electrical and mechanical engineering, considerable commercial experience. Prefers position in which desirable investment can be made of few thousand dollars and assume interest in established and profitable manufacturing business. Salary $5000.

278 Junior Member, technical graduate, number of years' experience in drafting, construction work and office work in connection with industrial plants and power plants; wishes to make a change.

279 Associate, 15 years' experience on blast furnaces, steel, rolling, pipe and tube mills, coke ovens and chemical apparatus, as draftsman, squad foreman and checker, desires to locate in the East, preferably near Philadelphia.

# CHANGES IN MEMBERSHIP

## CHANGES IN ADDRESS

ASHLEY, Edward E., Jr. (Junior, 1910), Mech. Engr., 527 Fifth Ave., New York, N. Y.

AUSTIN, Adolph Odell (Junior, 1905), York Mfg. Co., York, Pa.

AUSTIN, William S. (1902; 1906), Park Wks., Eastman Kodak Co., Rochester, N. Y.

BARTON, Henry L. (1903), care of Genl. Motors Co., 127 Woodward Ave., Detroit, Mich.

BERRY, Edgar H. (1905; 1907), present address unknown.

BOUTON, Geo. Innes (1901; 1904), Engr. East. Dist., Heine Safety Boiler Co., 11 Broadway, and *for mail*, 137 W. 82d St., New York, N. Y.

BROOKS, Louis C. (Junior, 1901), Elec. Engr., Industrial Control Dept., Genl. Elec. Co., and *for mail*, R. F. D. No. 1, Schenectady, N. Y.

BURTON, J. Harry (Junior, 1906), present address unknown.

CAMPBELL, Andrew C. (1885; 1889), Cons. Engr., 65 Bank St., and *for mail*, 186 Hillside Ave., Waterbury, Conn.

CURTIS, Edma H., Jr. (Junior, 1901), Mech. Engr., 1981 Cleneay Ave., Norwood, O.

EKSTRAND, Charles (1898; 1903), Supt., Lowell M. Palmer's Plants, York, Pa., and *for mail*, The Park, Boonton, N. J.

ELY, Theo. N. (1880), Manager, 1880–1882; Vice-President, 1882; Ch. of M. P., Pa. R. R., System E. and W. of Pittsburgh, Broad St. Sta., Philadelphia, and *for mail*, Bryn Mawr, Pa.

FINCH, Ellis Jerome (Junior, 1911), 260 W. 136th St., New York, N. Y.

FRANKENBERG, George T. (Associate, 1907), Supt., The Columbus Brass Co., and 86 Latta Ave., Columbus, O.

GAMPER, Herman (1900), Genl. Mgr., Erie Co., Erie, Pa.

HAAS, Lucian L. (Junior, 1910), Ch. Tool Designer, Alden Sampson Mfg. Co., Div. of the U. S. Motor Co., and *for mail*, 989 Oakland Ave., Detroit, Mich.

HALL, Robert E. (1898; 1905), V. P. and Treas., The Goulds Mfg. Co. of N. E., 58 Pearl St., Boston, Mass.

HALL, Walter Atwood (1911), Asst. to Mgr., Lynn Wks., Genl. Elec. Co., West Lynn, and *for mail*, 15 Hardy Rd., Swampscott, Mass.

HANSEN, T. H. C. (1905), Wire Spec. & Mch. Wks., 1108 High St., and 865 S. Clinton St., South Bend, Ind.

HOBERT, Stephen G. (1897; 1906), Cons. Engr., 179 W. Washington St., Chicago, and Clarenden Hills, Ill.

HUBBARD, Carleton Waterbury (Junior, 1911), Sayles Bleacheries, and *for mail*, 180 Chapel St., Saylesville, R. I.

HURLEY, Daniel (Junior, 1904), 42 E. Manning St., Providence, R. I.

IRELAND, Mark L. (Junior, 1902), First Lieut., Coast Artillery Corps. U. S. A., Fort Monroe, Va.

KEABLES, Austin Dow (Junior, 1910), The Charles, West Point, Ga.

KEELY, Royal R. (1901; 1907), 1704 Mt. Vernon St., Philadelphia, Pa.

KINKEAD, James A. (Associate, 1903), Res. Sales Mgr., Parkesburg Iron Co., 30 Church St., New York, N. Y., and Stelton, N. J.

KNEIP, Walter F. (Junior, 1904), Engrg. Dept., H. H. Franklin Mfg. Co., and *for mail*, 932 Bellevue Ave., Syracuse, N. Y.

LAIRD, Wilbur G. (Associate, 1906), Asst. Mgr., Candelaria Min. Co., Minas de San Pedro, Chihuahua, Mex., and *for mail*, 2300 18th St., Washington, D. C.

LARKIN, Everett P. (Junior, 1906), U. S. Metal Products Co., College Point, N. Y.

LEWIS, David J., Jr. (1892), Sales Mgr., Lytton Mfg. Corp., 1159 Hudson Terminal Bldg., 50 Church St., New York, N. Y., and *for mail*, 88 Riggs Pl., South Orange, N. J.

LOEB, Leo (Junior, 1911), Steam Engrg. Dept., Cambria Steel Co., Johnstown, Pa.

McCLATCHEY, A. F. (1889), 132 N. 4th St., Aurora, Ill.

MAXFIELD, Howard H. (1904), M. M., Pa. R. R. Co., 28th St., Pittsburgh, Pa.

MEYER, C. Louis (Junior, 1909), Trussed Concrete Steel Co., Detroit, Mich.

MORRIS, Henry G. (1882), Vice-President, 1887–1889; Commonwealth Bldg., 12th and Chestnut Sts., Philadelphia, Pa.

MOUNT, Carroll Hays (Junior, 1910), 195 W. 11th Ave., Columbus, O.

MYERS, David Moffat (Associate, 1907), Cons. Engr., 17 Battery Pl., and 157 W. 79th St., New York, N. Y.

ODE, Randolph Theodore (1901; 1908), Secy., Providence Engrg. Wks., and *for mail*, Box 1266, Providence, R. I.

OLMSTED, George C. (Junior, 1909), care of Brunt Mine, Virginia, Minn.

ORD, Henry C. (1905), Dominion Bridge Co., Ltd., Montreal, Que., Canada.

POLLAK, Charles P. (Associate, 1901), East. Sales Agt., Wickes Boiler Co., and *for mail*, Engineers Club, 32 W. 40th St., New York, N. Y.

REILLY, William J. (1901), Mgr., Denver Office, Babcock & Wilcox Co., 435 17th St., Denver, Colo.

ROYS, Lawrence (Junior, 1907), The Bucyrus Co., and P. O. Box 793, South Milwaukee; also 861 First Ave., Milwaukee, Wis.

SCOLLAN, John Joseph (1910), 74 Roncesvalles Ave., Toronto, Ont., Canada.

SIBSON, Horace E. (Junior, 1904), Mech. Engr., Harrison Safety Boiler Wks., 17th St. and Allegheny Ave., Philadelphia, and *for mail*, P. O. Box 159, Cynwyd, Pa.

SLEE, Norman S. (Junior, 1909), Babcock & Wilcox Co., 85 Liberty St., New York, N. Y. and *for mail*, 186 North Ave., E., Cranford, N. J.

STIRLING, Allan (1880), Manager, 1881–1884; Vice-President, 1885–1887; Life Member; Pres., Drexel Bldg., Philadelphia, and Pleasant Mt., Wayne Co., Pa.

SWARTWOUT, Everett W. (Junior, 1910), Mgr., Chicago Office, Nordberg Mfg. Co., 704 Schiller Bldg., Chicago, Ill.

THOMAS, Edward G. (1890; 1907), Mech. Engr., The Boss Mfg. Co., Kewanee, Ill.

THOMPSON, O. C. (Associate, 1910), Mech. Engr., Healy Box Corp., 105 W. 40th St., and *for mail*, 346 W. 57th St., New York, N. Y.

TRUETTE, Arthur Pierce (Junior, 1911), Goodyear Tire & Rubber Co., Akron, O.

WEAR, Burt C. (Junior, 1905), Engr., Steel Roof Truss Co., 1647 Pierce Bldg., St. Louis, Mo.

WEHNER, Louis (1901; 1907), Ch. Engr., The Vulcan Steam Shovel Co., 916 Summit St., Toledo, O.

YARNALL, D. Robert (Junior, 1903), Mech. Engr., 1109 Locust St., Philadelphia, Pa.

YAWGER, Edwin (Associate, 1899), Sales Mgr. Denver Dist., The Westinghouse Mch. Co., 1062 Gas & Elec. Bldg., Denver, Colo.

## NEW MEMBERS

DOWNES, Nate Worswic (Junior, 1911), Ch Draftsman, J. H. Brady, Cons. Engr. and Ch. Engr., Kansas City Sch. Dist., and *for mail*, 3126 Olive St., Kansas City, Mo.

DREW, Wilbert Shepard (1911), Dir. Sch. Mech. Arts, Prof. Agri. Mech., Agri. College of Utah, Logan, Utah.

GARRAHAN, F. B. (Junior, 1911), 29 W. 39th St., New York, N. Y.

GARTLEY, Alonzo (1911), Cons. Engr., C. Brewer & Co., Ltd., Honolulu, Hawaii.

GATES, John George (Junior, 1911), Draftsman and Designer, Russell, Burdsall & Ward Bolt and Nut Co., and *for mail*, 29 Summer St., Port Chester, N. Y.

GRAHAM, William Harvey (1911), care of N. S. Steel & Coal Co., Sydney Mines, Cape Breton, N. S.

HALL, Carl Albe (Junior, 1911), Mech. Engr., Dir., Parker & Young Co., Lisbon, and *for mail*, Concord, N. H.

HIDER, George Turner (Junior, 1911), Gorgona, Canal Zone, Panama.

JOHNSON, John S. A. (1911), Prof. Exper. Engrg., Va. Poly. Inst., Blacksburg, Va.

JOHNSON, Raymond D. (1911), Hyd. Engr., Ontario Power Co., and P. O. Box 3, Niagara Falls, N. Y.

KENDRICK, J. W. (1911), V. P., Atchison, Topeka & Santa Fé Ry., 1023 Ry. Exch., Chicago, Ill. and *for mail*, care of Outing Magazine, 315 Fifth Ave., New York, N. Y.

MAGRATH, Charles Bolton (Junior, 1911), Mech. Engr., Diamond Coal Co., Alta, and *for mail*, 369 Daly Ave., Ottawa, Canada.

SANKEY, H. Riall (1911), Dir. and Cons. Engr., Marconi Wireless Telegraph Co., Ltd., and *for mail*, 7 Charlbury Grove, Ealing W., England.

## DEATHS

FERGUSSON, Henry A.

# COMING MEETINGS

## September–October

**Advance notices of annual and semi-annual meetings of engineering societies are regularly published under this heading and secretaries or members of societies whose meetings are of interest to engineers are invited to send such notices for publication. They should be in the editor's hands by the 15th of the month preceding the meeting. When the titles of papers read at monthly meetings are furnished they will also be published.**

AMERICAN ASSOCIATION OF GENERAL PASSENGER AND TICKET AGENTS

September 19, annual meeting, St. Paul, Minn. Secy., C. M. Burt, Boston, Mass.

AMERICAN ELECTRIC RAILWAY ASSOCIATION

October 9–13, annual convention, Atlantic City, N. J. Secy., H. C. Donecker, 29 W. 39th St., New York.

AMERICAN ELECTROCHEMICAL SOCIETY

September 21–23, annual meeting, Toronto, Ont. Secy., Jos. W. Richards, Lehigh University, South Bethlehem, Pa.

AMERICAN INSTITUTE OF MINING ENGINEERS

October 10, annual convention, San Francisco, Cal., followed by trip to Japan. Secy., Joseph Struthers, 29 W. 39th St., New York.

AMERICAN MINING CONGRESS

September 26–29, annual session, Chicago, Ill. Secy., J. F. Callbreath, Denver, Colo.

THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS

Monthly Meetings: New York, October 10; New Haven, November 15. Secy., Calvin W. Rice, 29 W. 39th St., New York.

AMERICAN SOCIETY OF MUNICIPAL IMPROVEMENTS

September 26–29, annual convention, Grand Rapids, Mich. Secy., A. P. Folwell, 239 W. 39th St., New York.

ASSOCIATION OF EDISON ILLUMINATING COMPANIES

September 19-21, annual convention, Spring Lake, N. J. Secy., N. Y. Wilcox, Lowell, Mass.

COLORADO ELECTRIC LIGHT, POWER AND RAILWAY ASSOCIATION

September 13–15, annual convention, Glenwood Springs, Colo. Secy., F. D. Morris, 323 Hagerman Bldg., Colorado Springs.

ILLUMINATING ENGINEERING SOCIETY

September 25–27, annual convention, Chicago, Ill. Secy., Preston S. Millar, 29 W. 39th St., New York.

INTERNATIONAL ASSOCIATION OF MUNICIPAL ELECTRICIANS
September 12–15, annual meeting, St. Paul, Minn. Secy., C. R. George, Houston, Tex.

INTERNATIONAL CONGRESS OF THE APPLICATIONS OF ELECTRICITY
September 9–20, Turin, Italy. President of the Organizing Committee, L. Lombardi, 10, Via San Paolo, Milan.

IRON AND STEEL INSTITUTE
October 2–16, autumn meeting, Turin, Italy. Secy., G. C. Lloyd, 28 Victoria St., London, S. W., England.

MASTER CAR AND LOCOMOTIVE PAINTERS' ASSOCIATION
September 12–15, annual convention, Atlantic City, N. J. Secy., A. P. Dane, B. & M. R. R., Reading, Mass.

NATIONAL ASSOCIATION OF COTTON MANUFACTURERS
September 27–30, semi-annual meeting, Hotel Equinox, Manchester, Vt. Secy., C. J. H. Woodbury, Box 3672, Boston, Mass.

NATIONAL ASSOCIATION OF RAILWAY COMMISSIONERS
October 10, annual convention, Washington, D. C. Secy., Wm. H. Connolly.

NATIONAL BUILDING MATERIAL EXHIBITION
September 9–16, Trade Show, Madison Square Garden, New York. Mgr., P. J. Powers, 508 Flatiron Bldg.

NATIONAL CONSERVATION CONGRESS
September 25–27, Kansas City, Mo. Secy., Thomas R. Shipp, Washington, D. C.

NEW ENGLAND WATER WORKS ASSOCIATION
September 13–15, annual convention, Gloucester, Mass. Secy., Willard Kent, Narragansett Pier, R. I.

RAILWAY SIGNAL ASSOCIATION
October 10, annual convention, Colorado Springs, Colo. Secy., C. C. Rosenberg, Bethlehem, Pa.

ROADMASTERS AND MAINTENANCE OF WAY ASSOCIATION
September 12–15, annual meeting, St. Louis, Mo. Secy., W. S. Emery, P. & P. U. Ry., Peoria, Ill.

TRAVELING ENGINEERS' ASSOCIATION
August 29–September 2, annual convention, Hotel Sherman, Chicago, Ill. Secy., W. O. Thompson, care of N. Y. C. Car Shops, East Buffalo, N. Y.

VERMONT ELECTRICAL ASSOCIATION
September 13-14, annual meeting, Lake Dunmore, Vt. Secy., A. B. Marsden, Manchester.

## MEETINGS IN THE ENGINEERING SOCIETIES BUILDING

| Date | Society | Secretary | Time |
|---|---|---|---|
| September | | | |
| 1-2 | Institute of Operating Engineers | H. Collins | All day |
| 7 | Blue Room Engineering Society | W. D. Sprague | 8 p.m. |
| 14 | Illuminating Engineering Society | P. S. Millar | 8 p.m. |
| 15 | New York Railroad Club | H. D. Vought | 8 p.m. |
| 27 | Municipal Engineers of New York | C. D. Pollock | 8 p.m. |

| Date | Society | Secretary | Time |
|---|---|---|---|
| October | | | |
| 5 | Blue Room Engineering Society | W. D. Sprague | 8.00 p.m. |
| 10 | American Society of Mechanical Engineers | C. W. Rice | 8.15 p.m. |
| 12 | Illuminating Engineering Society | P. S. Millar | 8.00 p.m. |
| 13 | American Institute of Electrical Engineers | R. W. Pope | 8.15 p.m. |
| 17 | New York Telephone Society | T. H. Lawrence | 8.00 p.m. |
| 20 | New York Railroad Club | H. D. Vought | 8.15 p.m. |
| 25 | Municipal Engineers of New York | C. D. Pollock | 8.00 p.m. |

# OFFICERS AND COUNCIL

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E. D. MEIER

*Vice-Presidents*

Terms expire 1911

CHARLES WHITING BAKER
W. F. M. GOSS
ALEX. C. HUMPHREYS

Terms expire 1912

GEORGE M. BRILL
E. M. HERR
H. H. VAUGHAN

*Managers*

Terms expire 1911

H. L. GANTT
I. E. MOULTROP
W. J. SANDO

Terms expire 1912

H. G. STOTT
JAMES HARTNESS
H. G. REIST

Terms expire 1913

D. F. CRAWFORD
STANLEY G. FLAGG, JR.
E. B. KATTE

*Past-Presidents*

Members of the Council for 1911

FRED. W. TAYLOR
F. R. HUTTON
GEORGE WESTINGHOUSE
M. L. HOLMAN
JESSE M. SMITH

*Chairman of the Finance Committee*

ROBERT M. DIXON

*Honorary Secretary*

F. R. HUTTON

*Treasurer*

WILLIAM H. WILEY

*Secretary*

CALVIN W. RICE

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C. W. BAKER, *Vice-Chmn.*
H. L. GANTT
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H. G. REIST
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## STANDING COMMITTEES

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G. J. ROBERTS (1)
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H. L. DOHERTY (4)
W. L. SAUNDERS (5)

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*Meetings*

L. R. POMEROY (1), *Chmn.*
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H. DE B. PARSONS (3)
W. E. HALL (4)
C. J. H. WOODBURY (5)

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W. M. McFARLAND (2)
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E. G. SPILSBURY (5)

*Public Relations*

J. M. DODGE (5), *Chmn.*
R. W. HUNT (1)
D. C. JACKSON (2)
J. W. LIEB, JR. (3)
F. J. MILLER (4)

NOTE—Numbers in parentheses indicate number of years the member has yet to serve.

## SOCIETY REPRESENTATIVES

*John Fritz Medal*

F. R. HUTTON (1)
W. F. M. GOSS (2)
H. R. TOWNE (3)
J. A. BASHEAR (4)

*Trustees U. E. S.*

F. J. MILLER (1)
JESSE M. SMITH (2)
A. C. HUMPHREYS (3)

*A. A. A. S.*

A. C. HUMPHREYS
H. G. REIST

*I. A. for T. M.*

CHARLES KIRCHHOFF

*Fire Protection*

J. R. FREEMAN
I. H. WOOLSON

*Conservation Commission*

G. F. SWAIN
C. T. MAIN
J. R. FREEMAN

*Engineering Education*

A. C. HUMPHREYS
F. W. TAYLOR

## SPECIAL COMMITTEES

*Refrigeration*

D. S. JACOBUS
A. P. TRAUTWEIN
G. T. VOORHEES
P. DE C. BALL
E. F. MILLER

*Power Tests*

D. S. JACOBUS, *Chmn.*
E. T. ADAMS
G. H. BARRUS
L. P. BRECKENRIDGE
W. KENT
C. E. LUCKE
E. F. MILLER
A. WEST
A. G. WOOD

*Conservation*

G. F. SWAIN, *Chmn.*
C. W. BAKER
L. D. BURLINGAME
M. L. HOLMAN
C. W. RICE

*Student Branches*

F. R. HUTTON, *Chmn.*

*Flanges*

H. G. STOTT, *Chmn*
A. C. ASHTON
W. SCHWANHAUSSER
J. P. SPARROW

*Constitution and By-Laws*

JESSE M. SMITH, *Chmn.*
G. M. BASFORD
F. R. HUTTON
D. S. JACOBUS
H. G. STOTT

*Power House Piping*

H. G. STOTT, *Chmn.*
I. E. MOULTROP
H. P. NORTON
J. T. WHITTLESEY
F. R. HUTTON

*Involute Gears*

W. LEWIS, *Chmn.*
H. BILGRIM
E. R. FELLOWS
C. R. GABRIEL
G. LANZA

*Pipe Threads*

E. M. HERR, *Chmn.*
W. J. BALDWIN
G. M. BOND
S. G. FLAGG, JR.

*Society History*

J. E. SWEET
H. H. SUPLEE
F. R. HUTTON

*Tellers of Election*

W. T. DONNELLY
T. STEBBINS
G. A. ORROK

*Nominating*

R. C. CARPENTER
New York, *Chmn.*
R. H. FERNALD
Cleveland, O.
E. G. SPILSBURY
New York
A. M. HUNT
San Francisco, Cal.
C. J. H. WOODBURY
Boston, Mass.

*Standardization of Catalogues*

WM. KENT, *Chmn.*
M. L. COOKE
W. B. SNOW
J. R. BIBBINS

*Engineering Standards*

HENRY HESS, *Chmn.*
H. W. SPANGLER
CHAS. DAY
J. H. BARR

## OFFICERS OF AFFILIATED SOCIETY

*Providence Association of Mechanical Engineers*

E. C. BLISS, *President*
M. C. HAPPOLDT, *Vice-Pres.*
T. M. PHETTEPLACE, *Secy.*
A. H. WHATLEY, *Treas.*

NOTE—Numbers in parentheses indicate number of years the member has yet to serve.

## OFFICERS OF THE GAS POWER SECTION

*Chairman*
R. H. FERNALD

*Secretary*
GEO. A. ORROK

### *Gas Power Executive Committee*

F. H. STILLMAN (5), *Chmn.*
G. I. ROCKWOOD (1)
C. J. DAVIDSON (1)
E. D. DREYFUS (1)
F. R. HUTTON (2)
H. H. SUPLEE (3)
F. R. LOW (4)

### *Gas Power Committee on Meetings*

WM. T. MAGRUDER, *Chmn.*
W. H. BLAUVELT
E. D. DREYFUS
A. H. GOLDINGHAM
NISBET LATTA
H. B. MACFARLAND

### *Gas Power Literature Committee*

R. B. BLOEMEKE, *Chmn.*
H. S. ISHAM
W. F. MONAGHAN
A. W. H. GRIEPE
W. S. MORRISON
H. G. WOLFE
N. J. YOUNG
S. O. SANDELL
S. I. OESTERREICHER
J. MAIBAUM

### *Gas Power Installations Committee*

L. R. LENT, *Chmn.*
A. BEMENT
C. B. REARICK

### *Gas Power Plant Operations Committee*

I. E. MOULTROP, *Chmn.*
J. D. ANDREW
C. J. DAVIDSON
C. N. DUFFY
H. J. K. FREYN
W. S. TWINING
C. W. WHITING

### *Gas Power Membership Committee*

H. R. COBLEIGH, *Chmn.*
H. V. O. COES
A. E. JOHNSON
F. S. KING
A. F. STILLMAN
G. M. S. TAIT
GEORGE W. WHYTE
S. S. WYER

## OFFICERS OF STUDENT BRANCHES

| INSTITUTION | DATE AUTHORIZED BY COUNCIL | HONORARY CHAIRMAN | PRESIDENT | CORRESPONDING SECRETARY |
|---|---|---|---|---|
| Stevens Inst. of Tech. | Dec. 4, 1908 | Alex. C. Humphreys | A. E. Bauhan | A. D. Karr |
| Cornell University | Dec. 4, 1908 | R. C. Carpenter | F. E. Yoakem | D. S. Wegg, Jr. |
| Armour Inst. of Tech. | Mar. 9, 1909 | G. F. Gebhardt | C. E. Beck | F. H. Griffiths |
| Leland Stanford Jr. Univ. | Mar. 9, 1909 | C. H. Shattuck | H. H. Blee | C. W. Scholefield |
| Brooklyn Poly. Inst. | Mar. 9, 1909 | W. D. Ennis | A. L. Palmer | R. C. Ennis |
| Purdue University | Mar. 9, 1909 | L. V. Ludy | L. Jones | H. E. Sproull |
| University of Kansas | Mar. 9, 1909 | P. F. Walker | W. H. Judy | M. C. Conley |
| New York University | Nov. 9, 1909 | C. E. Houghton | Harry Anderson | Andrew Hamilton |
| Univ. of Illinois | Nov. 9, 1909 | W. F. M. Goss | F. J. Schlink | E. J. Hasselquist |
| Penna. State College | Nov. 9, 1909 | J. P. Jackson | J. A. Kinney | H. S. Rodgers |
| Columbia University | Nov. 9, 1909 | Chas. E. Lucke | N. E. Hendrickson | J. L. Haynes |
| Mass. Inst. of Tech. | Nov. 9, 1909 | Gaetano Lanza | J. A. Noyes | R. M. Ferry |
| Univ. of Cincinnati | Nov. 9, 1909 | J. T. Faig | C. J. Malone | J. H. Schneider |
| Univ. of Wisconsin | Nov. 9, 1909 | H. J. B. Thorkelson | F. B. Sheriff | L. F. Garlock |
| Univ. of Missouri | Dec. 7, 1909 | H. Wade Hibbard | F. T. Kennedy | Osmer N. Edgar |
| Univ. of Nebraska | Dec. 7, 1909 | C. R. Richards | W. O. Forman | C. A. Bennett |
| Univ. of Maine | Feb. 8, 1910 | Arthur C. Jewett | A. H. Blaisdell | W. B. Emerson |
| Univ. of Arkansas | Apr. 12, 1910 | B. N. Wilson | W. Q. Williams | H. W. Barton |
| Yale University | Oct. 11, 1910 | L. P. Breckenridge | F. M. Jones | W. St. C. Childs |
| Rensselaer Poly. Inst. | Dec. 9, 1910 | A. M. Greene, Jr. | G. K. Palsgrove | H. J. Parthesius |
| State Univ. of Ky. | Jan. 10, 1911 | F. P. Anderson | G. C. Mills | H. L. Moore |
| Ohio State University | Jan. 10, 1911 | W. T. Magruder | H. A. Shuler | H. M. Bone |
| Washington University | Mar. 10, 1911 | | | F. E. Glasgow |
| Lehigh University | June 2, 1911 | | | |

## MEETINGS OF THE SOCIETY

### *The Committee on Meetings*

L. R. POMEROY (1), *Chmn.*
C. E. LUCKE (2)
H. DE B. PARSONS (3)
W. E. HALL (4)
C. J. H. WOODBURY (5)

### *Meetings of the Society in Boston*

I. N. HOLLIS, *Chmn.*
I. E. MOULTROP, *Secy.*
E. F. MILLER
R. E. CURTIS
R. H. RICE

### *Meetings of the Society in New York*

W. RAUTENSTRAUCH, *Chmn.*
F. A. WALDRON, *Secy.*
F. H. COLVIN
E. VAN WINKLE
R. V. WRIGHT

### *Meetings of the Society in St. Louis*

E. L. OHLE, *Chmn.*
F. E. BAUSCH, *Secy.*
M. L. HOLMAN
R. H. TAIT
J. HUNTER

### *Meetings of the Society in San Francisco*

A. M. HUNT, *Chmn.*
T. W. RANSOM, *Secy.*
T. MORRIN
W. F. DURAND
E. C. JONES

### *Meetings of the Society in Philadelphia*

T. C. McBRIDE, *Chmn.*
D. R. YARNALL, *Secy.*
W. C. KERR
A. C. JACKSON
J. E. GIBSON
J. C. PARKER
JAMES CHRISTIE

### *Meetings of the Society in New Haven*

E. S. COOLEY, *Chmn.*
E. H. LOCKWOOD, *Secy.*
L. P. BRECKENRIDGE
F. L. BIGELOW
H. B. SARGENT

## SUB-COMMITTEES ON

### *Administration of Industrial Establishments*

CHAS. B. GOING, *Chmn.*
C. U. CARPENTER
JAMES HARTNESS
WORCESTER R. WARNER
STEVENSON TAYLOR

### *Textiles*

CHARLES T. PLUNKETT, *Chmn.*, Adams, Mass.
DANIEL M. BATES, Wilmington, Del.
JOHN ECCLES, Taftville, Conn.
EDW. W. FRANCE, Philadelphia, Pa.
EDWARD F. GREENE, Boston, Mass.
FRANKLIN W. HOBBS, Boston, Mass.
C. R. MAKEPEACE, Providence, R. I.
C. H. MANNING, Manchester, N. H.
HENRY F. MANSFIELD, Utica, N. Y.
EDWARD W. THOMAS, Lowell, Mass.

NOTE—Numbers in parentheses indicate the number of years the member has yet to serve

*Cement*

W. R. DUNN, *Acting Chmn.*
J. G. BERQUIST
W. F. COWHAM
J. W. FULLER, Jr.
L. L. GRIFFITHS
E. M. HAGAR
L. M. HUNT
F. W. KELLEY
MORRIS KIND
F. H. LEWIS
R. K. MEADE
EJNAR POSSELT
H. J. SEAMAN
A. C. TAGGE
H. STRUCKMANN
P. H. WILSON

*Machine Shop Practice*

F. E. ROGERS, *Chmn.*
L. D. BURLINGAME
W. L. CLARK
W. A. DIEFENDORF
A. L. DeLEEUW
F. L. EBERHARDT
F. A. ERRINGTON
A. A. FULLER
H. D. GORDON
H. K. HATHAWAY
E. J. KEARNEY
Wm. LODGE

*Standard Rules for Care and Construction of Boilers*

J. A. STEVENS, *Chmn.*
E. F. MILLER
C. L. HUSTON
H. C. MEINHOLTZ
R. C. CARPENTER
W. H. BOEHM
RICHARD HAMMOND

*Sub-Committee of Research Committee on Steam*

R. H. RICE, *Chmn.*
J. F. M. PATITZ
C. J. BACON
E. J. BERG
W. D. ENNIS
L. S. MARKS

# THE JOURNAL
OF
# THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS

VOL. 33 | OCTOBER, 1911 | NUMBER 10

## COMING MEETINGS

### NEW YORK MEETING, OCTOBER 9

Attention is called to the change of date of the October meeting, which will be held on Monday evening, October 9, to permit the attendance of the members of the National Machine Tool Builders Association whose convention in New York opens on the following day and to whom a cordial invitation to be present has been sent. The meeting will have the following general program:

A paper will be presented by L. P. Alford, editor-in-chief of The American Machinist, and H. C. Farrell, mechanical engineer of the United Shoe Machinery Company, on Factory Construction and Arrangement with special reference to the construction, development and arrangement of the United Shoe Machinery Company's plant at Beverly, Mass. Discussion will be grouped under the following heads and illustrated by lantern slides in so far as possible.

a Machinery Arrangement, covering the different methods of arranging machinery for manufacturing, to be discussed by Alexander Taylor, manager of works, Westinghouse Electric & Manufacturing Company, East Pittsburg, Pa.; L. D. Burlingame, chief draftsman, Brown & Sharpe Manufacturing Company, Providence, R. I.; and Charles Day of Dodge, Day & Zimmerman; Philadelphia.

b Artificial Shop Lighting, dealing with the advantages and disadvantages of diffused illumination, and the best types of lamps versus the advantage of individual lights at each machine. This will be discussed by C. E. Clewell, Westinghouse Electric & Manufacturing Company, East Pittsburg; G. H. Stickney, General Electric Company, Schenectady, N. Y.; and H. O. Stewart, Rochester Railway & Light Company, Rochester, N. Y.

c Factory Floors, giving the relative advantages and disadvantages of concrete floors, composition floors and wood floors, to be discussed by L. C. Wasson, Aberthaw Construction Company, Boston, Mass.; Henry Hess, president, Hess-Bright Manufacturing Company, Philadelphia; Gilbert Arnold, Stamford, Conn.; H. M. Lambourn, Yale & Towne Manufacturing Company, Stamford, Conn.

The subjects are live ones and a large attendance is expected. In addition to the discussors announced, all are invited to participate in the general discussion which will follow the formal presentation.

## BOSTON MEETING, OCTOBER 18

A meeting of the Society with the Boston section of the American Institute of Electrical Engineers and the Boston Society of Civil Engineers, will be held in Chipman Hall, Tremont Temple, on October 18. The Boston Society of Civil Engineers will have charge of the meeting and a paper will be read on Power System, Pacific Mills, Method and Rule Form and Cost of Operation, by Fred A. Wallace, master mechanic of the Pacific Mills, Lawrence, Mass.

## NEW HAVEN MEETING, NOVEMBER 15

A meeting of the Society will be held in New Haven on Wednesday, November 15, in the lecture room of the Mason Laboratory of Mechanical Engineering of the Sheffield Scientific School. Sessions will be arranged to occupy both afternoon and evening.

## ANNUAL MEETING

Plans are already in progress for the Annual Meeting of the Society to be held on December 5–8, the entertainment and social features of which will again be in charge of the Committee on Meetings of the Society in New York. Edward Van Winkle has been appointed chairman of the general Committee on Entertainment, with subcommittees to be announced later, and Mrs. Jesse M. Smith will this year be in charge of the Ladies Committee which will as usual add much to the social side of the gathering.

# CURRENT AFFAIRS OF THE SOCIETY

## NOTABLE IMPROVEMENTS IN THE LIBRARY

Some much needed improvements have been made in the library room of the Engineering Societies during the summer months by the Library Committee of the Founder Societies. Following out the original design of the architect, a second tier of stacks has been erected above the original tier, nearly doubling the capacity of the main room of the library. The framework and stairways are of steel construction and the flooring of glass to permit the passage of light.

The library now presents an appearance of even greater spaciousness than formerly and enjoys a collection and equipment in which the membership may well take pride. The new space provided is used largely for bound sets of periodicals, transactions, etc., formerly kept in the stack room on the floor below, so that they are now accessible for reference. The work was completed in time for the 21st annual convention of the New York Library Association, which opened in the Engineering Societies' Building on September 26, and which was attended by several hundred librarians from different parts of the country.

A mural painting, entitled "Engineering," by F. Dana Marsh, has also been placed in the large wall space at the rear of the library and greets the eye of the visitor as he enters the room. The painting was exhibited by Mr. Marsh at the Pennsylvania Academy last winter and has been placed by him in its present position, where it is hoped that it may remain through purchase by the societies or by individuals. The mural bears the inscription: "Engineering—the art of organizing and directing men and of controlling the forces and materials of nature for the benefit of the human race," Tredgold's famous definition of engineering. It shows against a background of great engineering works the mind and muscle which enter into their making. Various tools are in the foreground and silhouetted against the sky are steel structures in process of erection. Groups of men are at work, one of them swinging a crane into position for hoisting a dynamo. In the center is the engineer-in-chief, blueprint in hand, directing the work and bringing order out of chaos.

## SOCIETY BOOKPLATE

A bookplate, a representation of which appears herewith, reproduced full size, has been adopted by the Library Committee and will be placed in those books in the Engineering Societies Library owned by the Society. This has been secured through the efforts of


Ambrose Swasey who was appointed several years ago to take up the question of a suitable design. It bears the seal of the Society above an open volume and also the words, Ex libris American Society of Mechanical Engineers.

### PLANS FOR FINANCING LOCAL MEETINGS

At a special meeting of the Council held on September 15, a report of which will be found elsewhere, action was taken upon matters of unusual importance. One of these was the result of a direct canvass of the membership in New York as to the best method of raising funds for the conduct of meetings in New York, of other than a purely technical character, which are of course paid for out of Society funds. This has heretofore been done by individual subscriptions, but the plan has also been proposed and approved by many of increasing the dues of local members as is done by some societies. The Council, however, has outlined in a communication to the membership, published elsewhere, their desire to place the whole matter on a broader basis and to grant to local branches or professional sections generally the privilege of financing their activities. The matter is to be placed in the hands of a committee for formulation.

### CHANGE IN PRICE OF THE JOURNAL

The other action taken by the Council is a reduction in the subscription price to The Journal, making the price to the public $3 a year and 35 cents a copy and $2 per year to members, 25 cents per copy, which is to be included in the dues as heretofore. The objects of a great engineering society should be large and were well expressed by the founders of this Society in its Constitution which states that "it is to promote the arts and sciences connected with engineering and mechanical construction." One of the ways in which this object can be attained is by distributing its literature as widely as possible for the benefit of the profession and to this end the subscription price of The Journal is made at the cost of production. At the rate of $3 per year it should be possible to secure among the engineering profession a much wider reading of The Journal and of papers presented to the Society, thus adding to the prestige of the Society and directly benefiting its members.

### BROADENING OF THE SOCIETY'S ACTIVITIES

It is generally recognized that mechanical engineering is the foundation of engineering as a whole and that it is inclusive of many branches of engineering. This is indicated by a glance at The Journal of the Society for the past year in which will be noted papers upon a great diversity of subjects, extending over as wide a range as the following topics, taken at random: Milling Cutters, Manufacture of Small Machine Parts, Cement Machinery, Steam Turbines, Purchase of Fuel, Farm Tractors, Building Materials and Fires, Handling Freight, Regulation of Hydraulic Turbines, Smoke Abatement, Molding Machines, Prevention of Accidents, Blast-Furnace Gas-Power Plants, Blowing Engines.

In recognition of this situation and with the desire that the Transactions of the Society shall fairly represent the whole field which it purports to, and shall contain authoritative papers on the many subjects considered, the Committee on Meetings have issued a circular to the membership outlining the plan for the formation of a large number of sub-committees of their committee. These are to represent the different branches of mechanical engineering and are to be composed of experts in those branches especially qualified to secure the best possible material for the meetings of the Society, who will also aid in bringing the Society and its work to the attention of related bodies in a way that has never before been possible.

It is essential that in inaugurating so important a policy the co-operation of the entire membership be secured and the members are, therefore, asked to fill in the blanks which have been sent them with suggestions of names of members for the various committees. It is not necessary that these names should be of members of the Society, inasmuch as it is desired, first of all, to secure the best possible selection of names without regard to relationship with the Society.

Three committees have already been formed and are doing excellent work. One upon the Cement Industry was formed last spring and held a most successful meeting at the spring convention at Pittsburgh, and also have plans under way for another meeting. A second committee on the Manufacture of Textiles are arranging for a session at the annual meeting. The third committee on Machine Shop Practice has made similar progress. The successful work of the Gas Power Section was evident at the Pittsburgh meeting, where the Gas Power session was largely attended.

## LAND FUND

The responses to the circular of the Finance Committee, Messrs. R. M. Dixon and W. H. Marshall, have been gratifying. Of the $81,000 needed, certificates to the amount of $60,000 have been engaged and $40,000 actually paid in. There still, however, remains practically $20,000 to be secured and the membership is urged to call the matter to the attention of all who may be able to transfer invesments and so accomplish the purpose of the membership.

## ADDED CONVENIENCES FOR MEMBERS

The attention of the members of the Society is called to the added facilities recently completed in the mezzanine lavatory located below the ground floor of the Engineering Societies' Building. Dressing booths have been installed with all the necessary fixtures for changing clothes for evening dress, thereby saving the cost of hotel expenses to members. The check room for coats, etc., is on the second floor and it is hoped that members will avail themselves of these conveniences. All members are entitled to use these without expense.

CALVIN W. RICE, *Secretary.*

# REPORTS OF MEETINGS AND ANNOUNCEMENTS

## ST. LOUIS MEETING, SEPTEMBER 20

The members of the Society participated in the first meeting for the season of the Engineers Club of St. Louis, together with other engineering societies located in that city. A paper on the Colorado Springs Water Works, illustrated by very fine lantern slides, was presented by Hiram Phillips, member of the Engineers Club and of the American Society of Civil Engineers.

## SPECIAL MEETING OF THE COUNCIL

A special meeting of the Council was held on September 15, 1911, in the Society rooms, with President E. D. Meier in the chair. There were present Chas. Whiting Baker, R. M. Dixon, Stanley G. Flagg, H. L. Gantt, E. M. Herr, Alex. C. Humphreys, I. E. Moultrop, H. G. Stott, H. H. Vaughan, Wm. H. Wiley, and the Secretary. By invitation Walter Rautenstrauch, Chairman, F. A. Waldron, Secretary, and Edward Van Winkle, of the New York Committee on Meetings, were also present.

The President appointed H. L. Gantt and Wm. H. Wiley, tellers of election on the ballot cast for the admission of J. A. F. Aspinall to honorary membership and on their report Mr. Aspinall was declared elected.

The proposed amendment to C 57 of the Constitution was discussed. (See notice to the membership appearing on another page.)

The Executive Committee was appointed a special committee to advise with the Secretary in the preparation of a circular to be issued to the membership concerning this matter.

*Voted:* To rescind all previous action regarding the subscription price of The Journal and that the following action be taken:

*Voted:* In accordance with the suggestions of the Postoffice Department, that the subscription to The Journal be two dollars to members of the Society in all grades, to student members and affiliates of the Society paying dues, members of affiliated societies who do not pay dues, members of the three sister national engineering societies, libraries and colleges; to non-members not included in the above, three dollars.

*Voted:* To adopt the following amendment to By-Law 18, all requirements having been met:

The Council at any meeting may, in its discretion permanently remit the dues of any full Member of the Society who has been paying dues for thirty consecutive years or who shall have reached the age of seventy years after having paid dues for twenty-five consecutive years, provided that notice of such proposed action shall have been given at a previous meeting of the Council and the Committee on Membership shall have concurred in recommending that this action be taken. The Council may in its discretion, restore to membership any person dropped from the rolls for non-payment of dues, or otherwise, upon such terms and conditions as it may at the time deem best for the interests of the Society.

*Voted:* To confirm the appointment by the President of the following Committee to Formulate Standard Specifications for the Construction of Steam Boilers and other Pressure Vessels and for the Care of Same in Service: John A. Stevens, Chairman, E. F. Miller, C. L. Huston, H. C. Meinholtz, R. C. Carpenter, W. H. Boehm.

*Voted:* To confirm the formation of a Student Branch at Lehigh University.

*Voted:* To approve the design for a student members' pin, as submitted by the State University of Kentucky.

*Voted:* To confirm appointment of the following sub-committee on Machine Shop Practice of the Committee on Meetings:

F. E. Rogers, Chmn., L. D. Burlingame, W. L. Clark, W. A. Diefendorf, A. L. DeLeeuw, F. L. Eberhardt, F. A. Errington, A. A. Fuller, H. D. Gordon, H. K. Hathaway, E. J. Kearney, Wm. Lodge.

*Voted:* To confirm appointment of the following sub-committee on Cement Industry of the Committee on Meetings:

W. R. Dunn, Chmn., J. G. Berguist, W. F. Cowham, J. W. Fuller, Jr., L. L. Griffiths, E. M. Hagar, L. Lehigh Hunt, F. W. Kelley, Morris Kind, F. H. Lewis, R. K. Meade, Ejnar Posselt, H. J. Seaman, A. C. Tagge, H. Struckmann, P. H. Wilson.

*Voted:* That the Society officially participate in the 12th International Congress of Navigation to be held in Philadelphia, and that a committee be appointed by the chair to arrange the details.

*Voted:* To confirm the action of the Secretary in offering the use of the Society rooms to the American Society of Refrigerating Engineers for the reception of foreign delegates on the occasion of the international congress to be held in 1913.

*Voted:* That the Secretary reply to invitations received for the Spring Meeting of the Society, notably from Baltimore and the

Boston Chamber of Commerce, that same will be presented before the Spring Meeting in 1912, at which time the place for the next semi-annual meeting will be determined.

*Voted:* To confirm the appointment of Paul Doty and Max Toltz as Honorary Vice-Presidents to represent the Society at the inauguration of President Vincent of the University of Minnesota, on October 18.

*Voted:* To approve the appointment by the President of Louis Bendit, R. J. McCarty, F. L. Gilman, J. L. Harrington, J. H. Muhlfelt, as Honorary Vice-Presidents to the Third National Conservation Congress, to be held in Kansas City September 25–27, 1911.

The Secretary expressed the appreciation of Mrs. Chas. Wallace Hunt and her family for the bound memorial of Mr. Hunt, presented by the Council.

The following deaths were reported: A. E. Boehm, J. A. Caldwell, A. J. Hewlings, C. J. Larson, E. B. Yaryan, M. L. Abrahams, H. A. Fergusson, C. A. Hague, D. H. Haywood, C. S. Humphrey, Francis Schumann, D. G. Moore, Jas. Christie.

The following resignations were received and accepted with regret: H. B. P. Wicks, Dermot McEvoy, J. B. Spencer, C. E. Rommel, Mark Robinson, O. M. Stimson, William Hardie.

*Voted:* That the President be requested to send a special note of congratulation to Mr. A. M. Hunt, Chairman of the San Francisco Committee on Meetings, for the selection of subject of Oil Fuel and the able way in which it was handled, as reported in the August issue of The Journal.

*Voted:* To approve the minutes of the Council for May 30.

The Meeting adjourned.

## AMENDMENT TO THE CONSTITUTION

At the Spring Meeting, the Committee on Meetings of the Society in New York, presented the following amendment to the Constitution:

Members of all grades residing in New York and vicinity, and represented by the Committee on Meetings in New York city, shall have the privilege and authority by majority vote of such membership, to increase their annual dues by the sum of $3.00, such increase to be applied to financing such entertainment features of the Annual Meetings in New York city and its own local meetings, as their Committee on Meetings in New York city may elect.

The following comment has been made by the Committee on Meetings in New York:

In justification of this amendment let it be understood that the members residing in New York City have always paid for the entertainments given in connection with the Annual Meetings of the Society. Their committee appointed to provide such entertainment has had to assume the obligations incurred thereby and beg among the members for subscriptions to meet the bills. This has resulted in the burden coming heavily on some and being shifted by others. A canvass of the New York membership relating to this method of raising the funds has shown it to be very unpopular. In fact 82 per cent of the replies received from this canvass favored the plan of a $3 annual assessment for all New York members. This amendment, therefore, is intended to give the Committee on Meetings in New York City the proper authority to collect the sum which the New York membership by majority vote decides each member should contribute. The adoption of this amendment will result in placing the entertainment program of the Annual Meeting on a sure and stable financial footing.

## COMMENT OF THE COUNCIL

Under C 57 of the Constitution the Council, if it so elects, may comment upon notices of amendment to the Constitution, at the time the notice is sent to the membership and at a special meeting for that purpose the Council on September 15, passed the following resolution:

*Voted:* That in the opinion of the Council an amendment to the Constitution which makes possible a compulsory assessment for the purpose of entertainment, is undesirable. They consider that the suggested amendment of the New York members requires careful consideration with a view to developing a suitable plan for the purpose of financing geographic or professional section meetings.

*Voted:* That a Committee be appointed by the President to prepare plans for the proper organization and financing of local branches or professional sections of the Society, with instructions to prepare such an amendment to the proposed amendment of the Committee on Meetings in New York as will make it generally applicable to all members and conform to a definite scheme which is to be submitted to the Council previous to the annual meeting.

In the opinion of the Council, the Constitution should govern the Society generally rather than provide for special conditions. To that end, the Council trusts the proposed amendment will be so revised at the coming Annual Meeting, as to provide that the members, meeting in a given locality, have authority to make assessments for such Society purposes as these members may desire.

## TRANSACTIONS, VOLUME 32

In connection with the issuance of Transactions, Volume 32, covering the year 1910, attention is called to the following matter which has never been published in The Journal:

- SYMPOSIUM ON RAILWAY ELECTRIFICATION
  - Electrification of Suburban Railways, F. W. Carter
  - Cost of Electrically-Propelled Suburban Trains, H. M. Hobart
  - Discussion on Railway Electrification
- SYMPOSIUM ON LOCOMOTIVE HANDLING AT TERMINALS
  - English Running-Shed Practice, Cecil W. Paget
  - Discussion on Locomotive Handling at Terminals
- SYMPOSIUM ON HIGH-SPEED TOOLS
  - High-Speed Tools and Machines to Fit Them, H. I. Brackenbury
  - Topical Discussion of High-Speed Tools
    - Rapid Production in Machine Work, John Calder
    - Data on Manufacturing Methods with Machine Tools, L. D. Burlingame
    - Development of High-Speed Milling Machines, L. P. Alford
  - Discussion on High-Speed Tools
- SYMPOSIUM ON GEARING
  - Tooth Gearing. J. D. Stevens
  - Closures by Wilfred Lewis and J. D. Stevens
- DISCUSSIONS
  - The Transmission of Heat in Surface Condensation, George A. Orrok
  - Combustion and Boiler Efficiency, Edw. A. Uehling
  - Operating Conditions of Passenger Elevators, R. P. Bolton
  - First Large Gas-Engine Installation in American Steel Works, E. P. Coleman
  - Symposium on Grinding
    - The Field for Grinding, C. H. Norton
    - Precision Grinding, W. A. Viall
    - Modern Grinding Methods, B. M. W. Hanson
  - Steam Turbine Tests
    - Test of a 10,000-Kw. Steam Turbine, S. L. Naphtaly
    - Test of a 9,000-Kw. Turbo-Generator Set, F. H. Varney

# NECROLOGY

## WILLIAM LESTER CANNIFF

William Lester Canniff was born in Berea, Ohio, on May 23, 1862, and received his education in the public schools, acquiring his mechanical training through his own efforts and through experience. After obtaining a general knowledge as a machinist, electrician and stationary engineer, he decided upon tunnel work as his specialty and in 1896 entered the employ of the W. J. Gawne Company of Cleveland, contractors for the water works tunnel then in process of construction in that city, as master mechanic, and also assisted in the work of the second tunnel built shortly after the completion of the first. In 1900 he superintended the construction of the water works tunnel in Cincinnati, built by the same company, and had complete charge of the mechanical work. In 1905 he was employed by the Degnon Contracting Company of New York as mechanical superintendent on the Belmont tunnel under the East River, and in 1907 by the United Engineering and Contracting Company on the construction of the Pennsylvania tunnel, New York City. At the time of his death on August 29 he was serving the T. A. Gillespie Company of High Falls, N. Y., in the same capacity, being engaged on the Rondount siphon tunnel of the New York City aqueduct. During the three years of his work for this company he designed and erected the largest compressed air plant ever built under one roof in this country. Although Mr. Canniff invented a number of appliances he patented only two, the Union hose and pipe coupling, and a pneumatic grout mixer extensively used through the country, on the subject of which he was a recognized authority.

## OLIN AMES STRANAHAN

Olin Ames Stranahan who was born in Litchfield, Ohio, on July 18, 1866, died in New York City on September 6, 1911. Mr. Stranahan received his education at the Case School of Applied Science in Cleveland and at Cornell University, from which he was graduated in 1890. Upon graduation he entered the employ of Westinghouse, Church, Kerr & Company at Chicago, working up through their various departments to the position of chief engineer of their Chicago office. When the British Westinghouse Electric and Manufacturing Company, Ltd., was formed in 1900, Mr. Stranahan was placed in charge of their engine business, resigning in 1905 to accept the position of manager of the power department of the Allis-Chalmers Company, Milwaukee, Wis., shortly afterward becoming general sales manager. In 1907 he joined the Westinghouse Machine Company with headquarters in New York, having charge of gas engine sales and special power installation, and two years later took over the charge of the export machinery department of the John Deere Export Company of New York. At the time of his death he was general manager of the General Reduction, Gas and By-Products Company of the same city.

Mr. Stranahan specialized during most of his professional life in gas engines and was the owner of several valuable patents applying to gas engines and producers, and had a wide acquaintance in his own country and abroad. He was a member of the Western Society of Engineers, the Engineers Club of New York, and the Engineers Technical and Chicago Athletic Clubs of Chicago.

## JAMES CHRISTIE

James Christie was born near Ottawa, Canada, on August 28, 1840, and was of Scotch parentage. At the age of sixteen after a common school education, he came to the United States and under the guardianship of his uncle, one of the pioneer railroad constructors in this country, was employed with a railroad construction corps. In 1856 he served as an apprentice in the machine shop of locomotive works in Detroit, Michigan, and spent one year in Missouri as an assistant to engineers and contractors on the Pacific Railroad of Missouri. From there he went to Philadelphia, apprenticing himself to the I. P. Morris Company, proprietors of the Port Richmond Iron Works, where he learned the trade of a machinist. In 1865 he removed to Pittsburg as superintendent and engineer of the Fulton Foundry, and later engaged in the designing and construction of iron works. In Phillipsburg, N. J., his next location, he devoted himself, as superintendent of the Phillipsburg Manufacturing Company, to the construction of iron bridges. In 1876 he became construction engineer with the Pencoyd Iron Works of A. and P. Roberts & Company, where he continued until after the works had been absorbed by the American Bridge Company. Here he did his most important engineering work. As general mechanical assistant and to a great extent his own draftsman, he began at once to improve the methods of work, introducing machinery and organizing the men employed, as a result making the works one of the largest and most efficient in the Eastern part of the country. Upon his retirement from the company he established a consulting practice of his own.

In 1884 Mr. Christie published Experiments on the Strength of Wrought Iron Struts, based on his tests at Pencoyd, which won for him the Norman medal given by the American Society of Civil Engineers, and made at other times numerous contributions to general and scientific literature. During the Civil War he served in the Antietam campaign and in 1863 entered the engineer corps. He was through- out his life interested in public affairs and held several political offices, serving as Mayor of Phillipsburg in 1870.

He joined the Society in 1885 and was one of its Vice-Presidents from 1902 to 1904. At the time of his death on August 24, 1911, he was serving his second term as President of the Engineers Club of Philadelphia, and was also a member of the Franklin Institute, the American Philosophical Society, the American Society of Civil Engineers, and Fellow of the American Association for the Advancement of Science.

## CHAS. ARTHUR HAGUE

Chas. Arthur Hague was born at Newton, Mass., October 9, 1849, and died June 26, 1911. He began his professional career in 1872 as a draftsman and designer with the Clapp and Jones Manufacturing Company, Hudson, N. Y., remaining in their employ until 1875 when he became mechanical engineer and draftsman on steam engines, boilers, etc., for the Frank Douglas Machinery Company, of Chicago. In the following year he resigned to enter the employ of the Furst & Bradley Manufacturing Company as a master mechanic. While there he patented important improvements in the plows and other implements manufactured by them and designed and constructed numerous special machines adapted to their line. In 1884 he became superintendent of the E. P. Allis Company of Milwaukee and three years later became connected with the Knowles Steam Pump Company of New York. The following year he entered the employ of H. R. Worthington, New York, as mechanical engineer, remaining there until 1895 when he established a consulting practice of his own. Mr. Hague was the author of a book on Pumping Engines for Water Works.

## LEMUEL R. HOPTON

Lemuel R. Hopton was born at West Stratford, Conn., on June 20, 1873, and received his early education in the public and high schools of New Haven and his technical training in the Sheffield Scientific School of Yale University, from which he was graduated with honors in 1896. Until 1900 he remained at Yale, teaching machine design in the department of Mechanical Engineering at Sheffield Scientific School, when he left there to enter the employ of Carl H. Schultz, Inc., New York, as factory superintendent. In 1902 he resigned to take a similar position with the Enos Company of the same city, remaining with them until a short time before his death on September 5, 1911.

Mr. Hopton was the inventor of several electrical appliances used by the Enos Company, and also of the Opalux glass, used for high candle power lighting and manufactured by the Opalux Company, of which he was an officer and director. He was the author of many articles published in the electrical magazines and a member of the Illuminating Engineering Society, before which a number of his papers were presented.

## JAMES McLAUGHLIN

James McLaughlin who died on August 18 at Clifton Springs, N. Y., was born on May 8, 1867 at Castlefin, County Donegal, Ireland, coming to the United States with his parents at the age of fifteen. Here he entered the Philadelphia High School and later the University of Pennsylvania, where he received his training as a civil engineer. In 1885 he entered the employ of the Philadelphia & Reading Railway, as secretary to the general counsel, and two years later became bookkeeper and correspondent for the Philadelphia Engineering Works. Shortly afterward he decided to take up the practical and technical side of mechanical engineering and entered the shop of the company, also taking a course of lectures on mechanics at the University of Pennsylvania. In 1889 he became general manager of the Barr Pumping Engine Company of Philadelphia, and designed and installed many large high-duty pumping engines, principally in New England but also in Kansas City, Harrisburg, Trenton, Denver and other cities.

In 1903 he resigned to establish the firm of McLaughlin Brothers, Incorporated, for the design, construction and equipment of buildings, including reinforced concrete, steel and New England mill construction, power plants and electrical equipment, and plumbing and sprinkling systems. In the following year the main offices were removed from Philadelphia to Baltimore and many of the large buildings of Baltimore were erected under Mr. McLaughlin's supervision. He was at the time of his death president and general manager as well as senior member of the firm.

### MRS. ROBERT HENRY THURSTON

Announcement is made of the death of Mrs. Thurston, widow of Robert Henry Thurston, first President of the Society, at her home in Brooklyn, N. Y., on September 7, 1911.

# FACTORY CONSTRUCTION AND ARRANGEMENT

By L. P. Alford and H. C. Farrell

ABSTRACT OF PAPER

The arrangement and construction of the reinforced concrete factory buildings of the United Shoe Machinery Company at Beverly, Mass., are presented, with reference to their adaptability to the manufacture of light machinery. The advantages and disadvantages of concrete floors are discussed, and the experience of this plant given to show that such floors are satisfactory in the machine shop. The original manufacturing scheme, the one-shop plan, is described, together with the modifications that it has undergone since its inception. The original artificial lighting installation is shown with changes now being made to use the more recently developed higher efficiency lighting units. As the plant has had rapid growth, modifications based on experience have been made as new construction was undertaken, and these changes are traced in detail. Finally, the plant contains one of the first extensive developments in the use of steel storage racks. The design of these is given, together with an account of the conditions under which they were developed and the uniformly successful results in their use are shown.

# FACTORY CONSTRUCTION AND ARRANGEMENT

By L. P. Alford, New York

and

H. C. Farrell, Beverly, Mass.

Members of the Society

The plant of the United Shoe Machinery Company at Beverly, Mass., for the manufacture of boot and shoe machinery is the first factory constructed entirely of reinforced concrete, and stands today as the most extensive example of the use of this form of construction for machine-shop purposes in the country. The present floor area aggregates 600,000 sq. ft. and when the addition now being erected is completed, the total floor space will be 744,000 sq. ft., or more than 17 acres.

2 The site comprised some 250 acres fronting about one-half mile on the eastern division of the Boston & Maine Railroad and bisected by a tide-water stream known as the Bass River. The area lying between this river and the railroad track, averaging something like 1000 ft. in width, was selected for the buildings. The stream was dammed at two points, forming storage basins for fresh water to be used for condensing and manufacturing purposes. In addition, there was a third basin below high-tide level and provided with tide gates.

3 Development work now in progress will form another fresh-water basin further upstream, and the lowest freshwater basin will then be filled with tide water and used for condensing purposes.

## THE MANUFACTURING SCHEME

4 The machine-shop manufacturing departments were arranged according to the "one-shop plan." The only other plan that was seriously considered as a possible alternative was the "output-department plan." An analysis of the floor areas for the various departments showed that one-half of the machine-shop manufacturing

The American Society of Mechanical Engineers, 29 West 39th Street, New York. All papers are subject to revision.

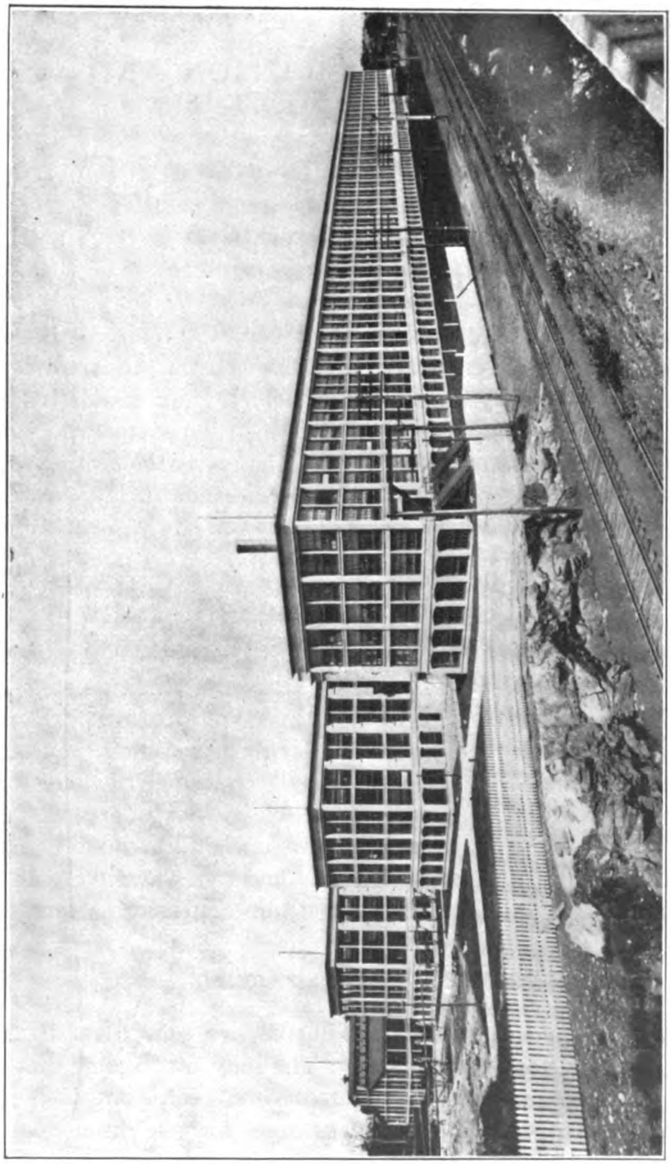

FIG. 1 VIEW OF PLANT AFTER ADDITIONS OF 1906–1907 WERE COMPLETED

area should be devoted to the regular machine-shop departments; the other half to be used for special, or associative departments. This led to the adoption of a four-storied building type as the most advantageous. The two middle floors were to be the manufacturing area; the lower floor for storage and certain departments requiring the least advantageous conditions; the upper story for experimental work, tool making and a few associative departments.

5 In addition, the foundry, hardening room, drop-forge shop and power house required separate buildings particularly designed for their needs. This led to a plan embodying four rows of parallel buildings of which the two in front were devoted to machine-shop uses, the third to storage and the hardening room and forge shop, and the fourth to the foundry and power house, these last being detached buildings. All of the other buildings were connected by means of tunnels and covered passageways above ground connecting all floor levels. A spur track passed between the third and fourth rows of buildings, serving the third row, and a second spur passed behind the fourth row of buildings, thus serving the foundry and power house.

6 Fig. 1 shows the plant after the additions of 1906 were completed. The main buildings, originally 520 ft. long, as shown here are 820 ft. Fig. 2 shows an outline plan of the buildings as they will be after the present additions are completed.

7 The additions now in progress will extend each of the two main buildings, *A* and *B*, 300 ft., or to a total length of 1120 ft.; will add a fourth toilet-room wing between them indicated by *ABXX*, and a detached drop-forge shop near the tide-water front of the property 300 ft. long, 80 ft. wide and connected with an independent power house.

8 All of the buildings are connected by pipe and cable tunnels (Fig. 2) which enter underground chambers containing the fans and heater coils for the indirect-heating systems. Fig. 3 is a typical cross-section of the tunnel entering building *ABX*. The walls are used for piping, and beneath the floor are vitrified conduits for the electric cables. The floor of this tunnel pitches upward from the power house, and a gutter at one side receives any moisture that may enter and conveys it to a sump in the power-house basement, from whence it is pumped to waste.

9 The method of supporting the pipes in this tunnel was to bolt 6 in. by 8 in. hard pine posts to the inner walls. To the outer faces of these posts the pipe hangers are fastened by lag screws. These posts are spaced 10 ft. on centers.

10 The modifications of this tunnel over those originally planned

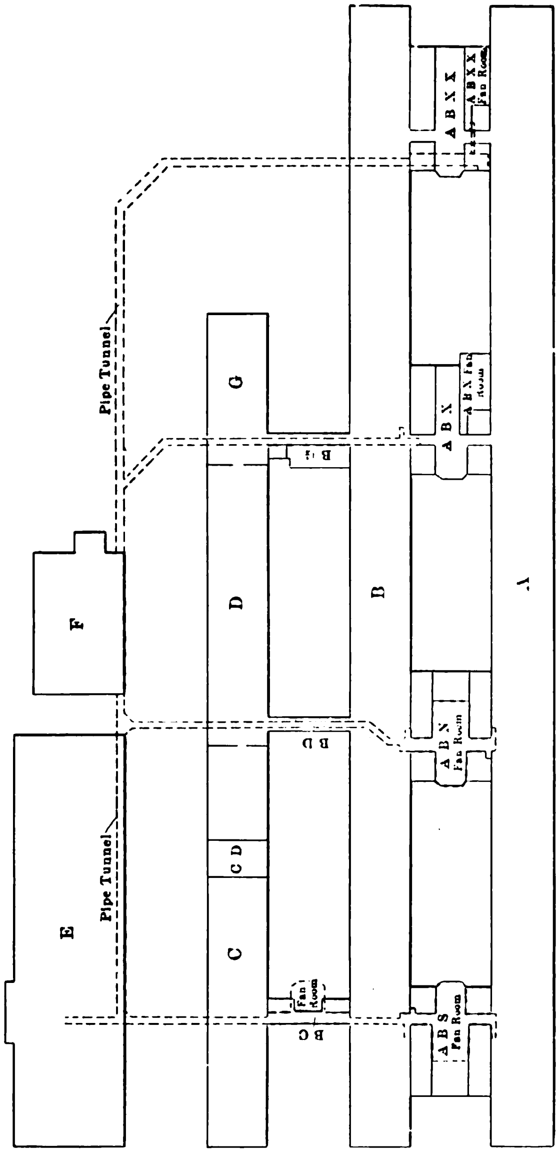


FIG. 2 PLAN OF BUILDINGS WHEN PRESENT ADDITIONS ARE COMPLETED

consisted in increasing both the width and height in order to give more room to facilitate changes and repairs and in the use of hard pine posts instead of cast-iron slotted supports for the pipe brackets. The width of the original tunnel was 5 ft. in the clear, the new one 7 ft., and an average height of 7 ft.

11 At points just within the walls of buildings *A* and *B* (Fig. 2) will be noticed short connections from the tunnels which serve as a point from which pipe risers are conducted vertically upward through the buildings.

### CONSTRUCTION OF THE MAIN BUILDINGS

12 The main buildings *A* and *B*, as well as the storage buildings *C* and *G*, are divided by two rows of interior columns into 20-ft. bays.

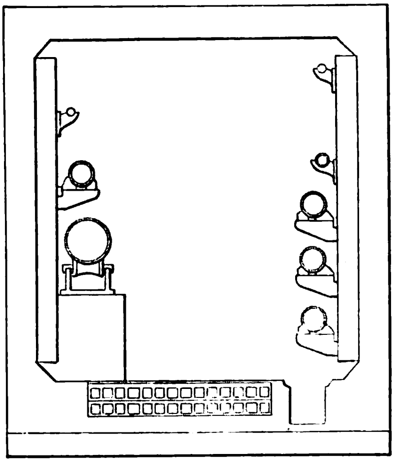

Fig. 3 Typical Cross-Section of Pipe and Cable Tunnel

The width of each of these buildings is therefore 60 ft. The original main buildings were constructed as monoliths, except that a shrinkage joint was introduced midway of the length, thus in effect giving two abutting buildings unconnected, except at the foundations. The toilet-room wings are similar monoliths, being separated from the main buildings by similar shrinkage joints.

13 Fig. 4 shows a typical cross-section of a main building. The exterior columns on one side are rectangular in section, spaced 20 ft. on

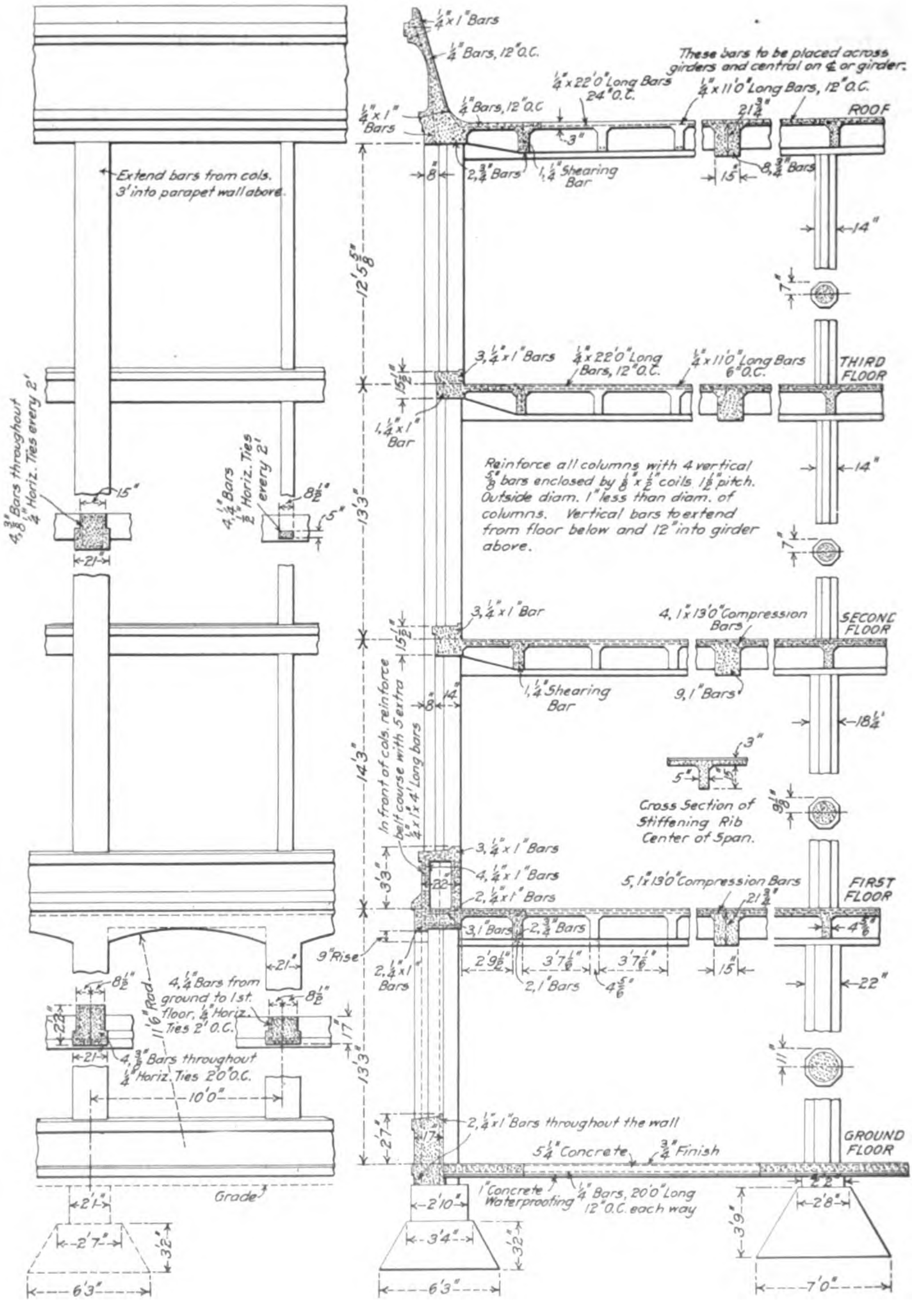


FIG. 4 TYPICAL PARTIAL CROSS-SECTION OF A MAIN BUILDING

centers and above the ground floor running from floor to ceiling with no intervening curtain wall. Midway between these columns is a small concrete mullion. On the other side the pilasters are very much larger as they contain the heating ducts of the indirect system. These pilasters in the original building were lined with hollow brick as a non-conductor of heat.

14 The interior columns are octagonal in section, and decrease in diameter from the lower floor upward. The floors have rectangular concrete girders carried by the columns and connected by shallow rectangular floor beams, stiffened by a bridging stringer midway of each 20-ft. span. The floors themselves are entirely of concrete, composed of an under floor of the same mixture as the beams and girders, covered with a granolithic wearing surface $\frac{3}{4}$ in. thick, which was applied when the under floor was green for the purpose of making a perfect bond of the two layers. The ground floor and the first floor were curtain-walled to a height of 30 in., with the exception of the eastern ground floor wall of building *A*, which was curtain-walled to a height of 6 ft. in order better to accommodate the building to the natural grade.

15 It may be well to point out at this place that when these buildings were developed, the use of reinforced concrete as a material of construction was very new and much of the work that was done had no foundation in precedent. The authors can recall with some amusement discussions over points considered of major importance, for which an easy solution was later found. One of these was the floors. A lengthy discussion took place as to whether or not a concrete floor was suitable for machine-shop purposes. It was finally determined that concrete floors should be used with the single exception of the stair treads, which were to be of wood. These concrete floors have been found to be so satisfactory that they were continued in the additions of 1906–1907 and will be used in the additions now in progress.

16 One of the arguments against a concrete floor upon which persons must work is its hardness, but our experience shows this to be unfounded. The real objection to a concrete floor lies in its coldness. Concrete is a much better conductor of heat than wood and for that reason, a cold concrete floor will rapidly withdraw bodily heat from the feet of anyone standing upon it. Therefore, the only floors which need special attention are those which are in contact with the ground. The lower floors of these buildings are of concrete some 12 in. thick and between the under floor and the upper floor are three thicknesses

of waterproofing felt mopped in with asphalt. When the employes were transferred from the old factories with wooden floors to the new, some complaints were heard for the first few weeks, or until the men had become accustomed to the change. Thereafter, there has been no difficulty except on the part of a new man, who has to go through his own period of becoming wonted to the new conditions.

17 Further objections raised to the use of these floors were those of wear due to the grinding action of the wheels of trucks, the chipping action of the ends of pinch bars used for moving heavy machines, the scouring action of metal boxes dragged over it, and, by far the most important, the difficulty of making floor repairs.

18 On the first floor of building *B*, however, a floor devoted to the heaviest work done in the plant, requiring the largest machine tools and receiving the largest and heaviest castings, the floor of the center bay has been refinished by adding 1½ in. of a one-to-two granolithic mixture. This, of course, covers the area that has received the greatest amount of wear, as in all of the buildings a central passageway 8 ft. wide was left between machine tools and other permanent fixtures.

19 The greatest difficulty in maintaining these floors has been found to lie in the making of minor repairs, namely, those necessitated by the crumbling away of the edges of the grooves with which the original floors were marked out, or the edges of cracks and repairs to small depressions caused by the wearing away of soft spots in the surface. Repairs made with any cement mixture have been uniformly unsuccessful, provided the area repaired was comparatively small. At present, such repairs are being made by using an asphalt mixture which is applied to the surface in a plastic condition and then bonded to the concrete by the application of heat from gasolene blow torches. This method is much more successful than the use of a cement mixture, although it does not entirely prevent the crumbling of the edge of the concrete where the concrete and asphalt join.

20 It was also feared that the oil required in an automatic screw machine department would penetrate the concrete and tend to disintegrate it, but it has been proved that this fear was unfounded. Repeated investigations throughout the past six years have failed to show that there is penetration through the glaze of the finish even in departments where the floor is constantly wet with oil. Where cracks are present the oil will find an entrance, its penetration beyond the limits of the crack is very little, and is not the cause of any apprehension whatever.

21 With regard to the possible injury from dust due to wear on the floors, there is no reason to believe that there has been any greater wear on the moving and sliding members of the machine tools than would have been the case in any other type of building.

22 The roofs of these buildings are similar in construction to the floors, except that the beams and slabs are much lighter. They are pitched from the center to the sides, the pitch being about 1 ft. in the distance of 30 ft. The coating is of tar composition.

23 A noticeable feature of the buildings is the large window area (Fig. 1), which is about 70 per cent of the total wall area. The window frames and sashes are of cypress and the sashes are double-hung, glazed with double-thick glass.

### THE ADDITIONS OF 1906-1907

24 While the addition to the main buildings in 1906–1907 presented no difference in appearance externally from the original construction, yet there are several changes of details. The floor loads are increased from 250 to 300 lb. per sq. ft. For this reason the columns, still octagonal in section, are 16 in. on the second floor instead of 14 in. across the flats, 14 in. on the third floor instead of 8 in. On the ground floor they remain 24 in. and on the first floor 18 in. This increase in the size of the columns necessitated an increase in the width of the girders and a corresponding decrease in their depth. The floor beams, while of the same depth, have an increase of 1 in. in width, namely, from 3 in. to 4 in., and the bridging stringer is correspondingly increased in width. Furthermore, the spacing of these beams is kept uniform to standardize the floor forms.

25 Carrying this standardization a step further, the same forms are used for the roof which, in this case, give a flat roof having the same sizes of girders and beams as those supporting the third floor. The floors were left perfectly smooth, without any marking whatever.

26 A slight change is made in the hot-air ducts in the pilasters, in that they are constructed entirely of concrete and without the non-conducting lining of hollow brick. The curtain walls are cored instead of cast solid as in the original plant.

27 In an attempt to obviate the difficulty of operating the large windows due to warping, the frames and sash of the addition are made of clear white pine, instead of cypress. This change has been fully justified.

28 The method of pouring the concrete in this addition was the same as that used in the original plant; that is, each floor level was

handled as a monolithic unit. The aggregate used in the mixtures of the original plant was natural gravel; in the addition, it was crushed native granite, taken from a ledge on the premises.

29 The method of finishing the exterior of the building, by hammering the exposed faces of the columns and walls, was identical in both sections. The difference in the color from the change in the aggregate is unnoticeable except by careful scrutiny.

### THE ADDITION OF 1911

30 The present addition does not differ, either in external or internal appearance from the addition of 1906–1907, but the method of erection has been radically modified. The other parts of the plant were poured floor by floor as monoliths. In the present construction, all of the columns, both exterior and interior, and all of the girders and beams were cast for each floor level in forms on the ground. These members were then lifted into position by means of a derrick, suitable provision being made for framing them together. The floor slab was then put in, a bay at a time poured upon forms supported by the beams and without using supporting horses or shores. Another change consisted in using steel window frames and sash instead of wood.

31 *Device for Fastening Ceiling Fixtures.* We have referred to the lack of precedent that existed in 1902–1903 in adapting concrete buildings to machine-shop uses. This lack is still further exemplified in connection with devices for supporting fixtures to concrete ceilings. We failed to find any such contrivance suited to our requirements, which may be briefly stated as follows:

*a* The device must permit of attaching fixtures at any point desired over the manufacturing areas, or, as it was aptly put, it must be as adaptable as the ceiling of a mill constructed building with wooden girders and floor.

*b* The device must be inexpensive in first cost and inexpensive to install.

*c* That part of the device that becomes a permanent part of the building, namely, the part which is built into place when the concrete is poured, must be very simple, inexpensive and not offer any serious disfigurement to the ceilings.

*d* The materials composing this device must be such as can be purchased in the open market, and should be fire resisting.

*e* The device must be such that the greater part need be put into place only when it is required for manufacturing purposes, thus keeping the investment as little as possible in areas set aside for growth.

32 As originally planned, it was deemed necessary to provide a device to support only the heavier fixtures, namely, the main-line shaft hangers, countershaft stringers, and the accompanying fixtures. No device was planned to support the lighter fixtures, such as electric

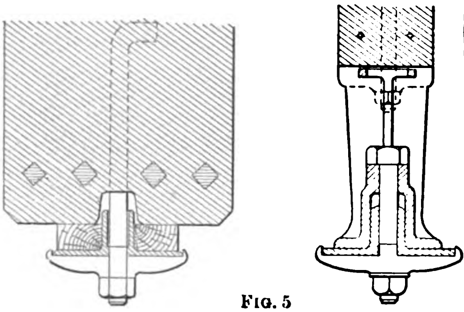

Fig. 5

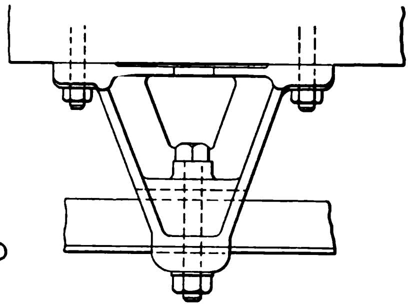

Fig. 6

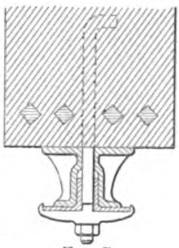

Fig. 7

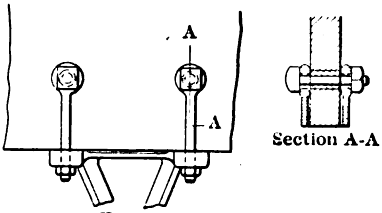


Fig. 8

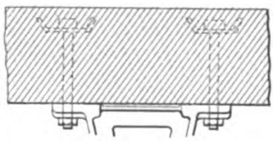

Fig. 9

Figs. 5 to 9 Details of Supports for Light Fixtures

light wire molding, electric light fixtures and small piping. However, a scheme for this latter purpose was worked out for the addition of 1906–1907 and will be described later.

33 The contrivance finally adopted consisted of a steel slot running crosswise of the building and fastened to the lower faces of the girders and bridging beams over all the manufacturing areas. By slipping a tee-headed bolt into this slot the ceiling fixtures are easily attached. Figs. 5 to 11, inclusive, show this device both in diagram and from photographs as actually installed. The slot consists of two small steel

angles placed back to back, with the opposing legs vertical, clamped by cast-iron hangers against the concrete beams. The clamping bolts are anchor bolts set in the beam and girder forms before the concrete was poured. These bolts in the girders in the final construction are 1 in. in diameter, pass through the hanger and the space between the angles and receive the clamp and nut on the lower face (Fig. 7). In the bridging beams the bolts are $\frac{3}{4}$ in. in diameter, set in pairs, each of which holds a cast-iron hanger of greater depth than those used on the girders, the angles in turn being bolted to the hangers by a 1-in. bolt and the same clamp as used under the girders (Fig. 6). The materials of which this device is composed are fire-

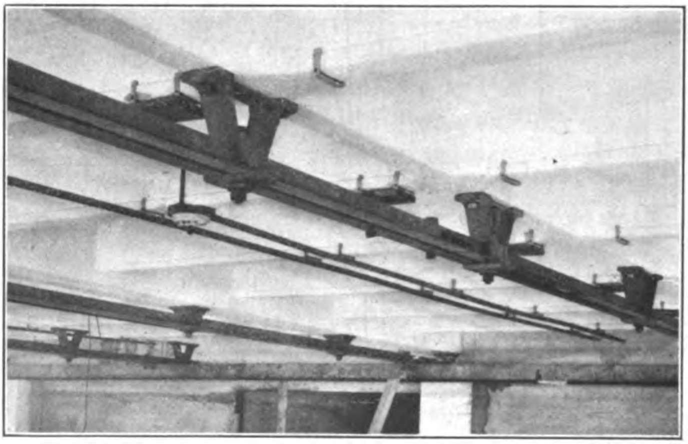

Fig. 10 Device for Supporting Light Fixtures

proof and, therefore, logically carry out the scheme of the fire-resisting concrete construction.

34 The spacing of the girder slot angles in the original building is approximately 3 ft. on centers and the angles are $2\frac{1}{2}$ in. by $2\frac{1}{2}$ in. by $\frac{1}{4}$ in. The bolts for the corresponding angles on the bridging beams are spaced about 6 ft. on centers and the angles are $2\frac{1}{2}$ in. by 3 in. by $\frac{5}{16}$ in.

35 In the addition of 1906–1907 the spacing for the anchor bolts is made uniformly 6 ft. on centers and the angles are of the same size as in the original building $2\frac{1}{2}$ in. by 3 in. by $\frac{5}{16}$ in.

36 In an experimental investigation of the strength of this slot, before any of it was used, it was found that the deflection under load lay

approximately midway between the estimated deflections, considering the angles, first, as beams supported at the ends, and second, as fixed at the ends. In each case the lower face of the slot was 6 in. wide, thus furnishing a firm footing for shaft hangers and the ends of counter shaft stringers. The tee-headed bolts used had shoulders 1 in. sq. just beneath the heads to prevent their turning round when the nuts were being tightened.

37 This device was installed over some 516,000 sq. ft. of floor area, aggregating 50,000 running ft. of metallic slot. In the original plant it has now been in use for over six years and its use and principle

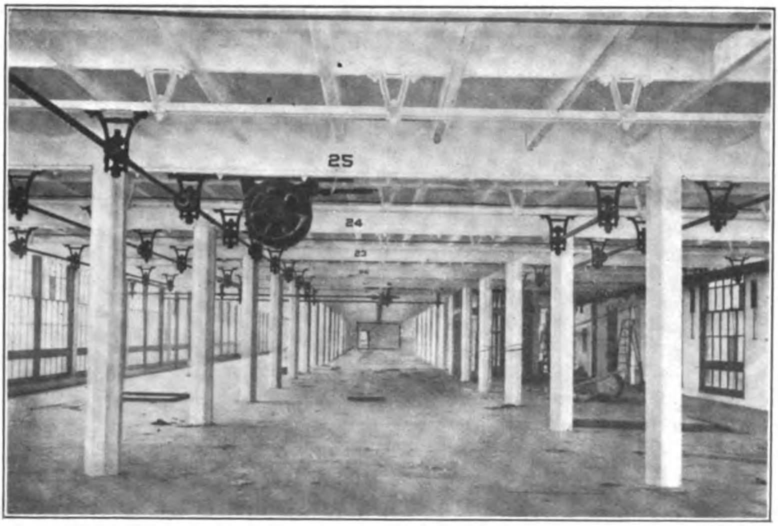


FIG. 11 SHAFTING AND MOTOR IN PLACE

have been extended to some parts of the foundry building and the basement of the power house, where it serves to support piping.

38 Mention has been made of the lack of provision in the original plant for supporting the light fixtures. In the first addition, however, such provision was made. The device consists of a half round groove having a radius of $\frac{3}{8}$ in., with its lower edge $1\frac{1}{2}$ in. above the lower face of the concrete beam. This groove was cast in both vertical faces of the floor beams. A small inexpensive sheet metal clamp is fitted into these grooves and held in place by a through-bolt passing directly beneath the lower face of the beam. To these hangers the

electric light wire molding, electric light fixtures, small pipe and other light fixtures and devices are attached. Figs. 10 and 12 show this contrivance and its application. In the addition now in progress, the metallic slot device as used in the first addition will be employed, as well as this later device for supporting the light fixtures.

39 Fig. 13 shows a rack or wire structure for carrying the secondary feeders for both the lighting and power circuits. It comprises two light channel beams set with their flanges facing, spaced about 20 in. apart and bolted to the slot system previously described. Wooden cleats rest on the lower flanges of these channels, are securely bolted in place and furnish a support for the mains on their upper surface and, if necessary, on their lower surface also. The space occupied by this structure is close to the wall on the side of the building having

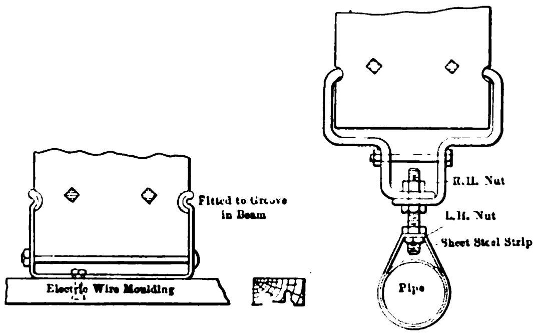


FIG. 12 ELECTRIC WIRE SUPPORT AND PIPE HANGER

the smaller windows because of the additional space necessary for the pilasters containing heating flues. It thus occupies no room required for main-line shaft or machine countershafts. It is also used for small piping for water, gas, compressed air and steam required for manufacturing purposes or in the operation of tools. These pipes are carried on hangers from the slot system and occupy a position beneath and at a safe distance from the electric mains.

40 *Attaching Machines to Concrete Floors.* The successful fastening of machines of all kinds to concrete floors was an easy problem to solve. No provision has ever been made by inserting in the floors anchor bolts, anchor nuts or any other device, at the time they were cast, anticipating any of the machine tools. Two methods are used. The first consists in the drilling of a small hole in the concrete floor slab, inserting an expansion sleeve of some kind, and fastening the

machine tool in place by lag screws. This method is used for all machines having feet that present only a small amount of area in contact with the floor, such as an ordinary small sized engine lathe. The second method is used for machine tools having box beds or a base presenting a large amount of area in contact with the floor, as the box bed of a planer or the base of a knee-type milling machine.

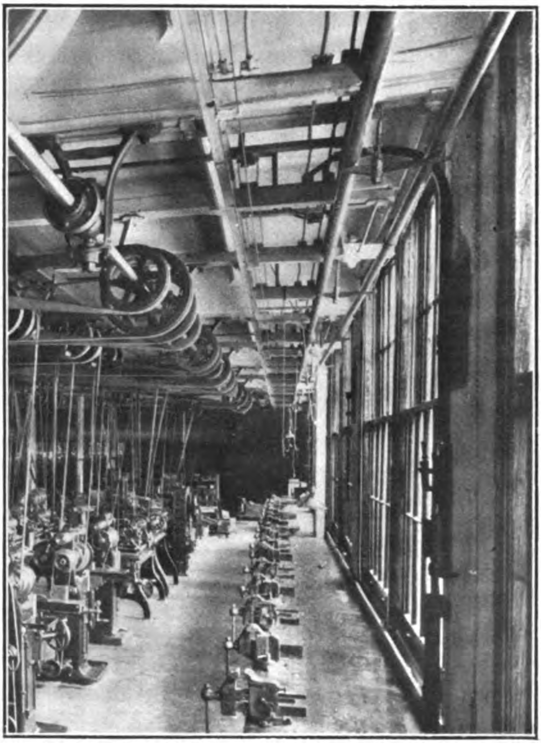

FIG. 13 STRUCTURE FOR CARRYING FEEDERS FOR LIGHT AND POWER CIRCUITS

The method in this case consists first in leveling the machine on steel wedges at a height of about ½ in. from the floor, flowing a stiff cement mortar under the base for a distance of 4 or 5 in., the mortar being entered around the entire outline of the base or bed, and then slacking back the wedges until the machine has settled firmly into the bed of mortar and at the same time is level. This mortar was allowed to set for 24 hours; the wedges then removed and the machine was ready for use.

41 These two methods have been successful, but one point requiring caution should perhaps be mentioned. In drilling the holes into the concrete floor care should be used as the point of the drill nears the lower side of the floor slab to avoid the spalling off of sections of the concrete. With an expansion sleeve of $1\frac{1}{2}$ in., which was finally adopted as a standard length by us, and with careful workmanship in drilling the holes, there should be no danger of chipping the under surface of the concrete floor if it is 3 in. thick or more. In case a

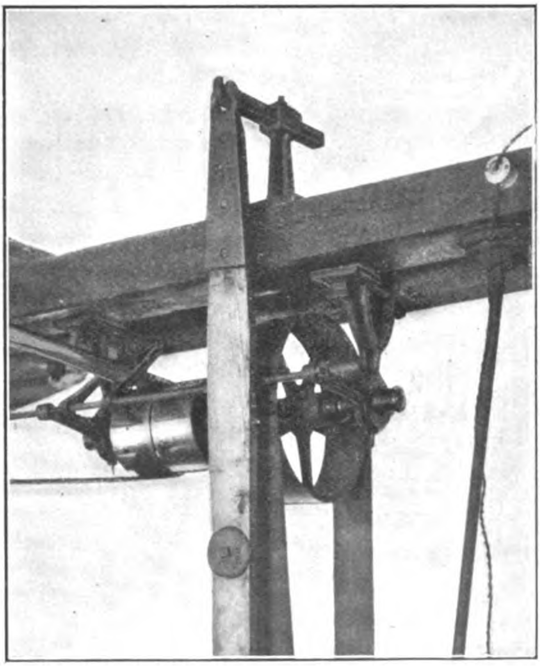

FIG. 14 COUNTERSHAFT AND BELT SHIFTER IN PLACE

large stone is encountered by the drill, it is very difficult to guard against this spalling action, and in this connection more difficulty has been experienced in the original plant where the large aggregate of the floor mixture is natural gravel, than in the following additions, where the aggregate is crushed granite.

42 On some of the larger, high-speed metal planers it has been necessary to put in stop dowels at each end to prevent the feet from sliding on the concrete floors. This refers to planers not supplied by the maker with lag screw holes in the feet.

43 There is still another exception to these two methods, applying to a limited number of high-speed machines, particularly those subjected to reciprocating motions and vibrations. It has been found necessary to bolt these machines through the floor with a large plate washer on the under side.

44 *Heating of Main Buildings.* Fig. 2 shows the underground fan chambers in each one of the main toilet-room wings. These chambers contain the heating engines, fans and coils for furnishing heat to the main machine-shop buildings and storage building *C*. In the original plant 7990 sq. ft. of radiating surface is provided for each of the machine-shop buildings, or 1 sq. ft. of radiating surface for each 218 cu. ft. of room volume. In this installation the ducts from the fans were carried outside of the buildings and connected underground to openings in the pilasters having the heating flues, by means of a flexible connection. The fan chambers under wings *ABS* and *ABN* contain, in addition to the fans for heating the main machine shops, fans for heating the toilet-room wings themselves. In the older part of the plant it was difficult to maintain a suitable temperature at the north ends of the machine-shop buildings in severe winter weather. For this reason, the heating factor in the 1906–1907 addition was made 1 sq. ft. of radiating surface for every 130 cu. ft. of room volume. A certain amount of this increase was intended to provide for the lack of heating capacity in the older part of the plant.

45 Another change consisted in bringing the hot-air ducts within the building line, placing them close against the outer wall and making this roof a part of the ground floor slab. This has the beneficial effect of tending to increase the temperature of the ground floor itself.

46 The heating plants for the toilet-room wing *ABX* were omitted and direct radiation by wall coils substituted. Experience has demonstrated that all of these modifications were wise, and in the addition now under way, the heating arrangements of the addition of 1906–1907 will be duplicated.

47 Because of the large window area, no provision was made for mechanical ventilation in the main buildings, except that in extremely hot weather the heating fans are run to supply fresh, outside air through the heating system.

48 *Lighting Systems.* The current generated at the power house is 575 volts, 3-phase, 60-cycle, distributed without transformation by the power circuits to 550-volt induction motors and transformed at a number of distributing centers to 110 volts for the lighting systems.

49 Three lighting systems are used, designated day, public and

machine-tool circuits. The primaries of all are independently controlled by switches in the power house.

50 The day circuits furnish light for the offices, drawing rooms, storage areas and wherever may be necessary in the day time, and each room is provided with its own switch control so that it may be had at any time.

51 The public circuits furnish light for the toilet, wash and locker rooms in the toilet-room wings, for all entrances and exits to the plant, for the cross corridors connecting the main buildings and for the longitudinal central passageways on all machine-shop floors. These circuits are controlled entirely from the power house.

52 The machine-tool circuits feed individual lights for the machine tools and manufacturing operations. These circuits are controlled on each floor and for comparatively short lengths, averaging about 200 ft.

53 In operation, the public-circuit switches in the power house are put in about 6.40 a.m., 20 minutes before the time of beginning work, thus furnishing light for the entrance of the employes to the plant. They remain in use until there is sufficient daylight to permit of unhindered movement throughout the passageways and aisles. These circuits are again brought into use in the afternoon and remain in until about 5.20, or for a sufficient length of time to permit everyone to leave the plant.

54 The machine-tool circuit is thrown in at starting-up time, 6.55 a.m., is pulled out at 12 m., put in again at 12.55 p.m., and pulled out again at 5 p.m.

55 The day-circuit switches are kept in at all times, connecting the line with the generators when they are running and with an outside source of current supply when they are shut down. Thus the offices, drawing rooms and a limited number of lights required for the night watchmen are available at all times.

56 In the original plant the day circuits and machine-tool circuits fed nothing but incandescent lamps, mainly 16 c.p. The public circuit feeds incandescent lamps in the toilet-room wings, a limited number of incandescents along the main aisles and passageways, and 7.5-ampere enclosed arcs at the junction points of the longitudinal central passageways of the main buildings and the cross passageways connecting these buildings through the wings.

57 These lighting systems are at present undergoing a modification, not as regards the original circuits themselves, or their control, but as regards the lighting units. The offices and drawing rooms have

been equipped with mercury vapor lamps of 150 and 300-c.p. sizes and have been found satisfactory for this service, with the possible exception of some slight difficulty in determining the colors of cards and inks in some of the office work. At the present time one section of a miller department is equipped with these lights, as an experimental test of their use on machine work that requires the best illumination. If this test is satisfactory, these lamps will probably be used to the exclusion of incandescents, not only in the extension now underway, but by replacement in the older manufacturing departments.

58 In case it is deemed inadvisable to use these for manufacturing processes, they will still be used to replace the arc lamps on the public

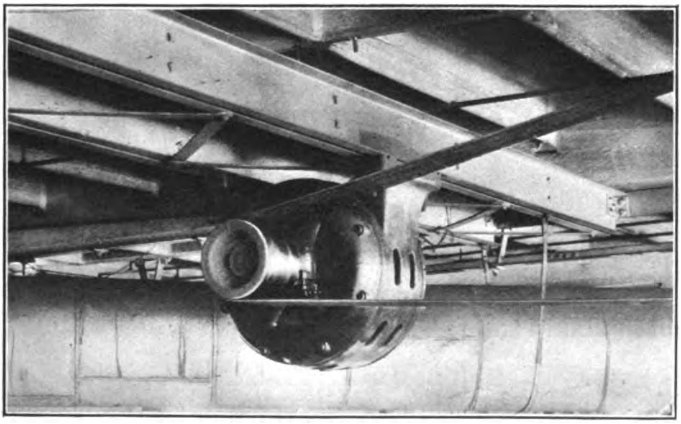

Fig. 15 Steel Structure for Attaching Motor to Ceiling.

circuits and for departments that require nothing but general illumination, such as setting up, storage, shipping, boxing and the like.

59 The lighting factors for the original installation were as follows: for offices and drawing rooms 0.5 c.p. per sq. ft. of floor area; for manufacturing departments, 0.3 c.p. per sq. ft. of floor area; and for the public circuits 1 c.p. for each 29 sq. ft. of floor area.

60 In the offices as now equipped, one 300 c.p. mercury-vapor arc lamp having a rating of 250 watts is used for an average of 250 sq. ft. of floor area. Similarly, the drawing rooms are successfully lighted with a wattage rating of 1.2 per sq. ft. of floor area. This factor is not as satisfactory as it should be, because the ceiling of the drawing

room is crossed by a number of sheet-metal ventilating ducts, so arranged that a larger number of lamps had to be installed to prevent objectionable shadows. The installation of these mercury arc lamps over the milling-machine area provides 90 watts for each 10 sq. ft. of floor area. The switch control for these mercury-vapor arc lamps is by twos in series lengthwise of the room.

61 *Power Equipment of the Machine Shops.* Induction motors are used throughout for power purposes, the departments being broken up into convenient groups to give motors of a reasonable size and to secure flexibility of control. These motors in every case are attached to the ceilings by steel structures, one type of which is illustrated by Fig. 15.

62 The number of motors used for the machine-shop areas aggregates 130 with a total horsepower rating of 2725. This gives a factor of 0.37 h.p. per 100 sq. ft. of floor area. The number of employes for these same manufacturing areas is 4500, giving a factor of 0.6 h.p. per workman. Tests indicate that these motors carry on an average about 90 per cent of their rated load.

63 *The Manufacturing Plan.* It was stated in the opening paragraphs that the plan of organization originally decided upon, was the so-called one-shop plan. The original plant was divided into departments and the machine tools arranged in keeping with this decision. When that installation was completed, it perhaps represented as large a typical example of this scheme of organization as we have ever known. Owing to the rapid increase of the business, the difficulty of getting suitably trained foremen and the multiplicity of the work of these large departments, a modification of the original plan has been necessary. As additions were completed and new machine tools installed, if the one-shop plan had been adhered to in its entirety, it would have meant the transference of certain entire departments to new floor areas in order that other departments might grow. The principal modification is the adopting of the output-department plan. The expression is here used with a meaning slightly different from the accepted one, in that the modified departments handle a line of similar work drawn from a number of different machines, instead of handling one machine or several similar associated machines. This modification, of course, has applied only to the general machine-shop manufacturing departments and not to special or associated departments, such as the screw machine work, and the like.

64 *Toilet-Room Wings.* The toilet-room wings, designated in Fig 2 by the letters *ABS*, *ABN*, *ABX* and *ABXX*, contain locker rooms

wash rooms, toilet rooms, tool storage and delivery rooms, stair wells and, as mentioned before, the connecting passageways between the main buildings. But little needs to be said about these buildings or their equipment, except to refer to Fig. 16 which is typical of the utilities.

65 All of the rooms are provided with mechanical ventilation, through a system of ducts in the walls leading to a chamber under

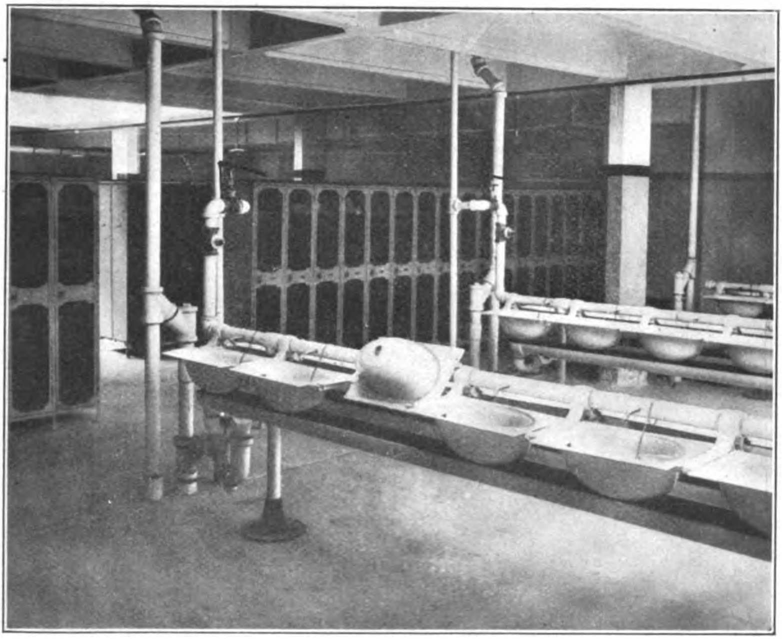

FIG. 16 VIEW SHOWING A ROOM IN ONE OF THE TOILET-ROOM WINGS

the roof containing a direct-connected ventilating fan discharging to the outside air.

66 In the original building there was no local ventilation for the toilet-room utilities themselves, but it was provided in the additions. The improvement in conditions has been marked.

67 One room of wing *ABN* is the emergency, or first-aid hospital, in charge of a registered male nurse. Here records are kept of any injury that is treated, no matter how trivial.

68 *The Foundry.* Fig. 17 shows the foundry building, with the molding floor and its steel-framed monitor roof (Fig. 18) on the first-

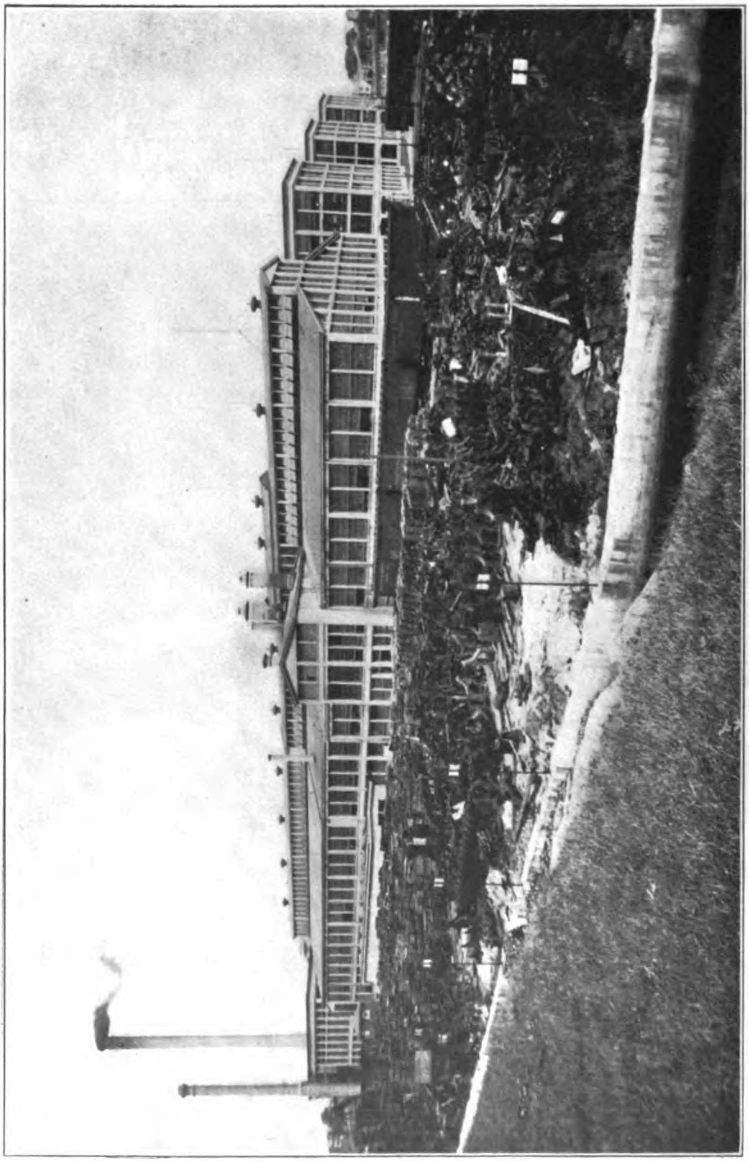

FIG. 17 GENERAL VIEW OF FOUNDRY BUILDING FROM THE REAR

floor level. This floor is devoted to accessory foundry departments, including the cleaning, flask-making, casting-storage and metal-pattern rooms. Beneath this floor is a storage space for foundry supplies, sand and coke. Here bins connect by means of inclined chutes, with an area alongside the spur track to facilitate the unloading of material. The heavy molding floors are equipped with electric hoists and hand cranes. The lighting as originally installed was with

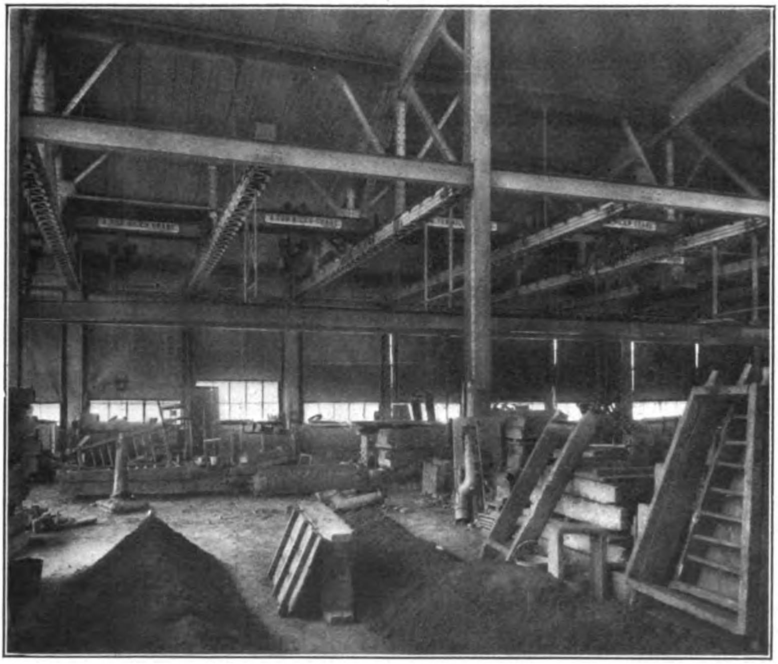

FIG. 18 SECTION OF MOLDING FLOOR

7.5-amperes incandescent arcs. This has since been modified by the introduction of mercury-vapor lamps of 0.083 watts per sq. ft. of floor area.

69 *Power House.* The power house designated by *F* (Fig. 2) is equipped with three Curtis vertical turbines, one of 1000 and two of 750 kw. capacity, with their auxiliaries.

70 The boiler house was originally equipped with two batteries of water-tube boilers, hand fired. When the additions of 1906–1907 were made, extra water-tube boilers were installed and mechanical

stokers were put in throughout the entire equipment. After this, coal and ash-handling machinery were added and an over-head storage capacity of 500 tons for coal.

71 *Storage Devices.* The lack of precedent was nowhere better demonstrated than in connection with metallic storage bins, racks

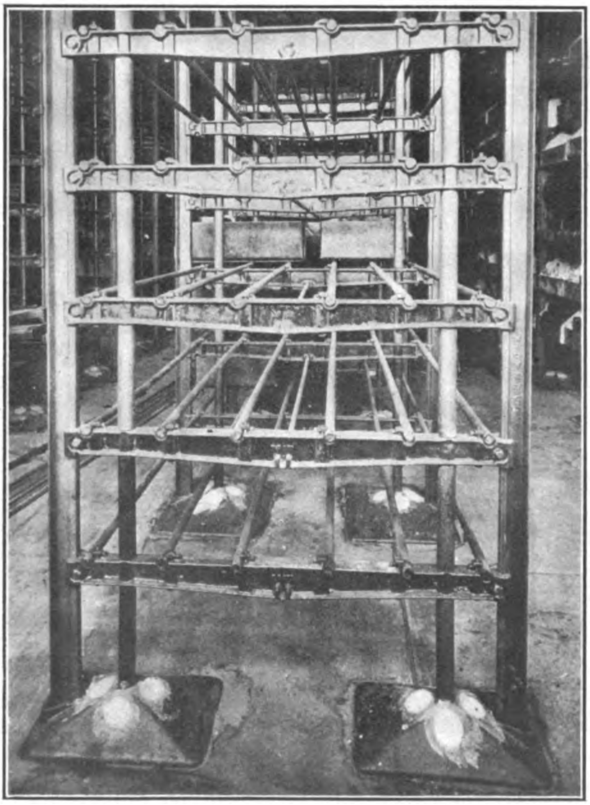

Fig. 19 Details of Storage Rack

and the like. Such devices today are the common equipment of many shops, but in 1903, when one of the authors endeavored to obtain a bid on such equipment, only one bidder was found in the United States. His proposal was based on an arrangement that very evidently had its prototype in library racks. The impracticability of the devices submitted and their excessive cost, led to the development of the type of rack and storage box illustrated in Figs. 19 and 20. The rack is composed of a series of small industrial railway rails, set vertically and arranged in pairs with their heads facing across the width of the rack. To these rails are clamped cross-bars of cast iron, spaced apart by $\frac{3}{4}$-in. pipe struts. Round rods run horizontally across these cast-iron frames and are clamped in place by bolts. The spacing between these skeleton shelves is varied to receive standard sizes of boxes, arranged on a unit system. They give storage volumes in the proportions of $\frac{1}{4}$, $\frac{1}{2}$, 1, 2, 4, 8 and 16, respectively. For certain large and

Fig. 20 Racks and Storage Boxes

bulky pieces, no boxes are used, but the parts are piled in place on the skeleton shelves. At the present time there are 248 racks of this type in use, each one having an available storage volume of 972 cu. ft. They occupy a floor space 60 ft. wide by 700 ft. long.

72 In order to facilitate the putting in and taking out of parts from the boxes at the top rack, a sliding ladder is installed in each space between two racks and serves both of them.

NOTE OF ACKNOWLEDGMENT

The designing and engineering work has been done by a number of engineers, for the main plant was constructed during the years 1903–1904; the first addition in 1906–1907; another addition was started in 1910 and the work is of such magnitude that it will not be finished until sometime in the year 1912.

Before this plant was built the United Shoe Machinery Company owned and operated a number of machine shops near Boston. When a decision was made to build an entirely new plant, a committee, composed of M. B. Kaven, S. D. LeLand, S. W. Ladd, Z. T. French and W. B. Trowbridge, was organized to investigate all of the existing factories, prepare a tentative scheme for the new plant and serve in an advisory capacity while the plans were being drawn. The architect was F. M. Andrews, then of Dayton, Ohio, who drew the original plans for steel framed buildings faced with brick and with wooden floors. Before any work of construction was started, however, it was decided to change to reinforced concrete. E. L. Ransome, of New York City, was the advisory concrete engineer, and Charles T. Main, then of Dean and Main, Boston, was consulting mechanical engineer. Mr. Ransome designed and supervised all of the concrete work in the additions of 1906–1907 and is now serving in a similar capacity for the additions in progress.

The authors of this paper have successively served as engineers for the owner in designing and installing the machine-shop equipment of the original plant and in all of the engineering work of the additions, with the exception of the concrete construction.

# OIL ENGINES

By H. R. Setz

## ABSTRACT OF PAPER

Starting with the older well-known types of oil engines, which were the natural sequence to the gasolene engine, this paper proceeds to give a description of the Diesel engine and its modifications, commonly known under the collective name of constant-pressure engines. This description is given in the form of a critical discussion, leading up to an explanation of the principles underlying the various processes of fuel injection. Particular attention is given to the development of smaller units.

# OIL ENGINES

By H. R. Setz,[1] Warren, Pa.

Non-Member

It has been reserved for modern engineering to give to liquid fuels the consideration due them by reason of their exceptional transportation and storage facilities, their high heating value and their small bulk as compared with all solid fuels.

2 The first successful solutions of the problem of using liquid fuels in internal-combustion engines were naturally attained with gasolene. This fuel, the lightest of the hydrocarbons obtained by fractional distillation of crude oil, vaporizes at comparatively low temperatures and readily forms an explosive mixture under ordinary atmospheric conditions. Only some form of carburetor was therefore required, aside from the usual constructive elements of the gas engine.

3 A far more serious problem presented itself when the utilization of the heavier hydrocarbons, such as kerosene, fuel oil and crude oil itself, was attempted. Many experiments showed that in order to get an explosive mixture, these heavy oils must first be converted at a comparatively high temperature into vapor before or during their mixture with air. For this purpose most oil engines have a hot chamber or vaporizer where the oil, after having been introduced as a liquid or in the form of spray, is converted into vapor and then taken up by and mixed with a current of air. The most notable methods now in use for securing a perfect mixture by means of a vaporizer are shown in Figs. 1, 2 and 3.

## VAPORIZING AND MIXING

4 In Fig. 1 evaporation and mixing are effected during the compression stroke. The oil is injected into an incandescent hood or

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chamber which, for starting, is heated up externally by means of a lamp, and afterwards kept red hot by the combustion of the mixture in it. During the compression stroke air from the cylinder rushes through the contracted opening into this chamber and mixes with the vapors therein, until at the end of the stroke, the right proportion of combustible to air is reached. The mixture is then ignited simply by direct contact with the hot walls of this vaporizing chamber, augmented slightly by the heat due to compression.

5 An arrangement commonly used by gasolene engine manufacturers to adapt their engines to the utilization of heavier hydrocarbons is shown in Fig. 2. The vaporizer chamber is provided with a jacket

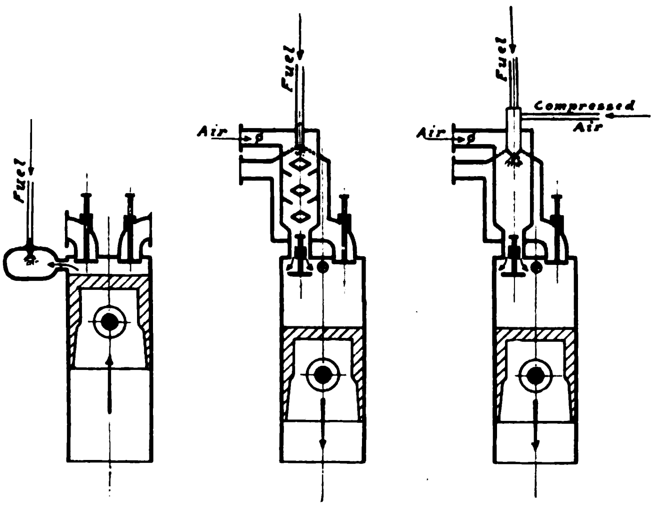


Fig. 1 Fig. 2 Fig. 3

Methods for Securing Mixture of Vapor and Air

space through which the exhaust gases pass, thus heating the vaporizer externally. A cloud of fuel vapor is produced by dropping the liquid fuel on the heated surfaces of the baffle plates inside the vaporizer. On the suction stroke of the piston free air enters this vaporizer and, in passing over the baffle plates, becomes heated and in the same time absorbs the oil vapors; the mixture thus formed and pre-heated then enters the cylinder and at the end of the compression stroke is ignited by an electric igniter.

6 In Fig. 3 the fuel oil is mixed with and broken up by a stream of compressed air of from 8 to 25 lb. pressure above atmosphere, so that

it enters the vaporizer chamber in the form of finely divided spray, and is immediately vaporized, due to the heat applied externally by the exhaust gases. The bulk of air, being aspirated during the suction stroke, then mixes with the fuel vapor and becomes pre-heated, thus forming the explosive charge. Compression and ignition are the same as in Fig. 2.

7 These types of oil engines, especially those of Figs. 1 and 2, are quite simple and therefore cheap in first cost. Their method of vaporization, however, is rather crude and gives rise to objections well borne out by practical experience, which are the cause of the prevailing prejudice against such oil engines. The chief drawback to all these vaporizers is the practical impossibility of vaporizing the fuel completely at all loads and under all conditions. The heat of the chamber should always be high enough to vaporize all the oil, but never hot enough to decompose it, or a deposit of carbon will be formed in the vaporizer and cylinder, accompanied by incomplete combustion, and therefore low efficiencies; this manifests itself by the objectionable smoke and odor of the exhaust gases. Another drawback is that in all engines of the type of Fig. 1, in order to obtain certainty of ignition and at the same time prevent pre-ignitions at different loads, the temperature of the vaporizer should vary with the load, a practical impossibility. The pre-heating of the mixture, as required for engines operating under the principles shown in Figs. 2 and 3, decreases the weight of the air aspirated, and therefore the capacity of the engine; while the throttling of the air in passing through the vaporizer chamber and passages, as well as the high back pressure due to the exhaust gases passing through the jacket space of the vaporizers, decreases the power output of such engines still more. The necessity of first heating the vaporizer externally by means of a lamp before the engine can be started is rather inconvenient as it takes at least five to ten minutes. The fuel consumption of these engines averages about 1 lb. of oil per b.h.p-hr., corresponding to a thermal efficiency of not over 15 per cent.

8 This outline covers in a general way the mechanical principles of some of the commercial liquid-fuel engines today on the market. A great variety of modifications is possible, such as the cycle of operation (2-stroke or 4-stroke), vertical or horizontal, regulation, valve gear, etc. However, whether these work on the 4-stroke or 2-stroke cycle, they all have in common the fact that the fuel and air mixture, after having been compressed, is instantaneously ignited, i.e., at constant volume, and according to this mode of heat application they

belong in the class of constant-volume engines. The efficiency of this thermodynamic cycle is greater with increasing degrees of compression; the latter, however, is limited on account of the danger of premature ignitions due to the compression temperature. Attempts have been made to attain high compression pressures at low temperatures by injecting water into the cylinder during the compression stroke. Banki of Hungary has succeeded in building a very efficient motor along these lines; he compressed as high as 250 lb. per sq. in., the resulting combustion pressures amounting to something like 700 lb. This necessitated engine parts of hydraulic press proportions which, together with a possibility of short-circuiting the ignition plugs on account of moisture deposits, failed to make this engine a commercial success. The use of a special scavenging pump in a 4-cycle engine was also attempted, by means of which fresh air could be swept through the cylinder at the end of the exhaust stroke, thus cleaning the clearance space from the residue of spent gases and at the same time cooling the combustion chamber walls. Although this permitted the compression pressure to be raised, the extra expense for the special scavenging pump did not warrant its adoption for general practice. Without such artificial means the safe limit of compression in the present constant-volume liquid-fuel engines has by long experience been found to be about 70 lb. in gasolene engines and hardly more than 60 lb. in kerosene engines with spontaneous (hot-bulb) ignition (Fig. 1). The efficiency of these types of engines is therefore not likely to be increased very much in the future. Considering this, as well as the undesirable features touched upon in the foregoing discussion, it is quite obvious that, as far as reliability and economy of operation are concerned, these engines fall far short of what may reasonably be expected, especially in view of what is being accomplished with gas engines.

### DIESEL ENGINE TYPE

9 An engine of decided advantages over those just discussed is the Diesel type, having the following characteristics of operation: During the compression stroke the cylinder contains air only, which is being compressed to about 500 lb., the resulting temperature reaching a point sufficiently high to ignite any liquid fuel injected into it. At the end of the compression stroke, fuel is gradually injected by means of an air blast at a pressure about 250 to 500 lb. above the compression pressure in the cylinder. This high-pressure air blast

completely atomizes the fuel during the injection period, and carries its small particles directly into the highly compressed and heated air in the cylinder, where they are immediately vaporized and ignited. By this method combustion is effected without explosion, as the continued admission of the fuel to about 10 per cent of the expansion stroke causes the development of heat to take place at approximately constant pressure. Since the oil particles are burned immediately after their mixture with air, there is no possibility of deposits forming on the cylinder walls and combustion is so complete that the exhaust products are entirely smokeless and without odor. Numerous tests made on Diesel engines of different sizes show an average fuel consumption of less than ½ lb. of oil per h.p-hr., corresponding to a thermal efficiency of about 30 per cent.

10 To the particular feature of compressing air alone to such a pressure and temperature that it will immediately vaporize and ignite the fuel injected into it, the constant-pressure engine as embodied in the Diesel motor undoubtedly owes its success. It lends itself admirably to the utilization of liquid fuels, as it does away at once with carburetors or vaporizers, and igniters; moreover it allows the burning of any liquid fuel without special accessories. For this same reason it is singularly well adapted to operation on the 2-stroke cycle. The doubtful practice of scavenging the cylinder with the fuel and air mixture, with its attendant loss of mixture through the exhaust ports, and the possibility of backfires, is therefore entirely eliminated. The result is that it embodies the full benefit of the 2-stroke cycle, practically twice the power capacity of a 4-stroke cycle engine of the same cylinder dimensions and speed. Another point of equal importance is the fact that with decreasing loads the efficiency of the constant-pressure engine decreases but very little, while that of the constant-volume engine drops very rapidly with lighter loads.

11 In view of these points, therefore, there can hardly be any question that for the utilization of liquid fuels the constant-pressure engine is far superior to the constant-volume engine. The great number of Diesel engine installations working under greatly varying conditions and with all kinds of fuels, abundantly proves this, particularly in Europe, where during the last three years engines of this type to an aggregate of over 250,000 h.p. have been built. Considering the fact that at the beginning of this century the Diesel engine had hardly emerged from the experimental stage, this is truly a remarkable achievement which cannot fail to attract engineering activity towards further developments in so promising a field of enterprise.

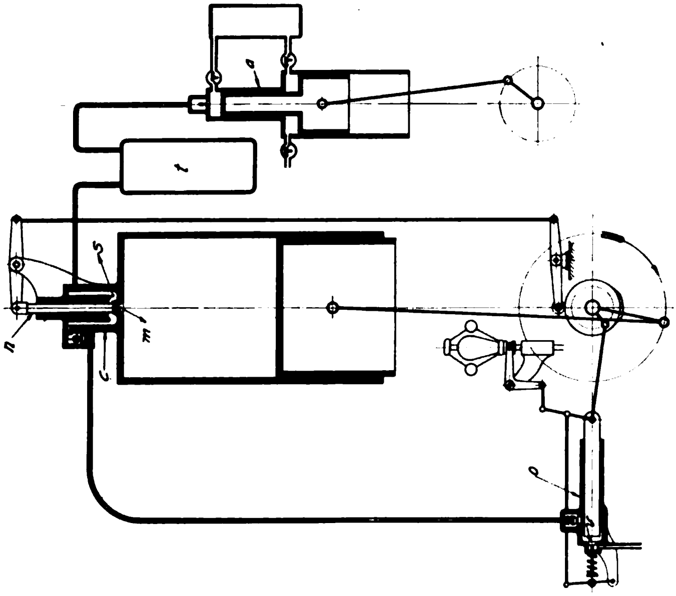


Fig. 4

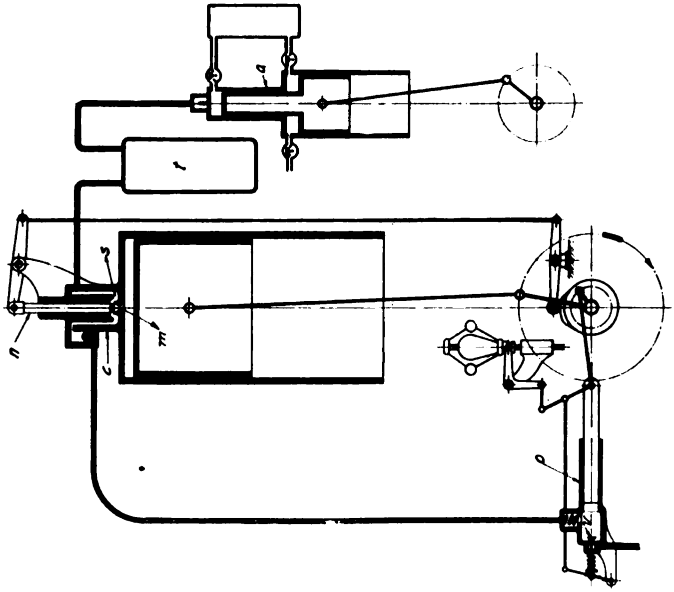


Fig. 5

Diesel Engine with "Closed" Injection Nozzle

A number of new types of constant-pressure oil engines have been brought out within the last few years, all differing more or less from one another in their mode of fuel injection.

12 The accompanying illustrations show schematically the mechanical combinations used to inject the fuel and the principal modifications recently brought out. Since this new era of oil-engine construction started with the advent of the Diesel engine, we will first analyze the injection process of this engine, so as to establish the functions of the various parts entering into it.

13 Fig. 4 represents the period where a measured quantity of fuel, according to the load on the engine, is being deposited in space *s* of the injection valve cage *c* by the oil pump *o*, the injection valve *n* being closed at that moment. Space *s* is continuously in communication with the air storage tank *t*, into which the 2-stage air compressor *a* delivers the air required for fuel injection at a pressure of from 750 to 1000 lb. (One or two additional tanks are automatically kept charged by the compressor with air of about the same pressure for starting the engine.) The oil must therefore be delivered into space *s* against this high pressure which, in view of the small quantity to be delivered, requires extremely accurate work and adjustments on the oil pump *o*. Since fuel and injection air come into contact with each other while injection valve *n* is still closed, that is, before the actual injection period, it is quite obvious that the valve cage *c*, as well as the injection air, must be well cooled in order to prevent dangerous premature ignitions or the formation of deposits due to partial evaporation of the deposited fuel.

14 Fig. 5 shows the actual injection period, which starts as soon as injection valve *n* opens; the latter therefore controls simultaneously the admission of fuel and injection of air into the cylinder. At all loads the points of opening and closing of the injection valve *n* remain unchanged, i.e., the length of the period the injection valve is open is constant. Within this period a variable quantity of fuel, according to the load, is to be injected. In order to accomplish this most satisfactorily it has been found necessary to increase the pressure of the injection air with increasing loads on the engine, i.e., with increasing amounts of fuel to be injected; Diesel engine manufacturers recommend a pressure increase of about 250 lb. from light to maximum load. Since compression in the engine cylinder is constant at all loads, this is undoubtedly due to the fact that all the fuel having previously been deposited in space *s*, must be accelerated and atomized by the injection air as soon as injection valve *n* opens. Furthermore, if the

injection air pressure is too high at light loads it may happen that no ignition is effected on account of the cooling effect of the injection air, of which more will be said later on.

15 The variation of injection air pressures with varying loads on a 4-cylinder 250-h.p. engine is given in Table 1, which also shows the indicated compressor work. To the writer's knowledge no arrangements have so far been made on stationary engines to vary automatically the pressure of the injection air according to load variations; this must be done by hand, at the judgment of the engine operator.

TABLE 1 VARIATION OF INJECTION AIR PRESSURES WITH VARYING LOADS

| ENGINE LOAD, B.H.P | INJECTION AIR PRESSURES, LB. | INJECTION AIR COMPRESSOR | |
|---|---|---|---|
| | | I.h.p. | Per cent Engine Load |
| 300 | 950 | 19.3 | 6.4 |
| 250 | 865 | 18.3 | 7.4 |
| 185 | 830 | 18.4 | 10.0 |
| 145 | 790 | 19.0 | 12.8 |

16 The foregoing analysis shows that the process of fuel injection resolves itself into two distinct phases, which are in no direct relation to each other:

*a* The measuring and depositing of the proper amount of fuel in the injection valve cage which is the function of the oil pump and may practically be performed at any time during the cycle of events in the engine. (Fig. 4 arbitrarily shows that this takes place at the beginning of the upward stroke of the piston.)

*b* The actual injection period, which is timed by the opening and closing of the injection valve, while it is the function of the injection air to pick up the fuel, atomize it and carry its small particles into the cylinder. The injection valve opens from 5 deg. to 8 deg. before the piston reaches the upper dead center, and closes about 28 deg. to 31 deg. past center. (The earlier opening and closing applies to heavier fuels.)

17 In order to properly distribute the oil and to direct the injection air so as to facilitate complete atomization, special accessories, atomizers or distributors, are used, which are placed in front of the injection nozzle *m*. Fig. 6 shows a typical atomizer used on

European Diesel engines. A series of plates *b*, arranged just below space *s* around the injection valve guide *g*, are provided with small holes in such a way that they straddle each other from plate to plate. These plates help to retain the oil after having been deposited in space *s*, while the holes will equally distribute it and mechanically divide the blast of injection air into small streams, thus disinte-

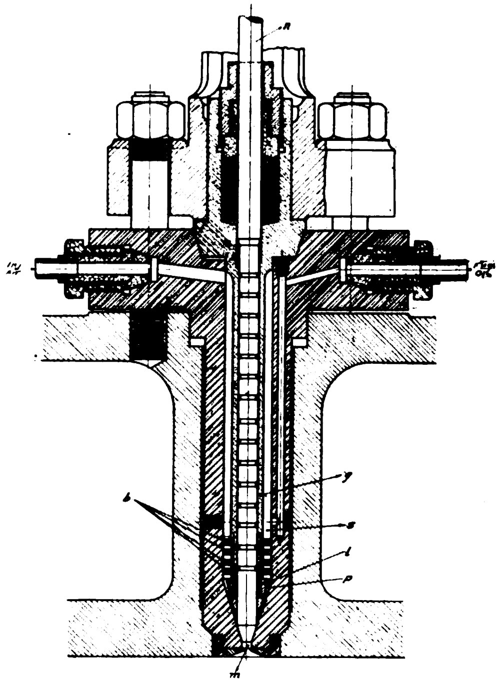

FIG 6. TYPICAL ATOMIZER USED ON EUROPEAN DIESEL ENGINES

grating the fuel passing down through them. By means of passages *p* arranged in the circumference of plug *l*, these streams are directed into the injection nozzle *m* where they acquire their maximum velocity. The resistance of the oil against the abrupt acceleration thus produced causes the oil to be disintegrated into small particles which are carried directly into the body of highly heated air in the combustion chamber.

## AMERICAN DIESEL ENGINE

18 On the American Diesel engine, a cross-section of the latest design of which is shown in Fig. 7, the fuel injection valve and atomizer are arranged horizontally on the side of the combustion chamber. Owing to this horizontal position particular care must be taken to distribute the oil equally around the circumference of the injection

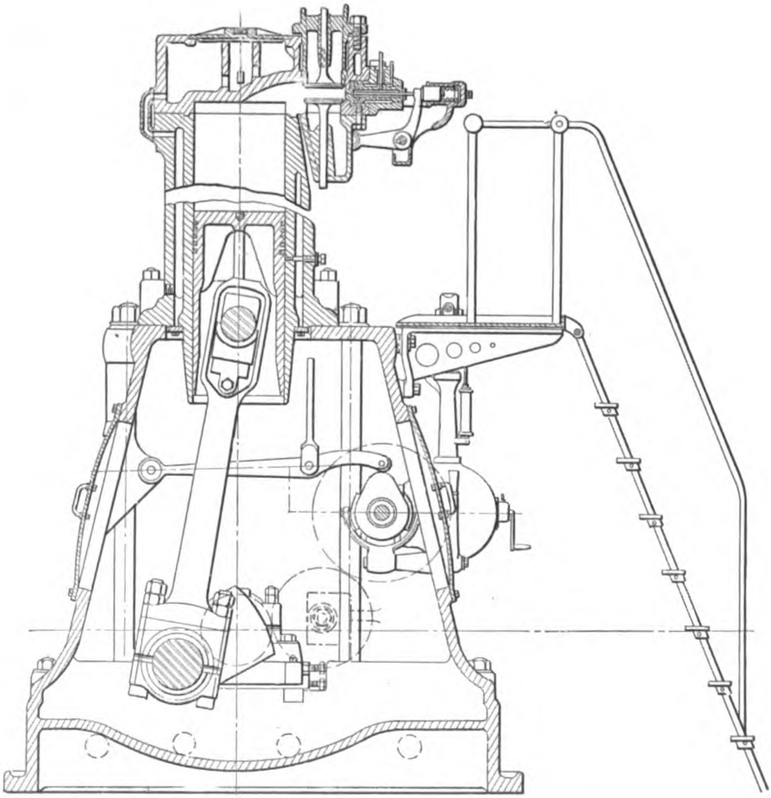

FIG. 7 CROSS-SECTION OF AMERICAN DIESEL ENGINE

valve. A sectional view of the atomizer is shown in Fig. 8. Oil and injection air come together in space *s*, the oil entering along passage *e* and annular ring space *r* through a ring of holes *h*. As the injection valve *n* opens, air and oil, being divided into small streams by a circle of holes *p*, are forced into the injection nozzle *m*, where these streams impinge upon each other, thus atomizing the fuel.

## SABATHÉ ENGINE

19 A modification of the Diesel engine has recently been brought out in France, known as the Sabathé motor, which is evidently an attempt to eliminate the rather inconvenient requirement of variable injection air pressures with varying loads. Its fundamental features are identical with those of the Diesel engine (Figs. 4 and 5), with this exception, however, that not only the delivery of oil but also the lift of the injection valve *n* are here varied by the governor according to the load on the engine. Constructional details of the injection valve and nozzle are shown in Fig. 9. Aside from the injection valve *n*, a second valve *v*, sliding on *n* and being ordinarily held down on its

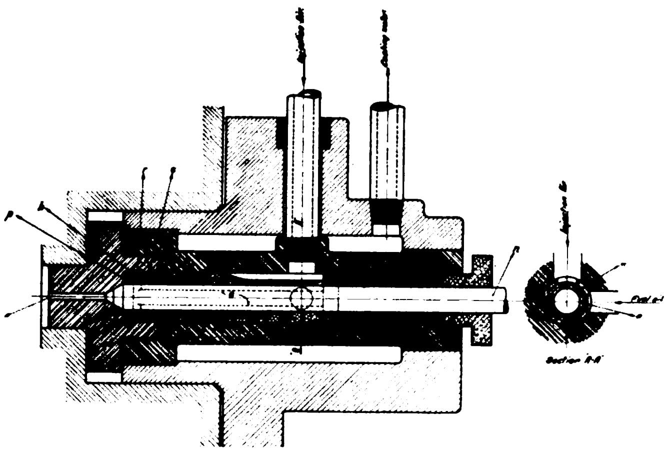

FIG. 8 ATOMIZER OF AMERICAN DIESEL ENGINE

seat by spring *i*, is provided. This valve *v* is lifted by collar *r* on the injection valve stem when the lift of the latter is sufficient to do so. On light loads only enough oil is delivered by the oil pump to fill chamber *e* underneath the valve *v*. This is blown into the cylinders when needle valve *n* lifts, the injection air passing down groove *p* in the needle valve stem. On heavier loads the amount of fuel delivered by the pump fills chamber *e* and overflows into space *s*; the lift of injection valve *n* is regulated by the governor in such a way that first the oil contained in chamber *e* is injected and then by lifting valve *v*, also that contained in space *s*. The pressure of the injection air is maintained at 800 lb.

DE LA VERGNE FH TYPE ENGINE

20 A notable combination of the Diesel principle, as illustrated by Figs. 4 and 5, with the hot-bulb arrangement of Fig. 1, is the type *FH* engine of the De La Vergne Machine Company, New York (Figs. 10 and 11). The engine operates on the 4-stroke cycle and compresses the air to about 250 to 300 lb., instead of 500 lb. as in the Diesel engine. The temperature thus obtained would not be high enough to

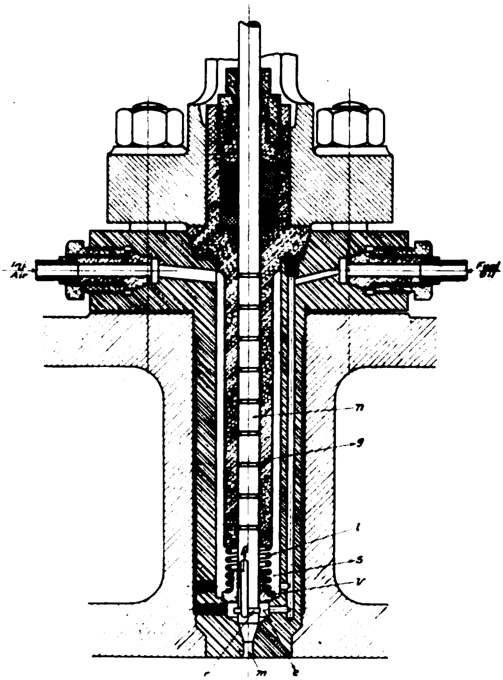


FIG. 9 ATOMIZER OF SABATHÉ ENGINE

ignite the fuel; recourse is therefore taken to a hot bulb *D*, the air in which, owing to the heat radiated from its uncooled walls, attains a higher temperature than that contained in the combustion chamber. For starting, this bulb is heated externally by means of a blow torch, 10 to 15 minutes being required for this purpose. At the end of the compression stroke the fuel is injected by means of an air blast of about 600 lb. pressure, from the injection nozzle *F* across the combustion chamber into the hot bulb *D*, where it is immediately ignited. Owing to the comparatively large distance the fuel spray has to transverse after it leaves nozzle *F* until it is ignited in *D*, ignition first produces a considerable pressure increase (combustion at constant volume), to be followed by combustion at approximately constant pressure. This is shown on the two indicator cards (Fig. 12), where it will be noticed that the maximum pressures reach very nearly 500 lb., i.e., about the same as in the Diesel engine. As far as strains in the engine are concerned there is, therefore, not much difference between these two types. However, it must be remembered that in the Diesel engine this high pressure must be obtained at the end of the compression stroke in order to secure ignition, while in the De La Vergne engine, ignition is certain at about half that pressure. The requirements as to workmanship, and especially attendance, are therefore less severe.

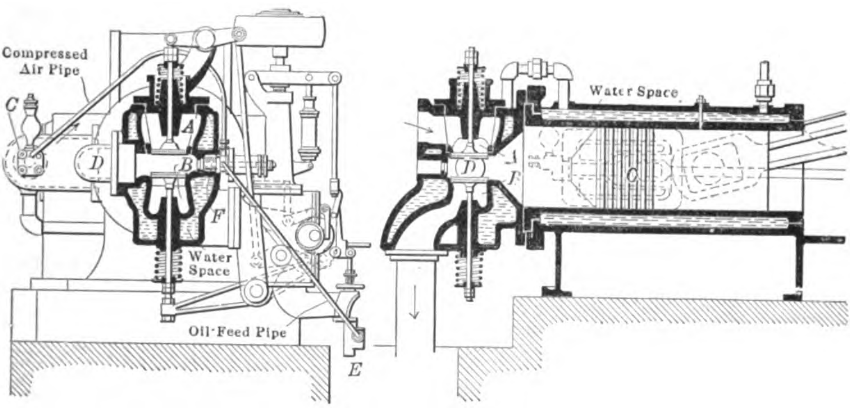


Fig. 10 Fig. 11

Type *FH* De La Vergne Engine

21 A 2-stage air compressor *C*, driven by an eccentric from the engine shaft, supplies the injection air. The air compressed by the first stage is stored in tanks *t* (Fig. 13), at a pressure of from 125 to 150 lb., and is available for starting the engine. The second stage of the compressor draws the air from one of these tanks, the amount drawn in being regulated by the governor by means of valve *v* to suit the varying charges of oil at each injection, and forces it directly into the injection valve cage, without an intermediary storage tank. It is needless to say that the resulting absence of tanks under extremely high pressures is a very desirable feature, while on the other hand it is, of course, imperative that the high-pressure stage of the compressor works with absolute certainty.

22 Fig. 14 shows constructional details of the injection valve and atomizer used on the type *FH* engine. Oil and injection air come together in annular space *s* formed between the injection valve guide *g* and cage *a*. As the injection valve *n* opens, oil and air proceed along the outside of guide *g* and are forced to pass through a series of chambers connected by a system of fine diagonal channels *d* on the outside of *g*. The oil is thus equally distributed around the circumference of needle valve guide *g* and enters injection nozzle *m* in a state of fine subdivision from where it is blown into the combustion chamber and hot bulb.

23 Undoubtedly owing to the fact that part of the oil charge is burned at constant volume, the fuel consumption of this engine is remarkably low considering the comparatively low compression. Thus according to tests made by Dr. Waldo on a 125-h.p. engine[1], the

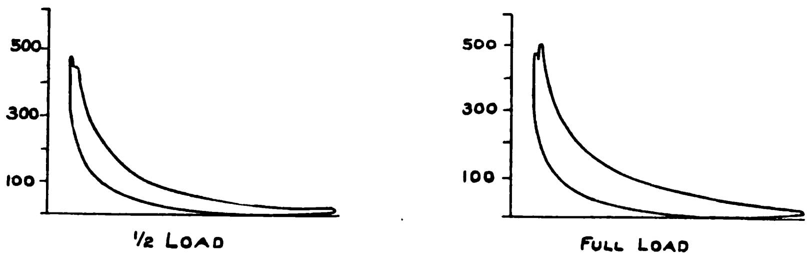


Fig. 12 Indicator Cards, Type *FH* De La Vergne Engine

minimum oil consumption was found to be 0.374 lb. per b.h.p-hr. with the engine carrying a load of 129 b.h.p. at 157 r.p.m. A report from the Snead and Company Iron Works, Jersey City, N. J., shows the following results for twelve months' operation. The plant, consisting of a twin cylinder 17 in. by 27½ in. engine, operated 3033 hr. at a load factor of 54 per cent; fuel oil consumption per h.p-hr., 0.506 lb.

### OIL-PUMP ARRANGEMENT

24 The fact that the function of the fuel oil pump is in no direct relation to the cycle of events in the cylinder is taken advantage of by some European Diesel engine manufacturers on their multi-cylinder engines. Instead of using one oil pump for every cylinder, as is, for instance, the practice of the American Diesel Engine Com-

[1] Engineering News, January 13, 1910.

pany, they use only one pump for all cylinders. This pump delivers the oil into a distributer where, by means of a series of check valves and restricted passages which artificially increase the resistance against flow, it is thus equally divided into as many streams as there are cylinders. Considering the severe conditions under which it has to work on the Diesel engine, the advantage derived from the resulting reduction of oil pump parts is obvious.

25 As to details of construction of the oil pump, current practice seems to indicate a preference for a positively operated plunger (operated by an eccentric) rather than one operated by a cam where the stroke is varied according to the load by letting the governor shift

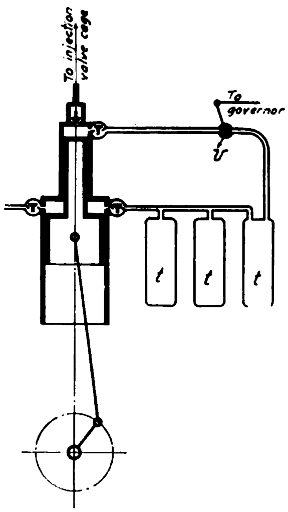


Fig. 13 Scheme of Injection and Starting Air Outfit of Type *FH* De La Vergne Engine

a wedge block in between the cam and the plunger. In the former the displacement of the plunger is of course constant and considerably larger than that required for the maximum charge of fuel oil; the excess amount of oil is discharged through the suction valve *v* (Figs. 4 and 5), the opening and closing of which is determined by the position of the governor. This valve and also the mechanism for its operation are constructive elements which require the utmost care in design as well as workmanship, as upon their proper action depends primarily the accuracy of fuel oil delivery. Frictional resistance of the valve, which is liable to prevent its prompt closing, is especially important and must be reduced to a minimum. It is therefore not advisable to have the valve stem pass through a stuffing box. The best practice at present is to use a positively-operated plunger for the operation of the inlet valve, this plunger passing through the stuffing box and thus practically eliminating friction as far as the valve is concerned.

### MODIFICATION OF DIESEL TYPE WITH OPEN FUEL INJECTION NOZZLE

26 A very promising departure from the original Diesel engine which has been developed particularly for horizontal engines during the last two or three years by several German designers, is represented by Figs. 15 and 16. Its distinguishing feature is the open fuel injec-

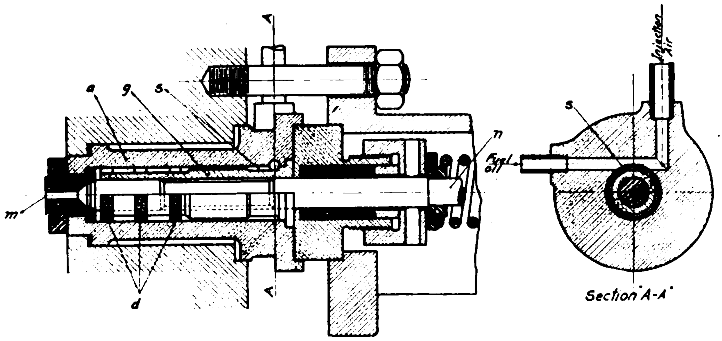


FIG. 14 ATOMIZER OF TYPE *FH* DE LA VERGNE ENGINE

tion nozzle *m*, through which space *s* is continuously in communication with the engine cylinder. Fig. 15 shows again the period where the oil pump *o* delivers a measured quantity of oil into space *s*; this happens when the piston begins its compression stroke, i.e., when the pressure in the engine cylinder and therefore in space *s* is low. Valve *n* opens shortly before the end of the compression stroke (Fig. 16), thereby admitting a blast of injection air, which picks up the fuel deposited in space *s* and blows it through injection nozzle *m* into the cylinder. Injection air of pressures varying with the load, the same as on the original Diesel engine, is taken from the storage tank *t* kept charged by the separate air compressor *a*.

27 Constructional details of a typical injection nozzle and air admission valve are shown in Figs. 17 and 18. It will be noticed that no atomizer is used; the oil is blown directly from space *s* through

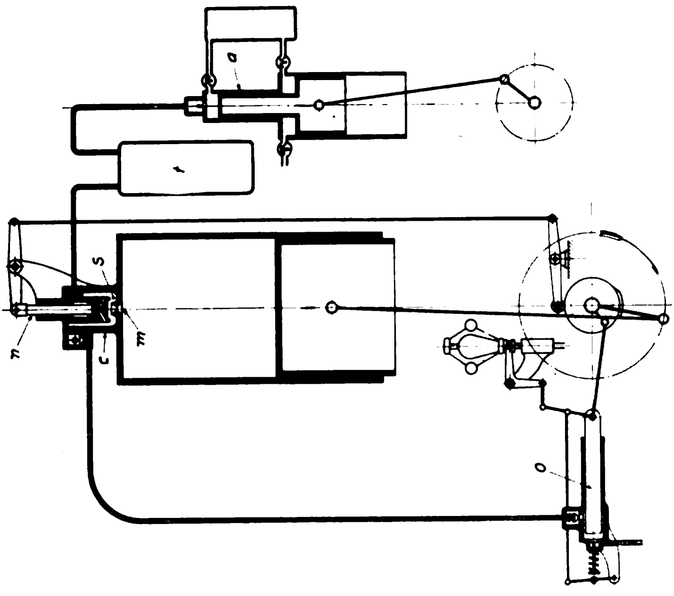

Fig 15

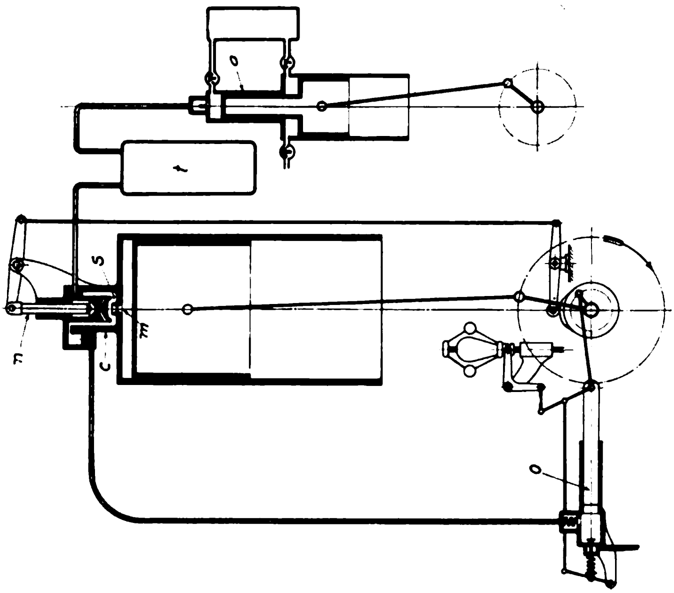

Fig. 16

Diesel Engine with "Open" Injection Nozzle injection nozzle *m* into the cylinder. The air admission valve *n* is operated by a push rod *r*, provided with a valve *v* on its inner end which prevents any leakage along rod *r*, except during the very short interval where it opens the air admission valve *n*. A stuffing box, such as on the injection valves *n* of the original Diesel engine (Figs. 6 and 7), is therefore not necessary. At the heavy pressures under which these stuffing boxes have to work it happens quite easily that by excessive tightening of the glands, the valves are prevented from closing properly, thus causing loss of injection air and even premature ignitions. By means of a test cock *K* the proper delivery of oil may be ascertained.

28 As already mentioned air of approximately the same pressure as injection air is being used for starting Diesel engines. It is evident that under such enormous pressures a very small charge of air will suffice for this purpose. This is taken advantage of in this case by operating valve *n*, for starting, by the same cam and lever as when the engine is in actual operation. By opening by-pass valve *y* communication to the cylinder will be established through passage *p*, through which, in addition to the open injection nozzle *m*, enough air is admitted to start the engine. This makes an admirably compact and simple arrangement, although, on account of the short duration of the starting air admission period, the proper starting point of the engine must be closely observed.

29 The method of depositing fuel in the open space *s* is undoubtedly of advantage so far as the oil pump is concerned as it permits the delivery of oil against a far lower pressure than in the original Diesel engine.

## AIR SUPPLY

30 In all the various types of modern oil engines just discussed the apparatus required to obtain the high-pressure injection air forms a comparatively complicated and therefore expensive accessory. The 2-stage air compressor contains four valves. Either the suction valve on the low-pressure or high-pressure stage must be provided with an adjusting device to vary the amount of air drawn in according to the oil charge. The storage tank *t* should also be provided with three valves, one to close it off towards the engine, one towards the compressor, and one safety valve. All these parts, together with a pipe line of sometimes considerable length with many joints, being continuously under a pressure of from 750 to 1000 lb., require no small degree of attention. That on the smaller units particularly, where

on account of their smallness these parts become extremely delicate, this becomes a matter of considerable importance, may be judged from the following dimensions of the 2-stage air compressor of the latest 5-h.p. Diesel engine: low-pressure cylinder diameter $2\frac{3}{4}$ in.; high-pressure cylinder diameter $\frac{15}{16}$ in.; stroke $2\frac{3}{8}$ in.

31 Attempts have been made to simplify matters by attaching one single-stage compressor, driven by a lever from the connecting rod, to each cylinder, this compressor receiving precompressed air out of the cylinder at a pressure of from 100 to 150 lb. This, however, necessitated an extra valve in each cylinder head, aside from other con-

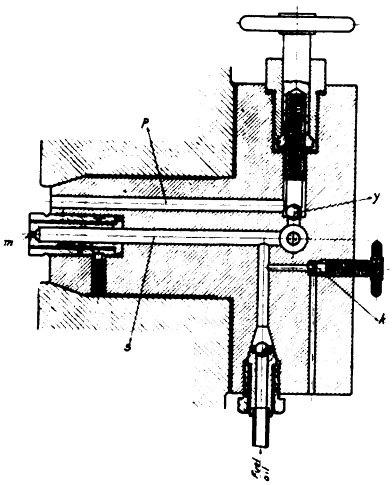

FIG. 17

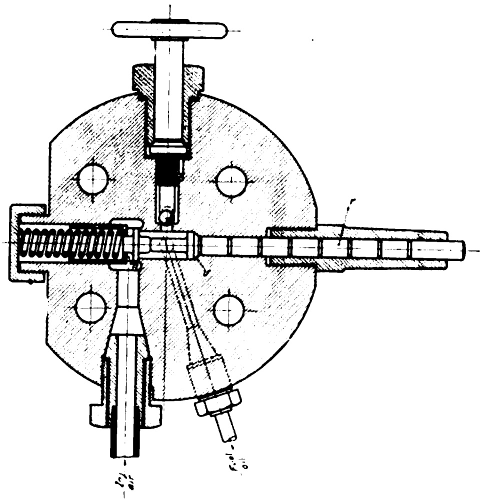

FIG. 18

TYPICAL "OPEN" INJECTION NOZZLE AND AIR VALVE

structive complications, and it was found furthermore that oil vapors, taken over with the air from the engine cylinder, had a tendency to foul the compressor valves, thereby rendering proper compression impossible.

32 In many respects far more promising at least for smaller units is the scheme to eliminate the air compressor entirely and instead to generate the injection air right in the engine at the moment fuel injection is to take place (Figs. 19 and 20). The special 2-stage air compressor is here replaced by a small chamber *a*, forming part of the engine cylinder and communicating with the latter through passages *i* and *k*. During the charging period (Fig. 19), the auxiliary piston

*t* is in its lowest position, so that port *i* is wide open, while the oil pump *o* delivers the proper amount of fuel into space *s* which communicates with the engine cylinder through the open injection nozzle *m*. Auxiliary piston *t* remains in this position until almost to the end of the compression stroke; up to this time the air pressure in chamber *a* will therefore be the same as in the engine cylinder.

33 To start the fuel injection (Fig. 20), auxiliary piston *t* is caused to move quickly upwards, thereby first covering passage *i*, and then

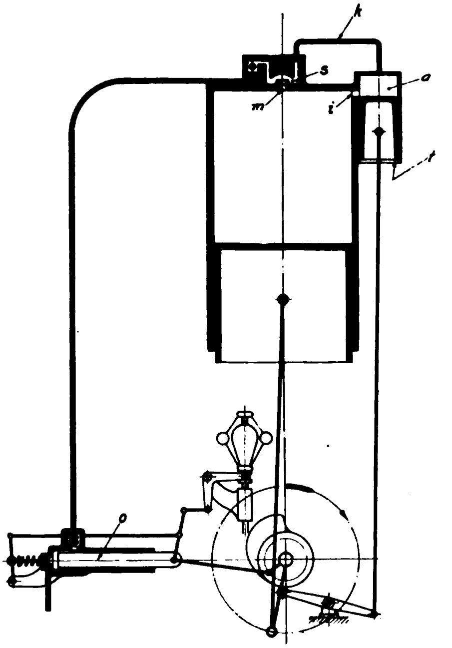


Fig. 19

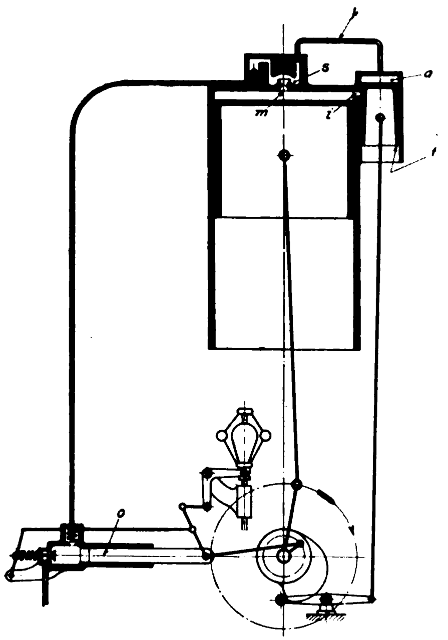


Fig. 20

Oil Engine with Auxiliary Injection Air Piston

compressing the air in chamber *a* to a pressure higher than the one in the cylinder. This causes the air to flow from *a* through passage *k* into space *s* where it picks up the deposited fuel and blows it through the injection nozzle *m* into the cylinder.

## TRINKLER-KÖRTING ENGINE

34 Fig. 21 shows a cut through the head end of an engine of this type, designed by Trinkler-Körting and built to work on the 4-stroke

cycle. The auxiliary piston *t* is provided with a stem of comparatively large diameter whereby the effective piston area is greatly reduced on this end; the piston stem passes through a stuffing box to the outside where it engages at *c* with lever *cde*. This lever, together with bell crank *fgh*, form a releasing gear operated by cams *b*. As shown on the cut, lever *cde* is just being released at *h;* owing to the larger

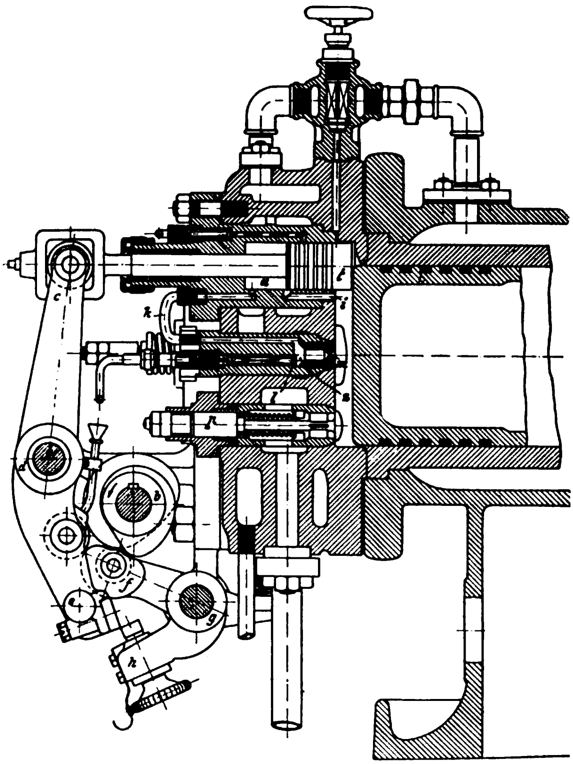

Fig. 21 Section through Head, Trinkler-Körting Engine

total pressure acting on the full piston area, this piston *t* is now caused to move quickly outwards, with the result already explained.

35 From the foregoing it will be noticed that while injection air is being generated in the chamber *a*, fuel is already deposited in space *s*. Since the latter is in communication with *a*, through the open passage *k* on one side, and with the engine cylinder through the open injection nozzle *m* on the other side, it is quite obvious that auxiliary piston *t* must be made to move at the highest possible speed so as to

prevent as much as possible the injection of fuel before the injection air has acquired the velocity necessary to atomize the fuel. This explains the use of a releasing gear for the auxiliary piston as shown in Fig. 21, although its limitations are well known; even on speeds which are considered moderate on internal-combustion engines this gear is liable to work rather noisily.

36 By depositing the fuel into the open space *s* at the beginning of the compression stroke the same advantages are derived as far as the oil pump is concerned as on the modified Diesel engine. A less desirable feature is the fact that the oil has to lie during the whole compression stroke in space *s* in contact with surfaces and air which attain high temperatures; this facilitates partial evaporation of the fuel, premature ignition if the fuel contains components of low volatility, and especially the formation of deposits which require frequent cleaning of the nozzle. This criticism applies to a certain

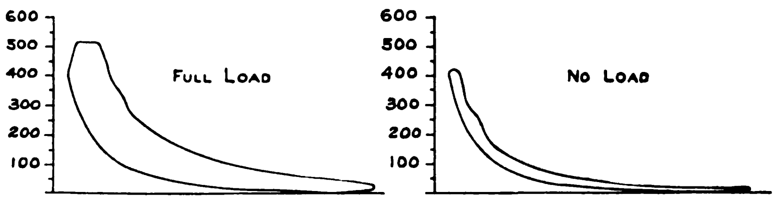


Fig 22 Indicator Cards, Trinkler-Körting Engine

extent also to the modified Diesel engine (Figs. 15 and 16), although it must be remembered that there the injection air, having been well cooled in the 2-stage compressor *a* and in tank *t*, helps to cool space *s* during the injection period, while in the Trinkler engine the temperature of the injection air will help to keep the temperature in *s* high.

37 A matter of considerable difficulty seems to be to pack properly the auxiliary piston stem. Since the auxiliary piston is exposed on both ends to the highest temperatures, while there is practically no means for cooling it nor even its chamber *a*, the temperature of its stem becomes considerably higher than what is considered allowable in stuffing box practice. In addition to this the stuffing box should be able to withstand maximum pressures of about 600 lb. All leakage along the stem should of course be prevented, especially since the air available for fuel injection amounts to only about one-tenth the clearance volume in the engine cylinder. On the other hand if the stuffing box gland is tightened too much, friction easily becomes so excessive as to render inaccurate the movement of piston *t*, which alone times the fuel injection period in this engine.

38 The pressure of the injection air generated in this engine remains practically constant at all loads, since it depends entirely upon the difference of the effective areas of piston *t*, i.e., the diameter of the piston stem. A variation of injection air pressures to suit the varying amounts of fuel, such as is found to be of advantage in the Diesel engine, is therefore out of the question.

39 Fig. 22 shows two indicator cards taken on a Trinkler engine.[1] It will be noticed that the compression pressure is 400 lb. At normal

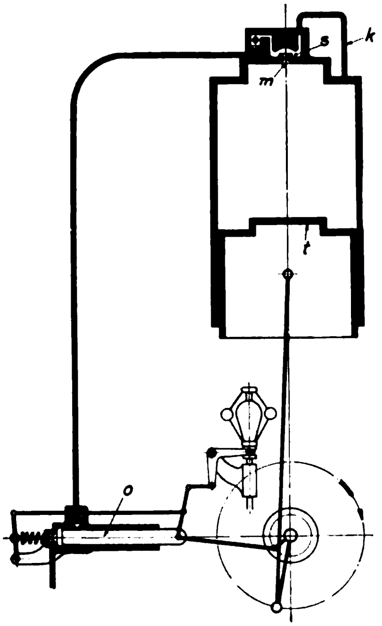


Fig. 23

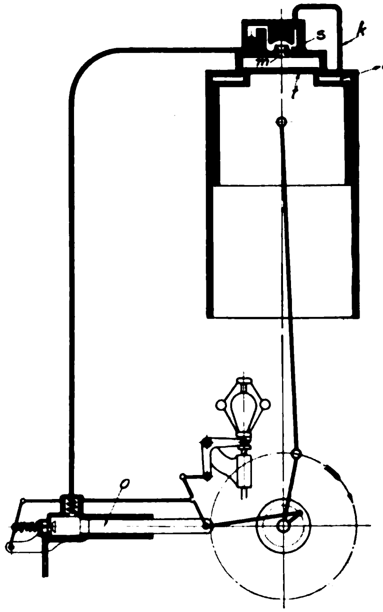


Fig. 24

Haselwander Engine

load combustion sets in, first at approximately constant volume and then at a constant pressure of about 500 lb. On a 12-h.p. motor the consumption of Russian fuel oil was found to be 0.48 lb. per b.h.p. at normal load, and 0.52 lb. per b.h.p. at one-half load.

## HASELWANDER ENGINE

40 Considerably simpler than the Trinkler engine although not working under quite the same principle, is the Haselwander engine,

[1] Zeitschrift des Vereins deutscher Ingenieure, 1907, p. 903.

(Figs. 23 and 24). The auxiliary piston *t* of the former is here replaced by the projection *t* on top of the main piston, while the cylinder top carries a corresponding contraction. As in the previous two examples, fuel is delivered by the oil pump *o* into space *s* at the beginning of the compression stroke (Fig. 23), and remains stored there, in front of the open injection nozzle *m*, until near the end of the stroke.

41 When nearing the upper dead center projection *t* of the main piston enters the contracted cylinder top, thereby forming an annular chamber *a* in the cylinder (Fig. 24), in which the air is being compressed to a higher pressure than the body of air above *t*. The injection air thus obtained in annular chamber *a* now flows through *k* into space *s*, where it displaces the stored fuel and injects it through nozzle *m* into the cylinder. The height of projection *t* is, of course, limited by the desideratum that fuel injection and ignition must not take place until the piston has practically finished its compression

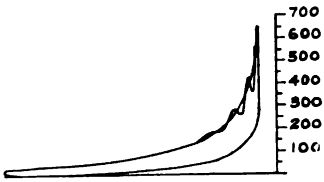


FIG. 25 INDICATOR CARD, HASELWANDER ENGINE

stroke, as otherwise the strain on the crank mechanism due to the sudden increase in pressure becomes excessive, especially after the engine is warmed up and ignition takes place much more quickly.

42 Strictly speaking the Haselwander engine does not therefore belong in the class of constant-pressure engines; fuel being injected during the short interval where projection *t* enters the contracted cylinder top and the end of the stroke, combustion will practically take place at constant volume. Since the air in the cylinder is compressed sufficiently high to ignite the fuel when injected into it, it follows that the maximum pressures in this engine must become rather high. This may be seen from the indicator card, Fig. 25, where the compression pressure is 240 lb., while the maximum explosion pressure amounts to about 650 lb. In his later designs, Haselwander has increased the compression pressure sufficiently to do away with the igniter which in his older models with lower compression was necessary for starting the cold engine. As far as thermal efficiency is concerned, this is a point in favor of the Haselwander engine, for it is well known that,

compression being equal, the constant-volume engine is superior to the constant-pressure engine. Tests made on a 10-h.p. single-cylinder, horizontal, 4-cycle engine of the older type, running at 250 r.p.m., gave the following results:

| | | | | | |
|---|---|---|---|---|---|
| Load in b.h.p. | 11.6 | 10.5 | 9.2 | 7.2 | 5.2 |
| Fuel consumption per b.h.p-hr. in lb. | 0.51 | 0.48 | 0.51 | 0.57 | 0.60 |

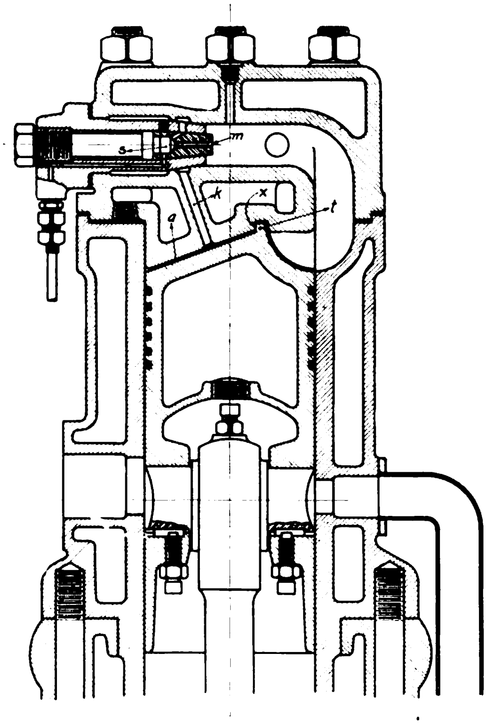


FIG. 26 HASELWANDER TWO-CYCLE ENGINE

The fuel used was Pechelbronner crude oil, specific gravity 0.814, heat value 18,350 b.t.u.

43 In order to prevent any possible ill effects from wear on piston and cylinder walls, the projection *t* fits into the contracted cylinder top with considerable clearance. This, however, produces the rather serious drawback of allowing the hot gases of combustion to flow past projection *t* into the annular space *a*, where the pressure is of course much lower at the time of explosion in the combustion chamber.

As a result projection *t* will gradually be scorched and burnt off, thus increasing the clearance space to an extent such as to cause excessive leakage losses of injection air.

44 This difficulty, it is claimed by the inventor, has been entirely overcome by the design shown in Fig. 26. Here the projection *t* has been very cleverly combined with the baffle plate commonly used on top of the piston of ordinary 2-cycle engines. By laying this baffle *t* in the plane in which the side thrust of the connecting rod manifests itself, the influence of wear on piston and cylinder walls has been eliminated, making it possible to reduce the clearance at *x* to a minimum.

45 The drawbacks incidental to the method of depositing fuel at the beginning of the compression stroke in space *s*, in front of the open injection nozzle *m*, undoubtedly make themselves felt in a larger measure in this engine. Not only is the temperature in space *s* kept high by the hot injection air, but it is liable to be increased very considerably by the burning products of combustion being blown back from the combustion chamber through nozzle *m* and space *s* into *a* where the pressure is at that moment lower.

## DISCUSSION OF ENGINE FEATURES OF DIFFERENT TYPES

46 The very favorable thermal efficiency of the Trinkler and Haselwander engines, their fuel consumption being almost equal to that of the Diesel engine, although obtained with far simpler means than in the latter, seems to point a way for future developments. Especially for units up to about 15 to 20 h.p., which by making proper provisions can be easily started by hand, the elimination of the extra air compressor is of great advantage. But even for larger units, where an air starting outfit is needed and as we have seen generally combined with the injection air compressor by Diesel engine manufacturers, the production of injection air by the principle incorporated in the Trinkler and Haselwander engines seems to offer certain advantages for the reason, as already mentioned in discussing the Diesel engine, that care must be taken to have the injection air well cooled; its temperature is very little higher than the engine-room temperature when it reaches the injection valve cage. The drop of pressure of the injection air during the injection period varies, according to the load, from 250 to 500 lb.; this, of course, is accompanied by a temperature drop. Since the volume of free air expended for every injection is equal to about one-twelfth to one-eleventh the displacement

of the piston, the amount of heat absorbed is therefore considerable. Thus by careful calorimetric measurements the operating temperature of the atomizer was determined to be 180 deg. fahr., which, considering the fact that its lower end reaches directly into the combustion chamber, is quite low. As a result the air and oil spray is cold enough when injected to lower materially the temperature of the air in the combustion chamber, thus endangering the certainty of ignition. This cooling effect manifested itself very strikingly

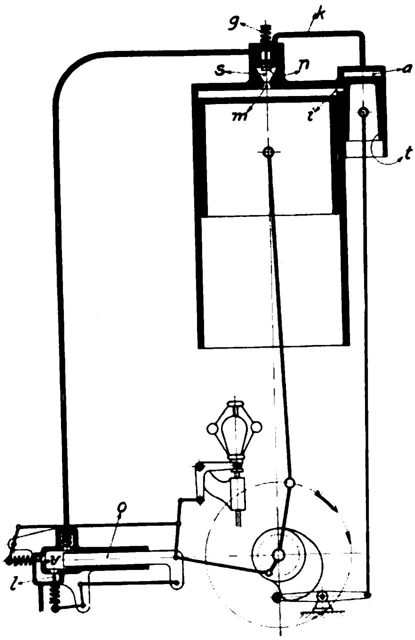

FIG. 27 SETZ OIL ENGINE WITH AUXILIARY INJECTION AIR PISTON

when the first attempts were made to burn heavy coal tar oils in the Diesel engine. Only after the engine had been in operation for some time, and was therefore warmed up, could the injection air pressure be raised sufficiently to get somewhat near complete combustion, but even then frequent "misses" or late explosions occurred. This difficulty could be successfully overcome only by injecting first a very small charge of a lighter oil, immediately followed by the charge of coal tar oil. Practically all the leading Diesel engine manufacturers in Germany have recently adopted this expedient, and quite a number of ingenious constructions have within the last year or two been developed for this purpose. In all these schemes the fundamental idea is to inject, with the very first particles of injection air, oil particles which will immediately be vaporized and ignited, before enough of the cold injection air enters the combustion chamber to cool the air there materially. Even for ordinary fuel oils this is a prime requisite in the design of atomizers and injection nozzles to counteract, without resorting to excessively high compression, the cooling effect of the injection air, especially at light loads.

47 It is evident that this phenomenon will at once be eliminated if the injection air is obtained as illustrated by the Trinkler and Haselwander engines, or by any other process which will produce heated injection air; thus in the Trinkler engine, with the compression pressure considerably lower than in the Diesel engine, self-ignition was successfully obtained from the start. Heated injection air, however, introduces the complications dealt with in discussing the method of depositing fuel in front of the open injection nozzle at the beginning of the compression stroke, or for that matter, in any engine where fuel (or fuel vapors) and air come into contact with each other before the actual injection period. This method of introducing the oil will, therefore, have to be abandoned in favor of a scheme for keeping it entirely separate from all air until the injection period begins.

48 There is another consideration which speaks for such a step. It will be noticed that the injection process of all these various types of engines distinctly resolves itself into the two phases alluded to in Par. 16. As a result the engine makes at least one-half a revolution between the time where the measured quantity of oil is delivered and where its energy is liberated in the engine cylinder; in other words, the development of the indicator diagram is not positively controlled by the governor. In order to accomplish this the oil admission period and the injection period must fall together; regulation will then be similar to that of the steam engine, where the energy carrier is admitted and controlled by the governor at the beginning of the working stroke.

49 Under this condition it should then be possible to use injection air of a higher temperature than is now feasible, and as a result the compression pressure in the cylinder may be materially lowered. It is true that this will slightly lower the thermal efficiency; on the other hand, it must be remembered that, at least for small units, extreme efficiency is not so much the desideratum, especially in this country, as extreme simplicity and reliability of operation, which are, of course, very dependent on the working pressures.

50 It seems probable that the introduction of the fuel into a blast of injection air at the moment fuel injection is to take place, instead of employing the old method where the air blast has to pick up the fuel, would, aside from the advantages just mentioned, make it possible to use injection air of a lower pressure. This induced the author

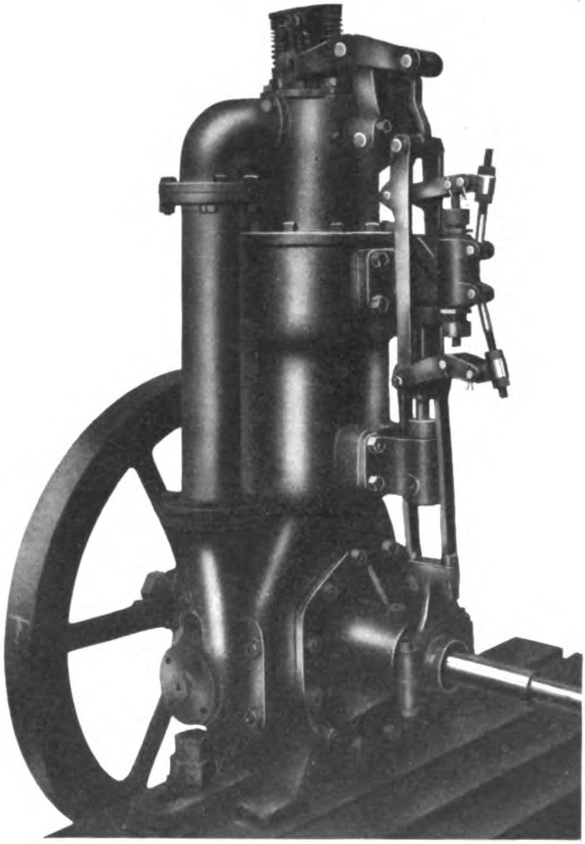

Fig. 28 Setz Engine Standing on Testing Block

some two years ago to build a simple apparatus by means of which either one of these two methods could be used. Since the observations to be made were of a relative nature only, the air and oil spray was merely blown into the atmosphere, although a series of such experiments conducted under actual working pressures, with various shapes of nozzles, would undoubtedly help to throw much light on a subject on which, judging from the many theories prevalent among designers of modern oil engines, little actual knowledge seems to exist. Unfortunately the limited time and means available did not permit the author to pursue his experiments as far as at first contemplated, nor to find a way to determine positively the important although elusive degree of atomization. After several futile attempts this was finally judged merely by two independent observers. Under these conditions few data of actual value could be obtained; the fact, however, has been positively established that in the case of the gradual introduction of the fuel into the injection air blast, considerably less energy was required to atomize it completely than under the old method. This was especially apparent when the oil was introduced in the form of a very fine film, thus affording a large surface over which the "disintegrating" of the oil could take place.

## SETZ ENGINE

51 On the strength of these observations, as well as on the foregoing critical analysis, an experimental engine was subsequently built, the general scheme of which is shown in Fig. 27, representing the injection period. The principle of obtaining injection air is the same as that described in Pars. 32 and 33 (Figs. 19 and 20). The auxiliary piston *t* has just produced injection air of sufficiently high pressure to obtain the desired velocity through passage *k*, from whence it is directed into space *s* in such a way as to cause it to circle around its wall down towards nozzle *m*. At this moment pump *o* begins gradually to force the required quantity of oil into space *s* at a velocity determined by the tension on spring *g* of valve *n*. The oil is therefore forced directly into the stream of injection air, the velocity of which is relatively much higher than that of the oil, and the resulting abrupt acceleration of particle for particle of oil produces a complete spray at a minimum expenditure of energy. An important feature of this arrangement is the fact that valve *n* admits the fuel in the form of a very fine, cone-shaped film, thus distributing it equally over the whole surface of the injection air blast. This introduction of the fuel continues until oil pump valve *v*, which is under control of the governor, opens, when valve *n* will automatically return to its seat and close off the oil passage, or rather the oil contained therein, from all contact with air until the next injection period begins. The functions of valve *n* are thus three-fold:

*a* To determine the velocity with which the oil is to enter space *s*.

*b* To distribute equally the oil introduced over the whole surface of the injection air stream.

*c* To prevent the possibility of air and oil coming in contact with each other except during the injection period.

52 It is evident that in this engine the duration of the injection period is determined by the oil pump *o*; provisions must therefore be made to start the admission of fuel under all loads at the same point, relatively, to the position of the main piston. This is accomplished by means of valve *l*, which always closes at a fixed point of the pump stroke when the delivery of oil begins and continues at a rate determined by the diameter and stroke of the plunger.

53 Fig. 28 gives a view of this engine standing on the testing block. In the near future the writer expects to be in a position to give a detailed description of the constructive elements used, and to produce the data obtained by the experimental investigations now going on. What little has already been obtained promises to prove the practicability of the scheme depicted by Fig. 27, which, in its practical form, represents an engine of surprising simplicity.

54 In conclusion the writer wishes to emphasize the fact that the design and manufacture of oil engines is preëminently a matter of detail work, which might appear insignificant compared with the general problems involved in the design of an engine. However, the history of the development of the Diesel engine shows that it is just these details requiring, if properly conceived, no small amount of engineering skill in their construction, that determine the practicability of the modern oil engine; aside from the purely analytical or speculative problems involved in these details, the selection of proper materials and "fits," which experience and close observation alone can teach, are matters of utmost importance, and only the very best of tools and extremely accurate workmanship, together with broad-minded business principles, will make it possible to reach the high standard necessary to attain success.

55 Looking over the situation of the oil-engine industry in this country, where conditions for extended activity on this field are probably more favorable than elsewhere, it must be admitted that very little has so far been accomplished. Our patent records are not wanting in evidences of interest, nor have manufacturers overlooked this prime mover. Of far greater moment than the patent specification

is a full appreciation of the importance of details, the development of which along sane principles must be the designer's foremost aim. That this may involve a considerable amount of experimental work should form no barrier, for the commercial possibilities are well worth every earnest effort. There is a growing demand in this country for reliable engines that will burn efficiently the heavier hydrocarbons, and it is safe to predict that the near future will see great strides towards the advance of these prime movers.

Since this paper was written an admirable treatise on the same subject by Prof. A. Naegel, appeared in No. 32 of the Zeitschrift des Vereins deutscher Ingenieure, which gives a very complete review of the present status of the modern oil engine in Germany. Particularly the very latest developments of large units, as well as the provisions made for the utilization of the heavy coal tar oils, are fully described and illustrated. Although it will probably be some time before American engineers will be called upon to direct their attention towards such advanced problems, a perusal of said article is herewith recommended, especially since the many excellent illustrations are highly suggestive.

# THE CORE ROOM: ITS EQUIPMENT AND MANAGEMENT

By Henry M. Lane

## ABSTRACT OF PAPER

This paper deals with the subject of foundry cores and core-room practice under the following headings: core-room location and arrangement; core sands and core binders; selection and compounding of core materials; core ovens and core drying; core pasting; core handling and core storage; core machines and core room rigging. Investigation of the subject has been made through the assistance of many firms and individuals interested in securing a more uniform product from the foundry and one of higher quality. A considerable portion of the work was done at the laboratory of the Robson Process Company, Covington, Va., where extensive experiments were made on cores and core sands and binders, including core baking. The object of the paper is to show mechanical engineers that it is possible to meet their requirements in the production of castings, but that to accomplish this result core room practice cannot be based on rule-of-thumb methods; instead it must approach the precision and certainty to be attained by the introduction of laboratory methods.

# THE CORE ROOM: ITS EQUIPMENT AND MANAGEMENT

By Henry M. Lane, Cleveland, O.

Member of the Society

The object of this paper is to bring to the attention of mechanical engineers the fact that by proper study of details in the foundry and core room, it is possible to produce castings better suited for machine construction than those now ordinarily furnished, particularly in regard to their interior or core surfaces.

2 For the present purpose a core may be considered as any body of sand that is formed apart from the mold and then introduced into the mold during its construction or after the mold proper is finished. The function of a core is to form certain faces of the casting, either interior or exterior.

3 Common sense dictates that the faces formed by the core should be as good as those formed by the body of sand comprising the mold proper. This, however, is not generally the case. Until recent times wooden boxes were largely used in making cores and little care was taken. The baked cores were filed to fit one another or the mold. No attempt was made to produce very accurate holes; in fact, the machine shop frequently preferred to cut openings from solid metal rather than to contend with irregular and poorly cored holes full of adhering sand and scale. There is no excuse for practice of this kind and a machine shop has a right to demand as perfect a finish on the interior of a casting as on the exterior.

4 Some of the best core-room practice is found in the specialty shops, such as of manufacturers of radiators, pipe fittings, gas stove burners and automobile engines. In these shops the equipment has been perfected to such an extent that the castings are turned out true to size within limits of a few hundredths or thousandths of an inch, proving that much thought has been spent on the core room and its

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equipment. But even in the finest and most progressive plants we find conditions which cause loss of time and money. In some plants where the engineers have given painstaking care to the design and construction of the core boxes and core driers, and are using various types of core machines, they are using sands of such a nature that the ingredients of the sand destroy a considerable portion of the oil or other material used as a binder, necessitating an excess of binder, which means unnecessary expense. Most core rooms, also, are hampered by some one condition which is considered a fixture, such as an antiquated oven, a cheap local sand or the prejudice of the foreman in favor of some binding material.

5 For the past four or five years the author has given particular attention to the problems of the core room. While many foundry friends have been ready to try experiments at his suggestion, there has been difficulty in harmonizing their results, or in harmonizing results in the same plant when the experiments were carried on a few weeks apart. All have felt the need of improvement in this line, but it required someone to act as a clearing house of ideas, to plan the tests, to see that they were carried out in different plants, and above all, a central laboratory which could unite the results of the different experiments.

6 At this juncture the Robson Process Company tendered the use of its well equipped chemical and physical laboratories at Covington, Va. and at the author's suggestion set aside a large room for the installation of core ovens and testing machines. With this laboratory available the coöperation of other manufacturers and dealers was asked and they have all rendered hearty assistance. In another part of this paper will be found a list of the sands furnished and tested and a list of the binders tested.

## THE LABORATORY AND EQUIPMENT

7 A general description of the laboratory equipment and methods used will prove helpful to a more ready understanding of the paper.

8 *Sand Mixing.* All of the sand samples are thoroughly mixed before the batches of cores are made. There is no regular mixing mill available and so the following method is adopted: The dry sand is measured out, the binder added, and the mass worked over by hand until the binder seems to be thoroughly distributed throughout the sand. In working by hand the sand is rubbed between the hands,

and the desired amount of water for tempering then added. A careful record of the e :act amount of water used should be kept in all cases so that the experiments can be duplicated with exactness. The sand is then taken on an iron plate and mixed by rubbing with an iron pipe as in Fig. 1. It will be noticed that the sand is made into a pile and a little of the end of the pile cut off with the pipe and rubbed forward at each stroke.

9 This method of mixing molding sands was used by Mr. Ronceray in illustrating the advantage of milling sands in a paper which he read before the American Foundrymen's Association at

Fig. 1 Mixing Sand on a Plate with an Iron Pipe

the Philadelphia convention some years ago. By this means, a good molding sand was made from clay and sharp sand.

10 It is a rule at the laboratory to mix each batch of sand by cutting it over five times on the plate in addition to the hand mixing. The batch is then taken to the core bench or core machine, as the case may be. Very large batches have to be worked over a little at a time on the plate.

11 *Core-Making Equipment.* A general view of the core-making bench and a portion of the core department is shown in Fig. 2. The central portion of the table is used for making cores by hand. At the ends of the table are mounted two core machines, the one at the right being a Wadsworth screw-feed machine, and the one at the left an Acme plunger-feed machine.

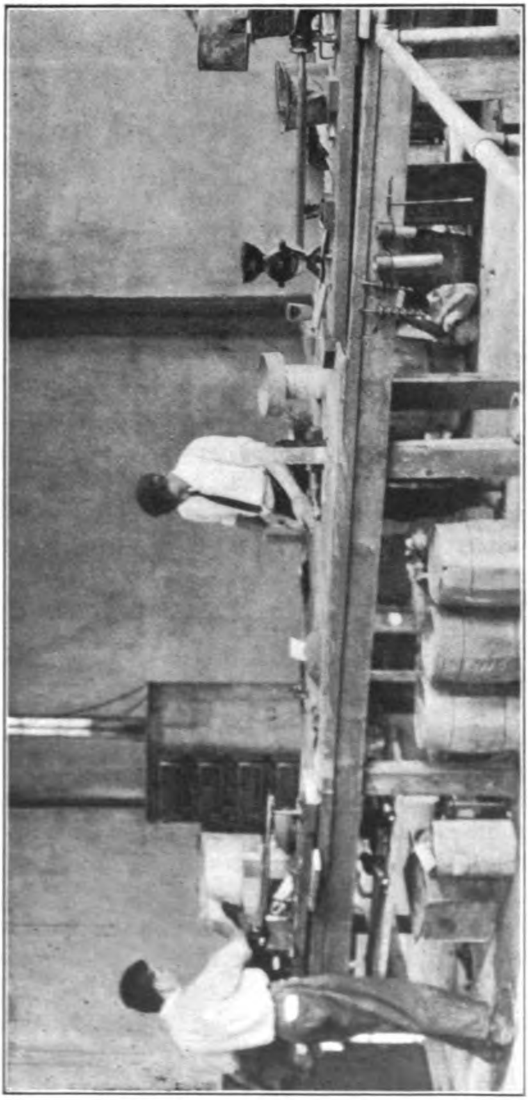

FIG. 2 CORE-MAKING BENCH IN TESTING LABORATORY

12 Both the machines are mounted on heavy planks hinged to the table at one end and arranged to be raised to various elevations

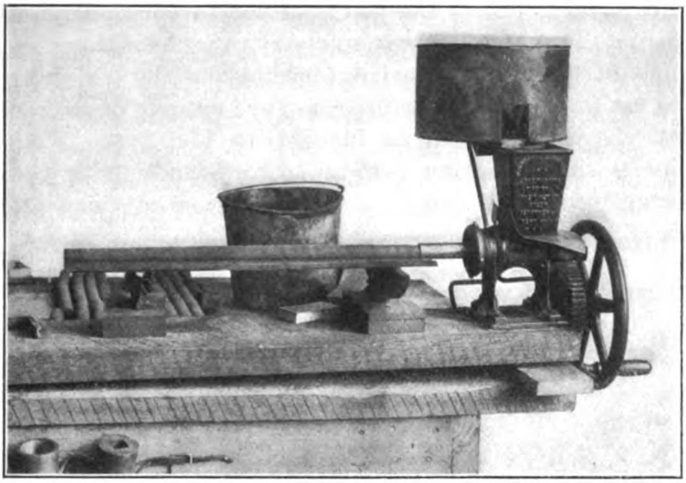

FIG. 3 WADSWORTH SCREW-FEED CORE MACHINE MAKING 1-IN. ROUND CORES

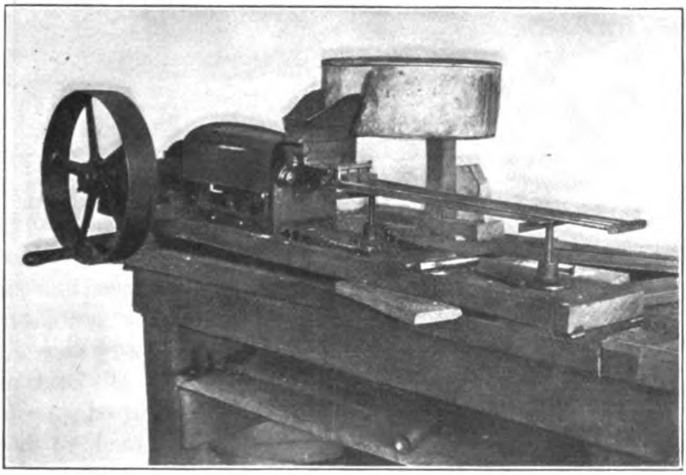

FIG. 4 ACME PLUNGER CORE MACHINE FITTED FOR MAKING 1-IN. SQ. CORES

at the other. This is better shown in Figs. 3 and 4. The device enables the machines to be tested when feeding the cores out on a level surface and also when running the cores down hill at various angles. This method of mounting was first called to the writer's attention while experiments were being carried on with one of the Acme plunger-feed machines in the making of cores of gangway or old core sand at one of the plants of the International Harvester Company. They found it was necessary to feed the cores down at an angle of 10 deg. to prevent buckling, but by so doing were able to use a very cheap mixture composed entirely of old sand and a relatively small amount of binder. In Fig. 3 the Wadsworth machine is shown making 1-in. round cores and forcing them out on corrugated plates. Fig. 4 shows the Acme machine fitted for making three square cores at a time, and also illustrates the rod

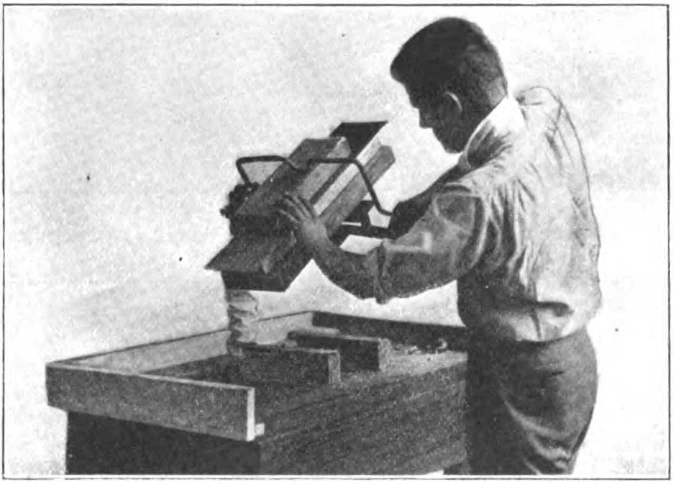

FIG. 5 DETROIT JAR-RAMMING CORE MACHINE IN THE ACT OF ROLLING OVER

guide for keeping the square cores straight after they are run out on the plate; round cores are run out on a corrugated plate. The Wadsworth machine is also fitted with square core dies and in this case the cores are straightened by means of a straight edge. To test the advantage of jar-rammed cores the jar-ramming machine shown in Fig. 5 was installed, which shows it in the act of being rolled over, the core having been formed, the plate placed upon it and clamped. The machine is then raised, rolled over, and let down on to the core plate when the core box is removed and the plate passed to the oven. This machine is used largely for making cores 2 in. square 15 in. long for breaking on supports 12 in. apart. This larger size of core was adopted to test out mixtures used for heavy co es.

13 *Core Testing.* Much thought was given to the proper method of testing cores and several devices have been tried. For testing cores in tension an ordinary concrete testing machine is used with the standard tension pieces made in the ordinary briquette mold shown in Fig. 6. These briquettes are 1 in. thick and 1 in. wide in the narrow part, so that they have an area of 1 sq. in. at the point where they are broken. The cores are pulled in a small testing machine shown in Fig. 7. This machine, however, has a capacity of only 56 lb. and it was found that many of the cores could not be broken with it. It is exceedingly delicate, however, and so is fitted pre-eminently for testing delicate or soft core mixtures such as are used in aluminum foundries for crucible steel work, etc.

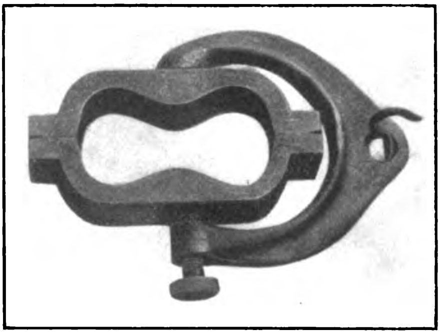

Fig. 6 Box or Mold used for making Test Cores for Tension Test

14 For testing cores which develop greater strength the device shown in Fig. 8 was first constructed. This consists of two supports, the tops of which are formed with a $\frac{1}{4}$-in. radius, giving a $\frac{1}{2}$-in. circle, the bearing points of the supports being exactly 12 in. apart. A 1-in. square core 15 in. long is made in the core box shown at the bottom of Fig. 8, and the core then laid across the top of the supports with the shackle in the center as shown. The shackle is located by means of the piece of wood shown at the right which has a notch cut in it so that when the shackle bears against the end of the stick the $\frac{1}{2}$-in. bolt will be exactly in the center of the core being tested. A pail is hung from the shackle and shot poured into it until the core breaks. The shackle is then dropped into the pail and the pail, shot, and shackle weighed on a spring balance, thus giving the weight which it took to break the core.

15 It was found that considerable care had to be taken to conduct the testing at about the same rate, that is, to pour the shot at about the same speed, so that the weight would come on to the core uniformly and at a given rate. Where the shot was poured very slowly the core would break at a much lower figure than where the shot was poured rapidly.

16 The use of a Fairbanks cement testing machine was secured at the Industrial Testing Laboratory of Cleveland and in Buffàlo at the

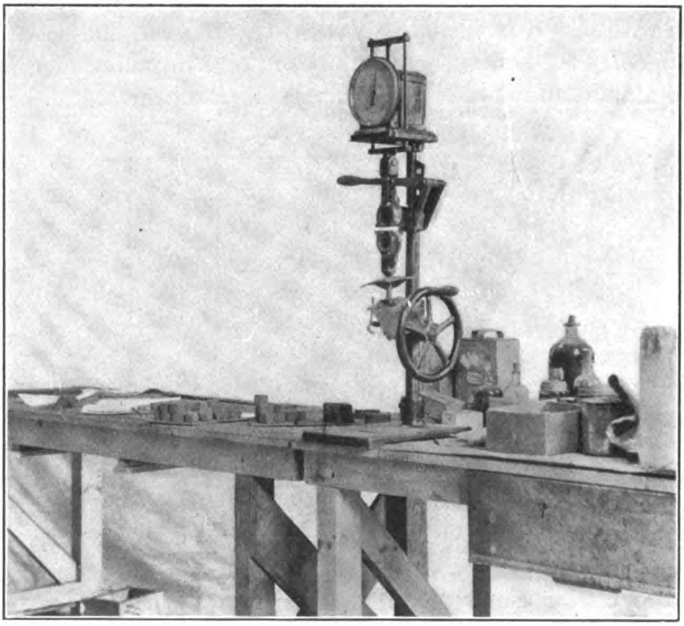

FIG. 7 TENSION-TESTING MACHINE USED IN CORE EXPERIMENTS

Buffalo Testing Laboratory. Series of cores were broken on these machines to test commercial mixtures.

17 The author believes the tension test to be the fairest comparative one for a core as it can be applied more uniformly and easily than a transverse test. Cores are also more delicate when tested in tension, and develop greater strength, and small errors do not make as great a relative difference. Core mixtures were found in use in foundries the tension strengths of which varied from less than 3 lb. per sq. in. to 150 lb. per sq. in., and apparently this wide range in strength is thoroughly justifiable to meet the varying needs of castings.

18 *Baking Equipment.* For baking the cores a small gas-fired oven was first used, which could be kept at a temperature of 400 to 410 deg. without difficulty. When larger cores were made, however, and tests of mixtures compared, it became necessary to bake batches of considerable size at a time, and so a Wadsworth portable core oven was installed as shown in Fig. 9. This illustration also shows the Bristol recording thermometers attached to the core oven. One of the thermometer bulbs was placed under the top shelf and the other at the top of the bottom shelf. Three-quarter-inch iron pipes were carried through the back of the oven so that the thermometer tubes were at about the center of the oven.

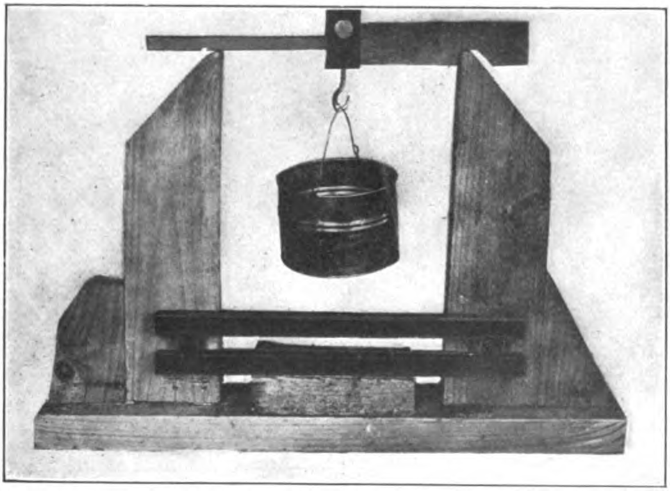

FIG. 8 DEVICE FOR BREAKING 1-IN. SQ. CORES

19 At first there was trouble in getting the required temperature in the oven, but by burning anthracite coal no further difficulty was experienced in maintaining the temperature at 400 to 410 deg. at either thermometer. In ordinary practice, however, when the vent at the top of the oven is wide open there is a difference of from 30 to 40 deg. between the two thermometers in this oven, the lower thermometer being the hottest. This is due to the fact that the cores on the upper shelves absorb heat and that the lower shelf is directly over the firebox. The lower thermometer at times is therefore affected by some directly radiated heat, and this would also affect any cores being dried, as the radiated heat would strike the bottom of the core plate and tend to dry cores from the bottom up.

20 The Bristol thermometers attached to the core oven in Fig. 9 have also been used in testing the temperature in other ovens in different foundry plants.

21 *Fineness Tests.* To determine the relative proportion of the different sized sand grains in a given core sand it was necessary to conduct fineness tests. This was done with a set of Tyler standard sieves, of 20, 60, 80, and 100 mesh. A fineness test was made on all

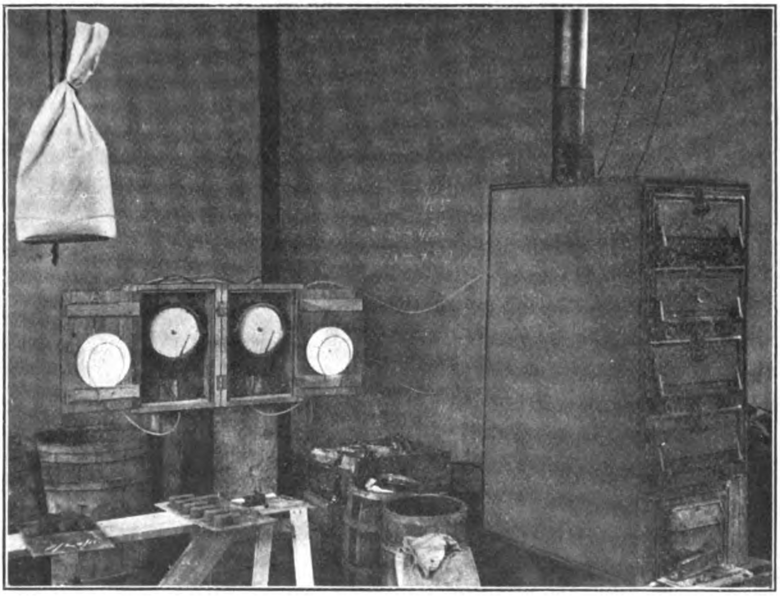

FIG. 9 WADSWORTH PORTABLE CORE OVEN WITH BRISTOL RECORDING THERMOMETERS ATTACHED

sands tested and was found to have an important bearing on the results that could be obtained with any given sand.

22 Other tests than those conducted at the Covington laboratory, as well as microscopic and photographic work and other investigations have been made possible by the assistance of various firms and individuals. Several of these to whom the author is especially indebted, together with firms who supplied apparatus for the laboratory, are mentioned at the end of the paper and to them the author expresses his thanks and appreciation.

## ACTION ON A CORE IN THE MOLD

23 *Introduction of Metal into a Mold.* Before proceeding with a discussion of the subject it may be well to state what happens when a core is surrounded with metal. The action is shown in Fig. 10, which represents a portion of a cylindrical casting in the process of pouring, at a point where the mold is about two-thirds full, the metal rising over the core. Metal enters the gate at the left and flows to the bottom of the opening under the core.

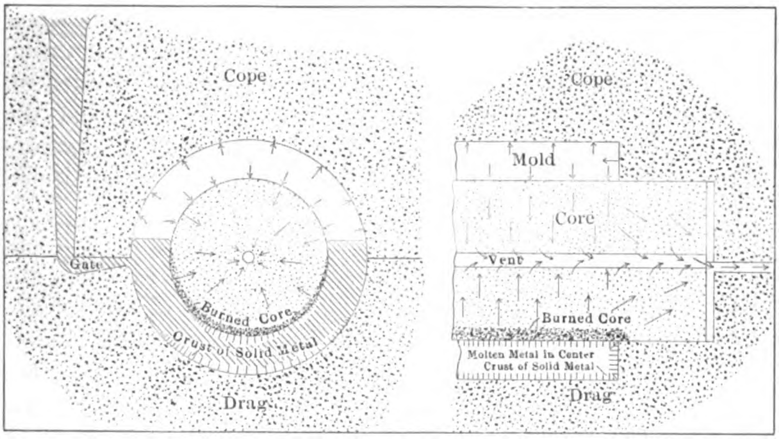


FIG. 10 MANNER IN WHICH A CORE IS ACTED UPON BY THE METAL AS IT ENTERS THE MOLD

24 At first the mold is full of air and the moment molten metal enters, this air becomes highly heated and expanded, thus instantly creating a pressure in the mold. The inflowing metal must not only expel a volume of air equal to the volume of the mold, but the expansion of the air greatly increases its volume. Then also, considerable steam is generated as the metal enters, and this too has to be expelled. This mass of air and steam escapes through both the mold and the core as indicated by the arrows in the upper portion of the illustration. As the metal fills the mold the gas pressure on the inside is relieved, but a new set of conditions appears which demands a porous mold and core.

25 If the metal is poured at the proper temperature, a skin or crust of solid metal forms almost instantly on the sides of the mold and the core (see Fig. 10), which prevents the passage of air or gas from the core or mold into the metal, or from the metal into the sand.

At first, however, the skin is rather flexible, and should gas be generated in either the mold or the core more rapidly than the vent can take care of it, it may blow back and scab the casting.

26 As the metal rises against the bottom of the core its surface is burned. As a core is dry, no steam is generated during this operation, but the hydrocarbon compounds in the core binder are driven off and forced through the core toward the central vent, as indicated by the arrows in Fig. 10.

27 *Gases Formed in Cores.* As long as air is present in the mold or core all forms of carbon are burned or oxidized so that the first gases to be expelled may contain carbon dioxide. As it becomes entirely surrounded with metal the air is quickly exhausted and from that time on only such hydrocarbon gases as can be distilled off by heat are expelled. From this it will readily be seen that the volume of gas generated in the pouring of metal around any core is largely determined by the volume of volatile hydrocarbons which can be distilled from the core binder.

28 The baking temperature to which the core is subjected will have an important bearing upon this subject. Certain binders can be baked at a high temperature so as to expel most of the volatile hydrocarbons and leave little but solid carbon as the core binder, but where this is done, an excess of binding material must be used, as the binding power of the hydrocarbon compounds is largely sacrificed. Then too, if the baking is continued until all of the volatile hydrocarbons are driven out, the volume of the binder is changed to such an extent that cracks or checks will generally be formed in the core. The ideal binder is one which contains sufficient hydrocarbons to give a strong core, but it must not give off during pouring gases which are injurious or even trying to the workmen. This subject will be referred to later under binders.

29 *Refractory Base of a Core.* The refractory material of which the core is composed should be of such a nature that it conducts heat but slowly, so that the rate at which the succeeding layers of hydrocarbon are distilled off is sufficiently slow to enable the vent to take care of the gases as they are formed.

30 There are some cases in which it is advisable to increase the conductivity of a core so as to cause it to act as a chill on the metal and when this is desired the binder problem is still further complicated.

31 After the metal has come in contact with the core and commenced to burn out the hydrocarbon compounds, there should still be some binding properties left to act until the skin of metal next

the core becomes sufficiently strong to resist any tendency of the molten mass of metal to cut the core.

32 Where metal must flow through or over a core it is difficult to prevent cutting or washing by using bonds of a carbonaceous nature only. Clay or a refractory bond of similar nature has to be resorted to; sometimes the surface of the core is protected by silica wash or clay and backing wash. If the binder is present in the core in sufficient quantity to leave a fairly large percentage of fixed or free carbon, the metal is not liable seriously to eat into or burn into the core. In many cases this condition necessitates the use of higher percentages of binder than would be required simply to furnish the necessary strength in the core.

### DIVISIONS OF THE SUBJECT

33 To avoid complication the subject is divided into sections and each treated separately. The sections selected are as follows: core-room location and arrangement; core sands and core binders; selection and compounding of core materials; core ovens and core drying; core pasting, core handling and core storage; core machines and core-room rigging.

### CORE ROOM LOCATION AND ARRANGEMENT

34 The location and area of the core room are of more importance in the production of castings than most foundrymen realize, since the modern tendency in certain classes of work is to throw an ever increasing responsibility on it, and some complicated castings such as air-cooled automobile cylinders are made in molds that are composed entirely of cores. The definition of a core as already given was carefully chosen with this phase of the subject in mind. The location depends upon several factors: the size of the individual cores, the number of pounds of cores used per molder per day, the strength of the individual cores and the method of handling the cores from the core room to the molders.

35 *Core-Room Area.* A series of observations of the proper area of the core room, extending over about fifteen years, has shown that the core room varies in area from 10 to over 50 per cent of the molding floor. This includes the space occupied by the ovens and core storage but not the core sand storage. In very heavy grey iron work, such as large Corliss engine cylinders, heavy machine-tool castings, large forging machines, etc., the space devoted to core making may

be equal to at least 60 per cent of the active molding floor space, but in this kind of heavy work about half is usually inactive, because heavy castings must be left in the sand several days to cool, hence the area as compared with the molding floor is about 30 per cent of the total.

36 The core-room proportion in the case of side floorwork in a grey iron foundry is generally much less because many of the molds require no cores and as a rule the floors are cleaned each day, so that the entire molding area is continually active and varies from 10 to 15 per cent of the area of the side floor.

37 In the case of loam work frequently only a very small number of cores are used which are not made on the loam floors, but of course when loam work is being carried on drying ovens are necessary and the entire proposition partakes of the nature of a core problem.

38 For light grey iron or malleable work the area of the core room depends entirely upon the character of the product. The fact that in the core storage the cores are kept on shelves one above another and the small ones are dried on cars having several shelves, tends to reduce very greatly the total area required. The cores for a given mold usually take up much less space than the mold itself and they are not accompanied by flasks. For grey iron work on automobile castings, including cylinders, the core department will have an area varying from 40 to 60 per cent of that of the foundry. In aluminum work for automobiles it is about 40 per cent, in brass jobbing shops 10 to 15 per cent, for brass fittings 20 to 25 per cent, while for iron fittings it takes from 20 to 45 per cent.

39 The core-storage space to be provided is also important. In the case of jobbing work comparatively little room is necessary, since the cores when completed are usually sent to the molders' floors. Where a line of standard work is being manufactured, provision should be made for carrying at least one-half of a day's supply of cores, and where night ovens are used for baking an entire day's supply.

40 *Handling Warm Cores.* In order to avoid rehandling whenever possible, cores should be sent from the core-oven trucks to the molders without placing them on storage shelves as this involves an extra handling. This question, however, brings up the advisability of handling cores hot. With many binders under such conditions more binder will have to be used than if they are allowed to cool.

41 One large foundry in this country using a great many oil-sand cores changes its oil-sand mixtures at about 3 p.m. by decreasing the amount of binder 15 per cent. The reason for this is that

the cores made subsequently will be run out of the core oven on to the plates and left to cool over night before they are handled, so that the full strength of the binder will be developed. During the day they are ordinarily taken from the plates hot and carried to the molders. In many cases a saving of 15 per cent of binder would more than pay for the rehandling of the cores and the placing of a core storage between the core department and the foundry.

42 *Transportation of Cores.* Where the number of cores used per molder is so great that the weight of the cores delivered to each approximates the number of pounds of castings turned out by him per day, the problem of transporting the cores becomes serious and must be taken into consideration in locating the core room. In this there must also be considered the element of breakage. Every core that is broken represents not only the loss of the sand and binder but also of the time expended in making it, the fuel for baking, and other labor in the way of transportation. Every possible precaution should therefore be taken to reduce this item.

43 If the cores are large and delicate, such as those required in aluminum or light crucible steel castings, they must give way readily before the shrinking metal and should be handled as little as possible, hence the core room should be near the molders.

44 If the cores are standard and sufficiently hard so that they are handled in boxes or in piles on boards as in some fitting shops, they will stand transportation a long way, and here it will pay to centralize the core department, equip it with labor-saving machinery, and reduce the cost to a minimum. The cores can then be distributed to the various departments without fear of serious loss through breakage. In the case of heavy work where they have to be handled with a crane, if there are several separate bays or departments it is frequently more economical to provide each section of the foundry with its own core room and to arrange it so that the main traveling cranes handle them from the core oven trucks to the molds at one operation.

45 For transporting cores about the foundry we have platforms commonly called boats, which are rectangular in shape, made of plank, with heavy battens on the back, supported at four corners by slings from the crane hook. The cores to be moved are piled on the platform and shifted to the parts of the foundry where they are to be used. For handling and transporting medium or fairly heavy cores a device of this kind saves rehandling and guards against breakage. It also does away with confusion in the gangway due in many plants to carrying of cores to the various floors. In some foundries the cores

are carried to molders on a trolley system in boxes or specially prepared cages supported by spiral springs. In other cases spring trucks running on the gangway floor or spring-supported platform cars running on industrial railways are used for the purpose.

46 In the case of medium heavy work, cores weighing 100 to 200 lb., the core-oven truck may be arranged so that each shelf can be lifted off by the traveling crane and used as a boat to carry the cores to the floor; in other cases the entire core car may be picked up by the cranes and delivered to the molders floor.

47 *Handling Core Sand.* As the core sand is bulky the problem of handling it assumes considerable prominence in most plants, and this necessitates the location of the core room in such a position that the sand can be delivered from the railroad cars into the storage bins with the least amount of handling. For the most effective work the sand should be as dry as possible, hence it should be put into storage at a dry season of the year, and at least a nine months' supply provided for. Buying the sand at this time of the year also reduces freight costs by eliminating water contained in the sand during rainy periods.

48 To sum up the matter, the location of the core room should be such as to minimize the handling of the cores, being nearer the molders in the case of very heavy work handled by the main cranes, or in cases where delicate cores are used, as in aluminum or light crucible steel work, and being centralized when they are strong enough to stand transportation.

49 The area will depend upon the product, and a fair estimate may be obtained by taking the number of cores required per man per day, and estimating the number of cores the coremaker will make per day, thus arriving at the number of benches required. The space occupied by coremakers' benches is as a rule about 35 to 40 per cent of the total core-room space, the balance being taken up with ovens and storage racks for green and dry cores.

## CORE SANDS AND CORE BINDERS

50 The term core sand covers a wide variety of materials adapted to different classes of core work and the conditions to be met in the core room necessitate the use of a number of grades of sand in most core rooms. In all core sands the principal heat resisting element is silica, the silica grains also forming what may be termed the back bone of the core. Ordinary molding sand rarely contains over 80 per cent silica, the balance being made up of alumina, oxide of iron, and other

impurities. In a molding sand a certain percentage of clay is necessary to form the bond. They may be divided into bondless or sharp sands for oil-sand mixtures or cores which require a great deal of vent; and the bonded sands and gravels. The sharp sands contain from 97 to 98.5 per cent silica, while the bonded sands contain from 97 to less than 90 per cent.

51 *Proper Condition of Bond in a Core.* Since a core must be sufficiently porous to vent freely, the sand composing it must be of such a nature that there will be a considerable percentage of voids or open spaces through which the vent may escape. In any core the individual grains of sands must be bound one to another with some material, collected, if possible, at the contact points thus leaving the spaces between free for vent passages. Anything that tends to roughen the surface of the grains of sand in the passages tends to retard the vent.

52 *Form of Sand Grains.* In concrete and masonry work sharp sand is desirable on account of the fact that it affords a better grip for the cement or lime in the mortar. For core work rounded grains of sand are the best because they give a maximum of vent passages and larger areas at the contact points for the bonding material to act. The strongest cores that the writer has seen used in practice were made from oil-sand mixtures with thoroughly rounded grains of sand, the individual grains being of approximately uniform size.

53 In concrete work the object is to fill all the voids between the particles of the material with finer stock, so that the final product will be a uniform solid mass. In making cores the requirement is radically different, as it is desirable to have the greatest possible number of fine voids; only they should be so fine that the metal will not tend to follow or flow into them. This necessitates the use of different sized grains in the core sand for different metals.

54 Some of the brass and bronze mixtures are particularly searching and will force their way into cores where iron would lie smoothly on the surface. There are two reasons for this, one that the melting temperature of the brass and bronze alloys is lower than that of the iron mixtures and hence they remain fluid for a longer time in contact with a core; and the other that the iron alloys seem to be more viscous when fluid and will not flow into as sharp corners as the brass and bronze alloys.

55 Aluminum in some respects behaves like iron in this particular. Sand mixtures which would be perfectly satisfactory for iron or steel or for aluminum may be wholly unsuited for brass or bronze. A brass

or bronze containing considerable phosphorus is particularly searching in its action, also an iron containing considerable phosphorus is more fluid than other mixtures and has more of a tendency to cut into a core. From this it will be seen that the selection of a particular grade of core sand must depend to a considerable extent on the metal to be cast.

56 *Early Day Core Practice.* In the earliest foundry practice cores were made from mixtures containing no artificial bonds. A sand was chosen containing enough clay to hold the grains together when dry, and if this showed a tendency to stick to the casting some sawdust or other carbonaceous material was added to the mixture, causing it to fall to pieces next to the casting more easily and clean out better. It is probable that the first artificial core binders used were rye and white flour and pea meal, and there are also records of the use of sour beer. In those days all molds were thoroughly dried before the metal was poured into them, so that it partook of the nature of a core. To harden and strengthen the face of the mold or core, it was frequently sprinkled with sour beer or molasses water and then dried. When the metal came in contact with the surface, it burned out the carbon of the binding material used at the surface and made it easy to clean out the core.

57 *American and Foreign Practice.* In America demand for a big output and cheap castings has developed a number of lines of foundry practice to an extent not found in any other country. The green sand mold is more universally used here and the variety of core binders exceeds that employed in any other country. At present probably the most common core binder used abroad is what is known as core gum, which is really dextrine, one of the products of the starch industry. Pea meal is also used abroad to a considerable extent and rye flour and linseed oil in certain foreign countries. America has been the first to introduce an extensive line of specially prepared binders.

58 *Kinds of Binders.* There are two classes of binders as regards their action on the sand. These are the true pastes, which do not flow to the contact points of the sand, and the binders that flow to the contact points as the drying and baking take place. All binders which act as a paste are not affected by clay in the sand. This is also true of resin and pitch. Binders that partake of the nature of an oil are injured and in some cases ruined by the presence of clay in the sand. The advantages of sharp sands and sands of uniform sized grains were never fully appreciated until the complicated problems of the water-cooled automobile engine cylinders required solution. At

first intricate systems of mechanically formed vents were used, but later it was discovered that by using clear silica sands and oil as a binder that the vent would find ample passage in the spaces between the rounded grains.

59 *Fitting the Binder to the Sand.* In selecting the core sand for any given location the problem to be solved is the finding of the cheapest finished core. Cores for a given class of work must have a given strength per square inch and must disintegrate when the metal is poured about them, so as to permit ample opportunity for the metal to shrink. Generally in producing a core of this kind a number of courses are open. A local bonded sand may be used with resin, flour, dextrine, black compound, glutrin, or molasses. As a rule black compound or pitch cores are more suited for heavy work than for light. For small work greater strength per square inch of core is generally required than for large work, and for great strength associated with free venting there must be a binder that will hold a sharp sand and at the same time permit the free circulation of the escaping gases. Flour or dextrine tend to a large extent to stop the vent, as do also the black compounds, which contain dextrine as a green binder. This calls for the use of an oil mixture, an oil and glutrin mixture, a glutrin and clay wash mixture, or molasses.

60 A number of different water soluble by-products from commercial processes have been or are used to some extent as core binders. In some places in the vicinity of rum distilleries a product known as distillery returns, distillery slop, or sour beer, is used; in other locations sour beer from breweries, but both are employed only in limited localities as they are weak adhesives and hence not good binders.

61 The principal objection to the use of molasses in the core room is the fact that this binder is not uniform in its adhesive properties. First fermentation has to be dealt with. To test its effect the writer measured out a quantity of molasses, diluted it with twice its volume of water, and let it stand in a crock. The specific gravity of the solution was taken every few days and batches of cores made from it were tested for strength. These fell off rapidly in strength as the fermentation proceeded, losing more than half, and at the sametime the specific gravity constantly decreased. Foundrymen have been known to purchase fermented molasses thinking that they were getting a cheap bond. In a case of this kind, however, one has no knowledge of the actual bonding power.

62 At the time the fermentation experiment was made on molasses a sample of glutrin was measured out, diluted to the same proportions,

and allowed to stand in a crock next to the molasses. Cores were made from it each time that cores were made from molasses. Those from glutrin gradually increased in strength with the age of the mixture, due to its slow concentration by evaporation. The molasses mixture was of course evaporated just as fast, but the composition was changing so rapidly from fermentation that the effect of evaporation did not show.

63 Another objection to molasses is the fact that no matter how honest the dealer or how free from fermentation the stock may be at the time it is used, its bonding power must depend upon the source from which it was derived. In making cane sugar the plant is topped in the field and the tops are thrown away because the juices in the upper part of the stalk have not been converted into sugar. If the stalks are topped too high, a large proportion of the juice carrying no sugar enters the fluid and remains in the molasses after the sugar has been crystallized.

64 As the molasses is the residuum of the sugar process it must contain all its impurities, and these vary with the source of material from which the sugar was made, the method of work, the way in which the cane was topped, and many other factors.

65 The only other water soluble bond extensively used in the foundry is glutrin, a by-product of paper manufacture by the sulphite process. The sap stored in the cells of the spruce wood used in paper making is extracted by boiling with the sulphite solution and when treated to remove certain undesirable elements, and concentrated, it becomes the binder known as glutrin. While its composition is complex, consisting of tannins, wood sugars and resin in soluble form, it is a product uniform in composition and hence in binding power, and it will not ferment.

66 *Use of the Microscope.* It has been found that a microscopic examination of the fracture of a core would tell much as to its venting properties and the efficiency of the bond, but thus far, however, it has proved impossible to produce a microphotograph that would show all that the human eye could see in examination of a core, because the focal depth of the micrographic lenses is exceedingly shallow, so that when examining cores at magnifications of 60 or more diameters it is necessary to rack the objective back and forth and examine the top, the middle and the bottom of a grain of sand, thus giving a clear mental picture of the bonding conditions. A microphotograph taken in the ordinary way does not show this as it has not sufficient depth of focus.

67 *Action of Oil in Binding Sands.* Oil of a proper grade is undoubtedly the strongest and, weight for weight, the most efficient binder known when dealing with clean silica grains. In the paint trade linseed oil is considered the best drying oil, and it is also the best core oil. The action of linseed oil in bonding a core is as follows: The material must be so thoroughly mixed with the sand that every grain is uniformly covered with oil or an emulsion of oil and water. When the heat of the core oven acts on the sand the moisture is evaporated and driven off. As the moisture passes through the core toward the outside the oil remains behind on account of its relatively high viscosity and first uniformly coats each grain of sand. By capillary attraction excess of oil tends to accumulate at the contact points of the sand grains and finally dries down here and forms an area of bond somewhat larger than the contact points. The heavier the oil, that is the more body it contains, the more will the space about the contact points be filleted and the bonding area increased. Most of the other drying oils contain less body than linseed, and hence do not give so firm a bonding mass at the contact points as is the case with linseed. All oil-sand mixtures must be tempered with water.

68 *Action of Paste in Binding sand.* The radical difference between the bonding of sharp sand with an oil and with flour or dextrine is that the latter forms small masses or grains of paste which dry on the face of the sand grains. These do not flow over it to the contact points, but dry in the place where they were left by the mixing machine. For this reason only those situated at the contact points become efficient as a binder. A microscopic examination of a flour or dextrine-bound core shows that certainly not less than 60 per cent of the material is inactive as a binder and is located in such a way that it tends to block the vent passages by giving the grains of sand a rough instead of the smooth varnished surface given to the grains by oil.

69 *Action of Resin and Pitch in Binding Sand.* Resin and pitch both bond sand by melting and flowing over or between the grains, collecting to a certain extent at their contact points as the core cools, but they are not so efficient as is oil. Resin and pitch do not enter into combination with clay, but their binding power is added to whatever power the clay may have. When such a core comes in contact with the molten metal in the mold, the carbon material of the resin or pitch is burned out, which disintegrates the core, thus making it possible to clean it from the casting; while if clay or natural bond alone were depended upon the bond would be hardened instead of softened, and it would be impossible to clean it rom the casting.

70 *Action of Molasses in Binding Sand.* The action of molasses in a core depends upon the rate of drying and the temperature. Under ordinary core-oven conditions where cores are put into a hot oven, the water is quickly expelled and the molasses brought to the boiling temperature. When it reaches the consistency of ordinary molasses candy, it boils up in a similar manner and then hardens in thin plates connecting the sand grains with a more or less intricate system, and with the carbon exposed in exceedingly thin surfaces, though of course, some of it dries at the contact points. If the core is taken from the oven at the critical point just as these plates are in their strongest condition, it will be found to be strong and serviceable; but if taken out too soon, it will not have developed sufficient strength to give a strong core, and if left in the core oven a little too long the carbon will have become rapidly oxidized and the strength of the core will fall off. For these reasons a molasses core is exceedingly sensitive and with ordinary existing core-oven conditions it is practically impossible to produce uniform results.

71 *Action of Glutrin in Binding Core Sand.* The compounds contained in glutrin are of such a nature that they do not enter into and combine with clay as does oil, but they do form with it an exceedingly efficient emulsion and tend to carry it from the faces of the sand to the contact points. In drying, glutrin behaves more like oil in that it tends to flow to the contact points.

72 In sharp sand without any clay bond the fact that glutrin lacks the viscosity of linseed oil, gives it a tendency to follow the moisture to the surface of the core. In a mixture of clear sharp sand a glutrin core will tend to have a very hard skin and a soft interior. This is well illustrated in the microphotograph shown in Fig. 11, which is a core made with clear Rockaway Beach sand and glutrin in the ratio of 1 part of glutrin to 50 parts of sand. The glutrin tended to sweat to the surface of the core, giving a hard surface as shown by the darker material along its face. The main body of the sand was bound fairly well but this dense layer on the outer surface interferes with the escape of the steam from the interior toward the latter part of the drying operations and may result in an imperfectly dried core. Attention is called, however, to the exceedingly open character of the core itself.

73 This sweating tendency is entirely overcome by introducing from ½ to 1 per cent of clay into the mixture, the clay and the glutrin together forming a compound which is sufficiently viscous so that it draws to the contact points rather than following the moisture to

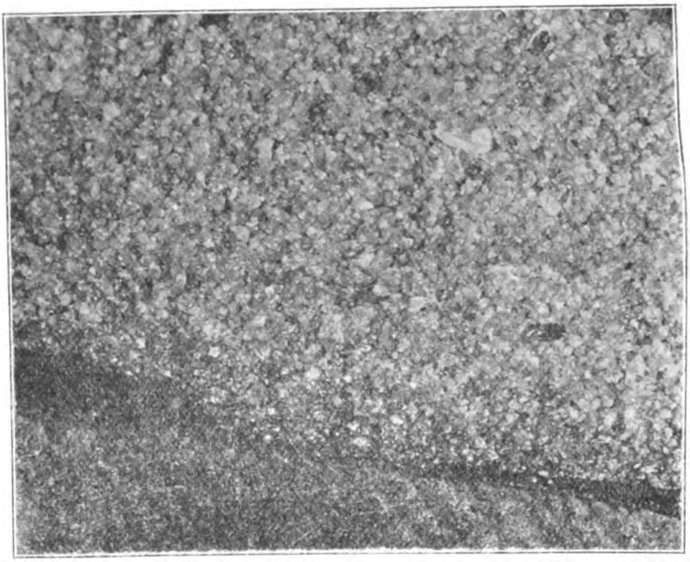

FIG. 11 ROCKAWAY BEACH CORE COMPOUND WITH GLUTRIN SHOWING SWEATING OF THE BINDER TO THE SURFACE OF THE CORE

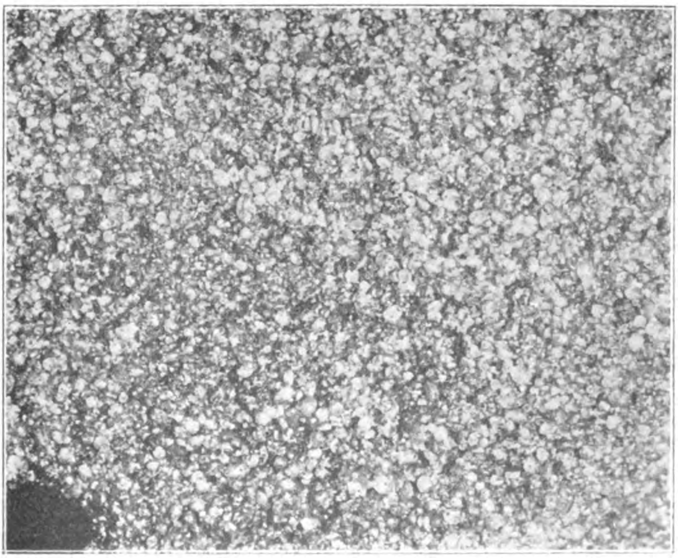

FIG. 12 OIL-SAND CORE FOR GAS STOVE BURNER

the surface of the core, making it strong and at the same time one which does not have the vent passages stopped. Glutrin can also be used in connection with oil in clear sand mixtures, as the oil prevents it from sweating to the surface of the core and the combination blends perfectly to form an efficient bond at the contact points.

74 Fig. 12 shows a microphotograph of a section of an oil-sand core intended for gas stove fittings, which was made from a mixture of 22 parts silica sand, three parts bank sand, and a commercial or blended oil at the ratio of 1 part of oil to 25 parts of sand. The exceedingly open chracter of the core is clearly shown, but its strength is about 75 lb. per sq. in. in tension. A core of this kind shows absolutely no tendency for the binder to sweat to the surface and as the sand from which the core is made is fairly uniform in size there is a maximum of voids or open spaces for vent passages.

75 Fig. 13 is a pitch bound core intended for heavy work. The mixture is known as a loam mixture, containing Zanesville loam as a base, the proportion of the ingredients being as follows: 12 parts new Zanesville loam, 14 parts old core sand, 4 parts pine sawdust, and 1 part ground pitch. This firm grinds its own pitch and mixes no dextrine with it, grinding it fairly coarse, so that occasionally fairly large spots show in the fracture of the core. It is mixed in a Standard Sand and Machine Company's batch mixer with about 11 per cent of water by weight. When rammed into the molds it has some green binding power due to the excessive amount of clay in the Zanesville loam. The cores are dried out in the neighborhood of 350 to 400 deg. in large ovens which are fired every night. The shrinkage of the sawdust and the driving out of the large amount of water gives the core considerable vent. The pitch and loam form the binders and as the pitch is rather coarsely ground some of it becomes active when the old core sand is introduced into the mixture. Probably at least 50 per cent of the pitch in the old core sand still possesses binding power. A core mixture of this kind would only show a strength of 10 or 12 lb. per sq. in. and in some cases not over 6 or 7 lb., so that the cores have to be strengthened by the use of rods and the face has to be protected by a blacking mixture.

76 Another core of very close composition is illustrated in Fig. 14, a section of a machine-made core intended for use in a brass foundry. The mixture consists of 32 parts of Del Ray bank sand, 32 parts of Lake sand from near Buffalo, 8 parts flour, and 1 part of oil, and is tempered with about 7 per cent of water by weight. The shrinkage of the flour paste together with the expelling of the water

FIG. 13 PITCH-BOUND CORE WITH BONDED MOLDING SAND BASE INTENDED FOR HEAVY WORK

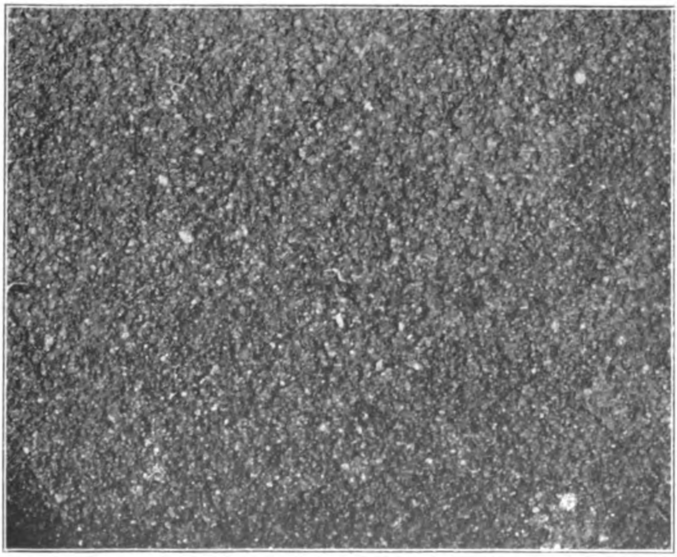

FIG. 14 MACHINE-MADE CORE FOR BRASS-FOUNDRY WORK

gives the core more vent than it appears to have. The relatively fine Del Ray bank sand serves to close up the spaces and prevent the brass from entering the core. The combined flour and oil bond burns out at a relatively low temperature, allowing the core to crush before the metal and also facilitating the cleaning of the core.

77 For cast-iron radiators the cores must have a great strength and at the same time vent with remarkable freedom. Many radiator companies are using relatively coarse sands in their mixtures. A microphotograph of a section of radiator core made from a coarse New England sand is shown in Fig. 15. This sand, however, carries a good deal of fine material with it which with the oil forms a network between the larger grains and to some extent stops the passages. The percentage of small material, however, is not sufficient to reduce the vent near the danger point. The firm using this grade of sand has installed a mill for washing the old sand and permitting its re-use in the cores.

78 Fig. 16 shows a microphotograph of a section of a core made entirely from the washed burned sand. The finer material is all washed away but each grain of sand is covered with a layer of oil so that when a core mixture is made the grains are primed, as it were. The fact that the grains already have an oil covering and that there is no fine material in the washed sand to absorb oil, has made it possible to produce stronger radiator cores from washed sand with the same percentage of oil that is used in the new sand cores.

79 The core shown in Fig. 17 is made from gangway sand with glutrin as a binder. The glutrin sweated to the surface of the core, forming a hard skin, indicated by the darker area near the outer edge of the core. The interior of this core was so soft that it would readily crush before the metal. These cores were used to form finished faces for bearings in agricultural machinery, the cores being knocked out of the castings, the hole cleaned and the parts assembled without machining. The fact that the glutrin sweat to the surface made a hard close surface which acted almost as a chill and produced a remarkably smooth casting. The rotten interior gave free vent. At another plant in the immediate vicinity some cores were made from the same sand with linseed oil as a binder but the binding ratio had to be very low, that is, a large amount of oil used to bind a given amount of sand. This was also true in the case of the glutrin.

80 *Reactions between the Sand and the Binder.* A quantity of gangway sand was shipped to the laboratory at Covington and together with other sands that had been giving trouble in different parts

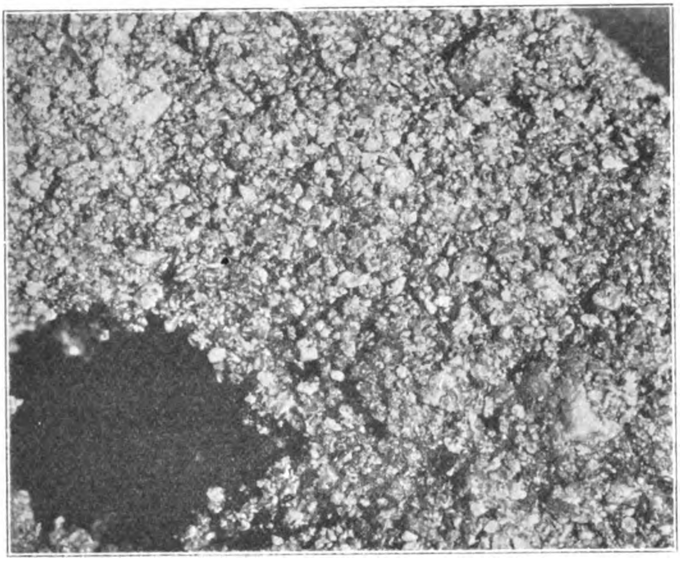

FIG. 15 RADIATOR CORE MADE FROM NEW BANK SAND

Showing how fine material holds the oil on the surface of the pebbles away from the contact points of the grains.

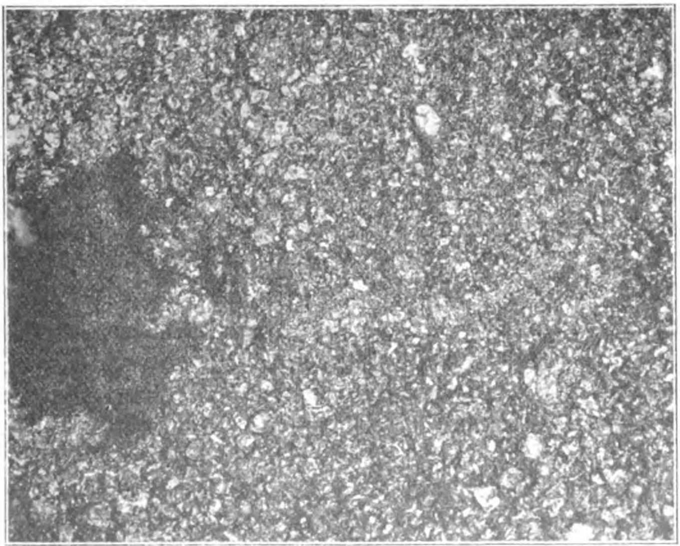

FIG. 16 RADIATOR CORE MADE FROM BURNED SAND

This sand was black and covered with charred oil (differing from that in Fig. 15) which makes the core appear to have less vent than that shown in Fig. 15.

of the country a series of experiments was started. From the behavior of these sands it was evident that some action was going on which destroyed the binder, other than the mere absorption of it, which takes place when the oil unites with clay and is rendered inoperative.

81 To test the correctness of this theory a batch of gangway sand and a batch of Michigan City sand were measured and placed in two bottles. As glutrin was wholly water soluble it was chosen as a binder. Three equal batches of glutrin were diluted with a given amount of water. One was placed on the Michigan City sand,

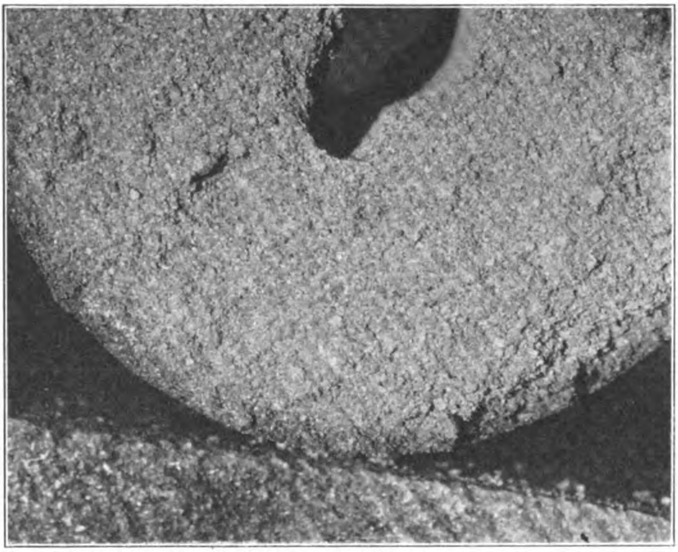

FIG. 17 CORE MADE FROM GANGWAY SAND WITH GLUTRIN AS A BINDER, SHOWING THE SWEATING OF THE BINDER TO THE SURFACE

another on the gangway sand, and the third held in reserve. After leaving the binder several hours each sand was leached with water until all the binder was washed out. The two batches of glutrin were then concentrated by boiling to expel the excess water. They were brought to the same volume as the batch held in reserve, and three sets of cores made, one from the glutrin which had been on the gangway sand, one from that which had been on the Michigan City sand, and the third from that which had not been on any sand.

82 There was very little difference in the strength of the cores from the second and third batch, but the cores made from the glutrin

which had been on the gangway sand were not one-fourth as strong as the others, showing that the sand had destroyed the bonding power of the glutrin. A few tests soon showed that it was alkaline and the addition of a small amount of acid destroyed the alkalies.

83 Following up this clue, two batches of cores were made from gangway sand, in one case the sand having been treated with acid to neutralize the alkalies and in the other it was left in its natural condition. The acidulated sand produced cores more than four times as strong as the other batch. Continuing the investigation, experiments were made by treating with acids a number of sands giving poor results with different binders and it was found that neutralizing the alkalies with acids increased the strength of the cores greatly. This is true both in the case of glutrin and oil.

84 Since these experiments the subject has been taken up with a number of foundrymen and several exceedingly interesting cases brought to light. In one instance a foundry was purchasing city water of a very pure grade at a relatively high cost. To avoid this expense an artesian well was sunk. Immediately trouble appeared. The cores cut and washed and it took some time to trace the difficulty. Finally the city water was again used and the trouble disappeared. The water from this well was clear, sparkling and tasted good, but it was high in lithia salts and evidently contained ingredients which combined with the binders to destroy them.

85 Alkalies tend to saponify oil, thus destroying its bonding power. They also seem to act on resin, glutrin, and some other binders. In the case of the large manufacturing concerns using a great many oil-sand cores it would probably pay to purify the water for the core room just as the feed water is purified for the boilers.

86 *Determining the Active Bond in Clay.* Formerly when a chemist received a sample of sand for analysis he determined the alumina, figured it as kaolin, and called it "bond." From various results with bonded sands it became evident that this free and easy method was not sufficient, and some way of differentiating between a fat and a lean clay had to be found. Several firms and different departments of the Government were making use of a test for colloidal matter. Chemists have long recognized a series of amorphous bodies known as colloids, or as one noted chemist writing in popular vein recently says, what in the laboratory are called "messes."

87 When matter is in one of the colloidal forms it has intimately associated with it a large amount of water, forming what is termed a "gel." The soluble colloids are called "sols." Certain clays are

far more plastic and have greater binding powers than others, and it has always been known that heat destroyed this binding power. It is now certain that in these clays at least a portion of the alumina is in the colloidal form. For decades the best clays have been found in the secondary deposits where they had been associated with organic matter, but these properties have been found even in the old fire-clays of the coal measures. When first exposed these are in a compact form much of the water having been expressed or driven out by pressure, and when exposed to the weather they absorb moisture.

88 A splendid example of colloidal clay is found in the Mississippi River. The Ohio and the upper Mississippi both flow through old rock formations while the Missouri and particularly the north and south branches of the Platte flow through more recent geological formations. These formations are rich in a highly colloidal clay, which when it comes into suspension in water remains indefinitely. Engineers had long puzzled over the fact that the water at the mouth of the Mississippi became clear as soon as it left the mouth of the river, but the explanation is exceedingly simple. The salt water of the sea destroys the colloids and allows the mineral matter to settle rapidly. Those familiar with the old Mississippi steamboat days will recall that the water supply for those boats was obtained by pumping the muddy water into tanks and introducing a little alum. The colloids were thus destroyed and the mud quickly settled.

89 The only test for colloids of which there is any record is the one used by several departments of the Government and a number of firms in this country, and is founded on experiments carried on in Germany.

90 The aniline dye known as malachite green is used for this purpose. A given amount of malachite green is weighed out and dissolved in 400 or 500 cu. cm. of water. Into this from 10 to 20 grams of the sand or clay to be examined is introduced and the whole is shaken in a shaking machine for an hour. The bottle containing the material is then taken out and the solid matter allowed to settle to the bottom. A portion of the liquid above the solid matter is drawn off, placed in a color tube, and compared with the dye diluted with the same amount of water which was used in making the original solution.

91 The amount of dye absorbed by the colloidal matter in the sand indicates the bond present in the sand. Table 1 shows a series of colloidal readings on a group of sands examined under the direction of the author. A sample of kaolin was taken as 100 per cent, and other sands were compared by the amount of dye they would

absorb. A number of clays have since been found that run considerably over 100 per cent.

92 This scale has served to compare the different sands in the laboratory but before a method of this kind becomes general throughout the country some standard should be fixed. The readings given in the table represent only a small portion of the determinations made. It will be noted that the materials may be grouped into three classes. The first three samples tested represent washed silica sands with approximately the same colloidal reading; the next five represent beach or lake sands from the shores of the Great Lakes. All of these are wind driven sands with about the same colloidal reading. These

TABLE 1 COLLOIDAL READING ON SANDS

| Name | Bond No. |
|---|---|
| Washed silica core sand, Bethlehem, Pa | 2.17 |
| Washed Ottawa silica sand, Ottawa, Ill | 2.30 |
| Silica sand, Derby, England | 2.50 |
| Sharp sand, Faribault, Minn | 5.02 |
| Core sand, Sauk Center, Minn | 5.21 |
| Michigan City core sand | 5.27 |
| Crystal Beach lake sand, Buffalo, N. Y | 5.30 |
| Beach sand, Buffalo Am. Rad. Co | 5.43 |
| Core sand, Falkirk, England | 10.66 |
| Core sand, Falkirk, England | 10.81 |
| Manistee lake sand, Flint, Mich | 10.70 |
| Old molding sand, Faribault, Minn | 10.80 |
| Silica core sand, Duquesne Steel Fdy. Co | 10.84 |
| Mansfield core sand, Birmingham, England | 15.38 |
| Bank sand, Rochester, Mich | 21.63 |
| New molding sand, Faribault, Minn | 32.60 |
| Gangway sand, Moline, Ill | 43.50 |
| Lumberton sand, Hainesport, N. J | 53.43 |
| Kaolin, Fimer and Amend | 107.00 |

are followed by five core sands which would ordinarily be considered as fairly sharp.

93 The first two are English core sands; the third is the Manistee sand as used at Flint and Detroit, Mich. The reading on the old molding sand given fourth is not to be depended upon for its original colloidal reading, since the use of a sand always changes the colloidal content, the colloids themselves being usually destroyed. Burnt sand, however, generally contains material which will destroy the dye and so give an apparent colloidal reading. The old molding sand really had very little bond, though the colloidal or dye reading would place it in a class having a fair amount. Another case of a burnt

sand is given near the bottom of the table, this being the same gangway sand from Moline, Ill., with which the tests in acidulated sand were first carried on. There was absolutely no colloidal matter in this sand. This and other tests led to the belief that the dye reading was to be depended upon when applied to new sands in the condition in which they are dug, but does not apply to material which has been exposed to molten metal. The very high colloidal reading of Lumberton sand is to be expected, as this contains a very large percentage of clay.

94 The behavior of many of the sands tested when made into oil-sand cores showed very conclusively that the dye test gives a good idea as to the amount of oil which would be destroyed by the sand. Apparently the dye reading gives not only the colloidal matter which will destroy the oil, but in the case of old or burnt sands gives a fair indication of the amount of alkali or other material present which would destroy the oil. This was noted in connection with the gangway sand from Moline. Further tests will be made along the line of examining sands and studying the relationship between the natural bonding power and the colloidal reading as given by the dye tests. Thus far this seems to be the best test found.

95 *Action of other Binders on Oil.* When an oil is used as a bond it is not only destroyed by any clay or colloidal matter present but may also be destroyed by other ingredients used as binders. Where green strength is required in a core, foundrymen frequently introduce flour or dextrine into oil-sand mixtures. The oil first combines with the flour to form an oil-flour paste which has very little bonding power, but when so held it is not in a position to act as a binder between the sand grains. In consequence what happens in a mixture of this kind is that a portion of the oil unites with the flour and is itself destroyed for binding purposes. At the same time it renders the flour less efficient than it would be had it been mixed with water. The balance of the oil can act in its usual manner between the sand grains.

96 *Testing Binding Power of Liquid Binders.* The final binding power of any compound is measured by the solid bond left in the baked core. Paint chemists test their oils by drying them down to a film and seeing what percentage of weight has been lost in this action. In the case of Table 2 the binders shown in the column at the left were each weighed out into porcelain crucibles and first placed in an air bath and subjected to a temperature of 100 deg. cent. or 212 deg. fahr. for 24 hours and then weighed. These results are entered in the second column. The crucibles were next placed in the core oven at

a temperature of 400 deg. for 1 hour and again weighed and the results indicated in column three. Some of the crucibles were then returned to the core oven for another hour, exposed to a heat of 410 deg., cooled, and again weighed and the results recorded in the fourth column. The samples were then all heated in the air over a blast lamp to burn off the carbon, and the percentage of ash is recorded in the fifth column.

TABLE 2 DETERMINATION OF SOLIDS IN LIQUID CORE BINDERS

| Name | Dried 24 Hours at 212 Deg. Fahr. | Dried 1 Hour at 400 Deg. Fahr. | Dried 1 Hour at 410 Deg. Fahr. | Burned to Ash | Remarks |
|---|---|---|---|---|---|
| Glutrin | 51.47 | 41.98 | ..... | 8.03 | Skin |
| Raw linseed oil | 100.22 | 96.98 | 95.22 | 0.22 | No skin |
| Boiled linseed oil | 93.49 | 90.23 | ..... | 0.54 | Skin |
| Soya bean oil | 100.91 | 96.45 | 94.26 | 0.65 | No skin |
| Fish oil | 100.52 | 92.70 | 91.25 | 1.20 | No skin |
| Paraffin oil | 72.05 | 33.36 | 10.40 | 0.11 | No skin |
| Corn oil | 100.72 | 95.35 | 93.12 | 0.42 | No skin; crawled |
| Cottonseed oil | 100.68 | 96.08 | 94.10 | 0.07 | No skin |
| Light tar oil | 31.18 | 11.65 | ..... | 0.09 | Slick crawled |
| Heavy tar oil | 67.21 | 38.27 | ..... | 0.06 | No skin; crawled |
| Resin oil | 62.89 | 19.59 | ..... | 0.06 | No skin; crawled |
| Crude tar oil | 51.83 | 34.32 | ..... | 0.06 | No skin; crawled very much |
| Resin oil | 63.64 | 10.12 | ..... | 0.03 | No skin; crawled |
| China wood oil | 102.20 | 98.75 | ..... | 0.03 | Skin |

97 Under the head of Remarks a statement is given as to the behavior of the liquid. Most of it dried down to a skin. The first exception to this was raw linseed oil, and the reason was that even when painted as a film on wood it takes at least 4 days for it to dry. There was evidently not a sufficiently free admission of air in the oven to dry down the bulk of oil in the crucible.

98 *Drying of Raw Linseed Oil.* The appearance of the sample of raw linseed oil after it had been in the core oven 1 hour at 400 deg. is shown in Fig. 18. Had this oil been evenly distributed through a body of sand there would have been sufficient circulation through the body of sand completely to oxidize it. These tests, however, show that while raw, linseed oil is one of the strongest binding oils we have; it is nevertheless a very slow drying oil, and hence pure linseed oil cores would probably take longer to dry than those made from other oils.

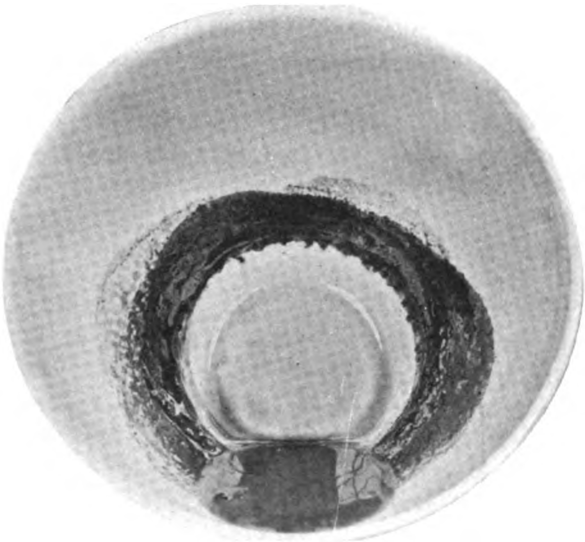

FIG. 18 RAW LINSEED OIL TESTED FOR DRYING QUALITIES

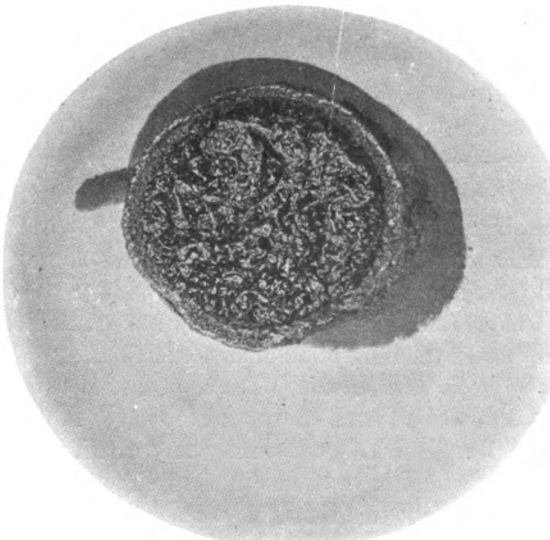

FIG. 19 CHINA WOOD OIL TESTED FOR DRYING QUALITIES

99 *Drying China Wood Oil.* The appearance of the surface of the skin in the case of some of the oils after test No. 2 is interesting. Fig. 19 shows the China wood oil made from the tung nut which grows in China. This is a relatively new oil in this country, and partakes at once of the nature of an oil and a varnish gum, being to some extent a natural varnish. It contains its own driers, so that it dries down fairly readily. It will be noticed under the tests in the second column that China wood oil gained 2.2 per cent in weight by oxidation when exposed to a temperature of 212 deg. fahr. Several of the oils gained slightly, but China wood oil leads them all in this respect. It also showed the greatest percentage of weight after one hour in the core oven and the film was strong and tough. When tested as a binding oil it gave excellent results.

100 *Drying of Light Tar Oil.* The light tar and a number of similar oils crawled up the face of the crucible and dried down to a hard glazed film. The crucible containing the light tar oil as photographed after the test recorded in column 2 is shown in Fig 20. This oil had left only 11.65 per cent of its original weight as a bonding medium. Such oils are used as blending oils in liquid core compounds.

101 *Drying of Boiled Linseed oil.* The boiled linseed oil dried down to a film in the air bath as would be expected, on account of the fact that it contains artificial driers. The appearance of the film of the boiled oil after the test recorded in column 3 is shown in Fig. 21. Formerly the term, boiled oil, meant linseed oil which had been boiled in open kettles exposed to the air so as partially to oxidize it and certain mineral oxides were added to it. Such oil when used for mixing paints dried down to a film much more rapidly than raw oil. Today practically all of the boiled oil on the market is a compound which has been heated to a certain temperature below that of the boiling point of linseed oil and had various so-called driers added to it, which chemists call catalysts. That is, they are in this case bodies having the property of taking oxygen from the air and delivering it to the oil to hasten its oxidation or drying. The boiling of linseed oil in a kettle or the making of so-called boiled oil by adding driers hastens its setting or drying by partially oxidizing the material. Hence a lower ultimate bonding power would be expected from such an oil, and results seem to show that this is true. For this reason, when considered purely from the standpoint of an efficient bond a raw oil is better than a boiled one.

102 *Effect of a Sticky Oil on Piecework.* The author ran across an interesting condition where the pieceworkers in a core room claimed

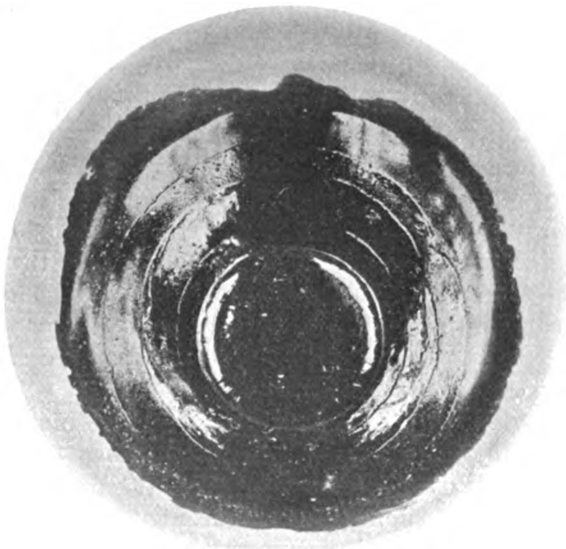

FIG. 20 LIGHT TAR OIL TESTED FOR DRYING QUALITIES

FIG. 21 BOILED LINSEED OIL TESTED FOR DRYING QUALITIES

that they could not make a good output when using raw oil, since it gummed the boxes more rapidly than boiled oil. The chemist in charge stated the reason was that the raw oil contained mucilaginous "foots" which had been taken out of the boiled oil. Several oil chemists claim that in the modern process of boiling oil everything in the raw oil is to be found in the boiled oil, but that the mucilaginous material may be partially eliminated by combining it with driers.

103 *Linseed Oil "Foots."* Practically all linseed oil is now made by the hot pressing process, and as it comes from the press contains some exceedingly fine meal, which settles to the bottom of the oil storage tanks and is known as foots. After the clear oil has been drawn off that at the bottom containing the foots is used as a core oil by many foundrymen. It has high binding power but tends to stick to the boxes.

104 *Comparison of Molasses and Glutrin Films.* Before leaving the subject of the tests made to determine the amount of binding power in the various materials, it may be well to illustrate the films left by glutrin and molasses. Fig. 22 shows the glutrin film which dried down to a compact mass very much like the oils. This explains why glutrin cores do not swell in baking, but retain their size and shape so that the baked core if it has been properly supported during baking can be returned to the box after drying and will fit perfectly. Fig. 23 shows the film left by molasses. The liquid boiled to the top of the crucible forming a rough mass composed of bubbles. This is why molasses cores are frequently distorted during baking.

105 *Fineness Tests on Sands.* It has already been stated that the size of the grains of sand should be as uniform as possible if the core is to have the maximum amount of venting space. The various sands examined were all tested for fineness and the results given in Table 3. The amount recorded in each column is that which remained on the sieve of the size given at the top of the column. The percentage of material passing through the 100-mesh sieve is recorded in the column headed, 100 +.

106 The fineness number given in the righthand column is arbitrary, and is intended for the comparison of different sands. It was reached in the following manner: The percentage which remained on each sieve is multiplied by the number of the sieve through which it passed, with the exception of that which remained on No. 20. This is also multiplied by 20 so as not to introduce a great error. These products are all added and divided by the amount of sand taken which gives the fineness number.

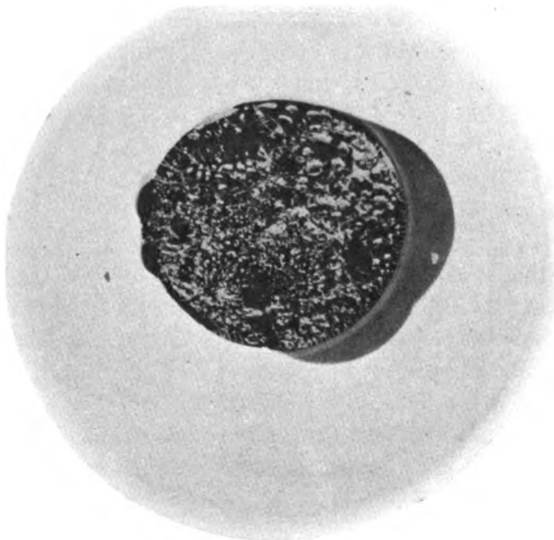

FIG. 22 GLUTRIN DRIED DOWN TO A FILM, SHOWING NO SWELLING

FIG. 23 MOLASSES DRIED DOWN TO A FILM, SHOWING HOW IT SWELLED TO FILL THE ENTIRE CRUCIBLE

TABLE 3 FINENESS TEST

| Sand | Mesh 20 | 40 | 60 | 80 | 100 | 100† | Fineness Number |
|---|---|---|---|---|---|---|---|
| New England bank | 3.7 | 11.6 | 17 | 11.6 | 13.7 | 40.6 | 68 |
| Rockaway Beach | 0.7 | 14.5 | 46 | 23.5 | 11 | 2.7 | 47 |
| Michigan City core | 0.5 | 9.8 | 41.5 | 35.75 | 9.55 | 1.8 | 50 |
| Coarse bank, Cleveland | 6.3 | 59.6 | 22.3 | 5.0 | 2.6 | 3.1 | 30 |
| Clay, Cleveland | 2.8 | 30 | 11.0 | 4.9 | 10.3 | 41.7 | 64 |
| Washed silica core | 0.1 | 1.7 | 30.7 | 38.0 | 22.3 | 6.7 | 60 |
| Lake Manistee, Mich | 0.2 | 4.3 | 9.8 | 12.3 | 12.4 | 60.7 | 83 |
| Bank, Rochester, Mich | 0.1 | 45.7 | 50.2 | 3.3 | 0.1 | 0.9 | 32 |
| Strawbridge, England | 2.0 | 16.5 | 9.6 | 10.2 | 22.7 | 40.0 | 72 |
| Mansfield, England | 0.3 | 10.1 | 10.3 | 10.6 | 23.7 | 42.5 | 74 |
| Burnt, Mansfield, England | 0.1 | 6.3 | 7.2 | 10.7 | 27.9 | 43.6 | 77 |
| Gangway, Moline, Ill | 1.8 | 7.9 | 10.9 | 9.6 | 12.5 | 55.7 | 78 |
| Core, Pittsburgh, Pa | 5.3 | 42.6 | 37.0 | 5.1 | 4.4 | 5.0 | 27 |
| Bank, Buffalo, N.Y | 3.1 | 32.0 | 38.5 | 11.8 | 5.2 | 8.2 | 42 |
| Lake, Buffalo, N. Y | 0.1 | 12.6 | 33.7 | 24.4 | 21.6 | 7.3 | 55 |
| Core, Buffalo, N. Y | 6.3 | 71.8 | 20.1 | 0.8 | 1.0 | 0.1 | 25 |
| Falkirk, England | 7.6 | 32.3 | 32.5 | 12.9 | 7.7 | 5.0 | 40 |
| Core, Faribault, Minn | 0.2 | 2.5 | 38.2 | 33.4 | 17.6 | 7.1 | 57 |
| Silica, Ottawa, Ill | 0.1 | 72.8 | 21.6 | 3.1 | 0.8 | 0.7 | 26 |
| Derby, England | 2.5 | 8.3 | 46.5 | 27.3 | 10.5 | 3.1 | 49 |
| Lumberton, Philadelphia, Pa | 9.0 | 34.5 | 24.1 | 9.1 | 12.6 | 9.1 | 41 |
| Core, Zanesville, O | 6.0 | 44.0 | 2.7 | 9.1 | 15.4 | 20.0 | 49 |
| Molding, Zanesville, O | 41.1 | 31.5 | 15.2 | 3.3 | 1.7 | 6.5 | 30 |
| Molding, Zanesville, O | 0.6 | 1.2 | 0.4 | 0.3 | 1.1 | 95.1 | 97 |
| Washed silica, Millington, Ill | 0.1 | 56.7 | 23.8 | 6.5 | 5.7 | 6.7 | 36 |
| Magnesia, Millington, Ill | 4.3 | 48.6 | 20.7 | 5.8 | 6.8 | 13.4 | 41 |
| Core, Sauk Center, Minn | 2.4 | 6.0 | 19.2 | 19.5 | 17.5 | 33.9 | 69 |
| Lumen Bearing Co.'s lake | 0.1 | 4.35 | 19.1 | 34.05 | 31.2 | 10.75 | 58 |
| Delray bank, Detroit, Mich | 1.5 | 0.55 | 5.1 | 5.75 | 21.15 | 55.05 | 76 |
| Dolly Ann, Covington, Va | 9.4 | 32.6 | 26.9 | 16.2 | 6.9 | 6.8 | 41 |
| Providence River | 0.5 | 2.2 | 6.5 | 6.5 | 13.5 | 69.8 | 88 |
| Rockaway Beach | 0.1 | 8.7 | 34.6 | 36.7 | 14.2 | 5.1 | 54 |
| Indiana bank | 0.1 | 6.6 | 44.8 | 33.6 | 12.6 | 1.6 | 50 |
| Magnesia core, Millington, Ill | 0.1 | 46.1 | 25.2 | 7.2 | 1.2 | 19.3 | 44 |
| Yellow, sharp | 0.1 | 30.5 | 48.5 | 13.9 | 2.1 | 3.6 | 39 |
| Bank, Cleveland, O | 12.7 | 26.4 | 27.3 | 7.2 | 6.0 | 20.2 | 48 |
| Light molding, Cleveland, O | 13.8 | 25.5 | 9.2 | 4.5 | 3.8 | 42.0 | 59 |
| Travers City, Mich | 2.0 | 38.4 | 42.3 | 9.2 | 3.5 | 3.2 | 36 |
| Silica dust | 0.7 | 1.2 | 14.1 | 10.3 | 9.9 | 62.3 | 82 |
| Sugar, Cleveland, O | 17.1 | 36.2 | 23.2 | 11.5 | 5.3 | 5.5 | 37 |
| Delray bank, Delray, Mich | 0.2 | 0.9 | 5.3 | 10.5 | 25.1 | 57.1 | 86 |
| Gravel, Cleveland, O | 31.5 | 24.3 | 14.2 | 6.2 | 7.2 | 15.4 | 42 |
| Bank, Cleveland, O | 6.0 | 10.8 | 14.8 | 11.1 | 21.1 | 34.4 | 67 |
| Gravel, Cleveland, O | 41.8 | 32.1 | 20.5 | 3.3 | 0.2 | 1.0 | 26 |
| Sand blast, Cleveland, O | 2.2 | 7.9 | 12.6 | 9.8 | 13.5 | 52.8 | 76 |
| Silica, Cleveland, O | 1.4 | 5.5 | 17.7 | 7.8 | 19.8 | 57.0 | 86 |

TABLE 3 FINENESS TEST—Con.

| Sand | | | Mesh | | | | Fineness Number |
|---|---|---|---|---|---|---|---|
| Silica, Cleveland, O | 3.8 | 37.8 | 40.4 | 10.3 | 4.2 | 2.4 | 36 |
| Sharp, Cleveland, O | 2.6 | 5.6 | 29.3 | 39.1 | 19.8 | 3.5 | 56 |
| Bank, Chicago, Ill | 0.1 | 7.4 | 40.4 | 28.5 | 19.2 | 4.0 | 54 |
| Custer Park, Custer Park, Ill | 0.3 | 5.9 | 29.8 | 19.3 | 18.2 | 24.7 | 64 |
| Silica, Cleveland, O | 0.1 | 6.1 | 42.4 | 36.2 | 13.3 | 1.7 | 52 |
| Bank, Cleveland, O | 4.1 | 13.2 | 18.1 | 13.3 | 19.0 | 31.7 | 52 |
| Silica, Cleveland, O | 0.1 | 54.4 | 34.0 | 5.9 | 3.1 | 2.0 | 33 |

107 It is interesting to note that most of the sands adopted by foundrymen through experimental work have very nearly uniform sized grains, or at least will leave more than half of the sand on two consecutive sieves. For instance, the Michigan City core sand, the third in the column, has over 75 per cent of its sand on the 60 and 80-mesh sieves; the washed Ottawa silica sand has 72.8 per cent of its grains on the 40-mesh sieve, and 21.6 per cent on the 60-mesh sieve, or over 94 per cent of the sand on two consecutive sieves. The Del Ray bank sand so extensively used by brass foundries, is exceedingly fine, 55 per cent of it having passed the 100-mesh sieve. As seen under the microscope the grains are clean and rounded so that it has considerable vent. One of the fine sands used in the east is the Providence River sand, and of this 69.8 per cent passed the 100-mesh sieve.

108 *Specifications for Core Sand.* More investigation along this line and the coöperation of manufacturers will result in specifications for core sands for different classes of work. These specifications should include the relative fineness, the percentage of bonding material which will destroy oil, as determined by the dye test for colloids or some other test to be determined later, and the percentage of alkalies or lime.

109 *Mineral Composition of Sand Grains and Its Effect.* A good core sand should be free from shale or limestone pebbles if it is to be used with oil, since the shale is liable to form a fluxing ingredient. For some classes of grey iron work, sands carrying a considerable percentage of limestone pebbles are used. These sands cannot be used with oil, but can be used with pitch compounds or glutrin. The first time they are exposed to molten metal, however, the lime which is next to the casting will be burned to quick lime. This will result in a considerable volume of carbon dioxide gas which must pass out through the vent, but the burning of the limestone to quick lime will partially disintegrate the core and make it easy to clean. If any of this old core sand is used in the new mix, the quick lime contained in

it becomes a rather efficient binder, acting much as does flour or starch in that only the portion of the lime in contact with the sand grains is affected, the balance of it simply stopping up the vent.

110 At least two large foundries are making extensive use of a core-sand mixture containing heavily bonded loam sand and a quantity of limestone pebbles. For some classes of very heavy work no artificial binder is used, the clay in the new sand and the quicklime in the old sand being depended upon for that purpose. It is necessary in such cases, however, to give the cores a coat of blacking in order to peel the castings, and in making up the cores a large amount of coke has to be used to form vent passages.

111 *Effect of Moisture on Volume of Sand.* In experimenting with a wide range of binders several sands representing different types were selected as standards and cores made with each series. The Ottawa silica sand, Michigan City sand, and the Rockaway Beach sand, were three types of sharp sands, or sands carrying comparatively little bond, selected. One day the man making the cores reported that from a measured amount of sand he was obtaining more cores than formerly. Upon investigating it was found that he had taken one batch of sand from the bottom of a bin of Michigan City sand where it was wet and the next from the top of the adjoining bin where it was dry. To see if this would explain the matter a quantity of dry Michigan City sand was measured, 10 per cent of water by volume added to it, the mass mixed over by hand, and an attempt made to put it back in the same measure from which it had been poured. It was found that 40 per cent could not be returned to the measure. Experiments were then made by taking measured amounts of sand and adding first 1 per cent and then 2 per cent of water, and so on up to 20 per cent or more. It was found that at first each addition of water increased the volume of sand until about 10 per cent had been added, and that beyond this the volume began to decrease once more, until the volume of water was so great that the sand could settle out of it, when the volume of sand became very nearly the same as that for dry sand.

112 The explanation is simple. In dry sand the grains slide past each other until the maximum number of bearing points are in contact. When there is just sufficient water present to form a film over each grain of sand, two grains coming in contact adhere and will not move further without the application of force. Fairly hard ramming will not even drive the sand back to its former volume. This condition is graphically illustrated in Fig. 24. On the left there are two

graduated cylinders, one containing 500 cu. cm. of dry Michigan City sand and the other 50 cu. cm. of water. On the right is shown the large cylinder with the wet sand in it, and the 10 per cent of water having been mixed with the sand by hand and the material dumped back into the cylinder. It filled the cylinder up to the 780 cu.cm. mark, an increase of 270 cu. cm. or over 50 per cent. In putting the sand in, the cylinder was rapped down on the hand as hard as pos-

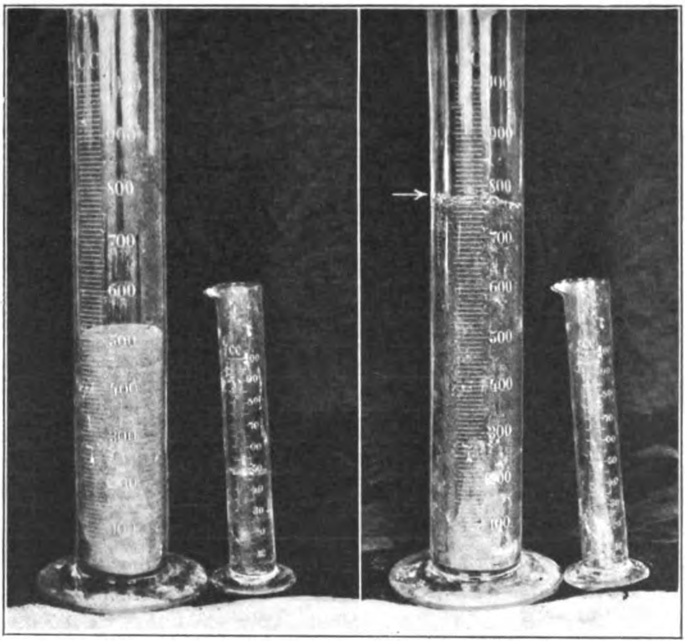

FIG. 24 CHANGE IN VOLUME OF SAND CAUSED BY THE ADDITION OF 10 PER CENT OF WATER

sible without danger of breaking it. The results of experiments with New England bank sand and Rockaway Beach sand are given in Tables 4 and 5.

113 The practical application of this is that if the men in the core room are allowed to take sand as it comes and measure it by volume they will be getting constantly varying ratios between the sand and the binder. If a given volume of dry sand is taken it will contain a certain number of grains and there will be a certain ratio to the binder. If the same volume of wet sand is taken there will

be a very much smaller number of grains and hence a larger proportion of binder or smaller binding ratio, which will result in a stronger core, provided the mixing is properly done.

114 All core sand should be dried before the binding material is mixed with it. If the core sand is measured by weight the introduction of moisture in it also introduces an error. Fortunately these errors tend to make stronger cores than would result from the use of dry sand, on account of the decrease in the bonding ratio, but this increase in the proportion of binder is an unnecessary and increasing expense which must be borne.

TABLE 4 TESTS WITH NEW ENGLAND BANK SAND FROM WATERBURY, CONN.

| Sand, by Volume | Water, by Volume | Water by Weight, Per Cent | Sand Water Added, Volume | Increased in Volume, Per Cent |
|---|---|---|---|---|
| 500 | 5 | 0.77 | 590 | 18 |
| 500 | 10 | 1.54 | 680 | 36 |
| 500 | 15 | 2.31 | 750 | 50 |
| 500 | 30 | 4.62 | 790 | 58 |
| 500 | 45 | 6.93 | 830 | 66 |
| 500 | 60 | 9.24 | 810 | 62 |
| 500 | 75 | 11.55 | 810 | 62 |
| 500 | 90 | 13.86 | 800 | 60 |

TABLE 5 TESTS WITH ROCKAWAY BEACH SAND, ROCKAWAY BEACH.

| Sand, by Volume | Water, by Volume | Water by Weight, Per Cent | Sand Water Added Volume | Increase in Volume, Per Cent |
|---|---|---|---|---|
| 500 | 5 | 0.68 | 700 | 40 |
| 500 | 10 | 1.36 | 740 | 48 |
| 500 | 15 | 2.04 | 730 | 46 |
| 500 | 30 | 4.08 | 700 | 40 |
| 500 | 45 | 6.12 | 810 | 62 |
| 500 | 60 | 8.16 | 810 | 62 |
| 500 | 1000 | Flooded | 470 | .. |

115 *Effect of Damp Sand on Hand-Mixed Oil-Sand Cores.* In connection with the use of damp sands an interesting core is shown in Fig. 25. This was made from sharp Lake sand and oil at the ratio of 50 to 1. The sand was fairly damp when taken from the bin, containing at least 3 per cent of moisture by weight. The sand was spread on the coremakers' bench, the oil measured and poured over it, and the batch thoroughly mixed by hand, until the oil appeared to be evenly distributed. A little water was then added to temper it

thoroughly and again rubbed over two or three times by hand. It was not passed through a riddle, however.

116 A batch of cores were made from it and baked. When they came from the oven small white spots of unbonded sand appeared on the surface and the sand could be poured from these. The hole shown in Fig. 25 is less than $\frac{1}{16}$ in. wide and a little over $\frac{1}{8}$ in. high. It extends into the core for $\frac{3}{8}$ in. A number of these were seen all over the surface of the core.

117 Another batch of sand was mixed in the same way, and passed through a No. 4 riddle once. Cores were made from this and baked. They were found to contain little spots where a dozen or more grains of sand had adhered and the water on them had prevented the oil from covering them. These spots of dry sand fell out leaving small spots on the face of the core and upon breaking the same condition was found to exist through its entire body. A portion of the same batch was put in a mixing mill and ground for 2 minutes. Cores made from this showed perfectly uniform results.

118 These experiments clearly showed two facts: first, damp sand should never be used in making up core mixtures, and second, core sand should be ground or thoroughly mixed to insure the incorporation of the oil with the sand and the covering of every grain of sand with the oil.

119 *Binders Tested.* A partial list of the binders tested is given in Table 6. This contains nothing but materials from which binding compounds are made or materials used as binders, without being incorporated with other materials to form core mixtures. The name of the one donating the sample is shown at the right. In addition, a number of other makers of core compounds have furnished samples of their standard products. In this investigation, however, the underlying principles which govern the bonding of core sands are sought and hence, so far as possible, known compounds are used.

120 The results of one series of tests in comparing some of the binders is shown in Fig. 26. The paraffine oil and crude oil which are frequently used in core oils for blending show no binding power whatever, or at least they broke at less than 1 lb. per sq. in. The black compounds tested in this series were not suited for use with the Rockaway Beach sand, but should have been used with those containing some loam. The pitch referred to is what is known as parolite, a product furnished by the Standard Oil Company. A sample of raw linseed oil was also tested in this series, but could not

be broken on the testing machine then in use. Since this time experiments have been tried and oil sand cores made at the ratio of 1 to 50, breaking as high as 160 lb. per sq. in. in tension.

### SELECTION AND COMPOUNDING OF CORE MATERIALS

121 *Cores for Steel Foundry Work.* The selection of the proper materials for use in any given core room depends upon local conditions as to supply of core-forming materials and the product being manufactured. A wider variety of materials can be used in connection with grey iron work than in most other classes of work.

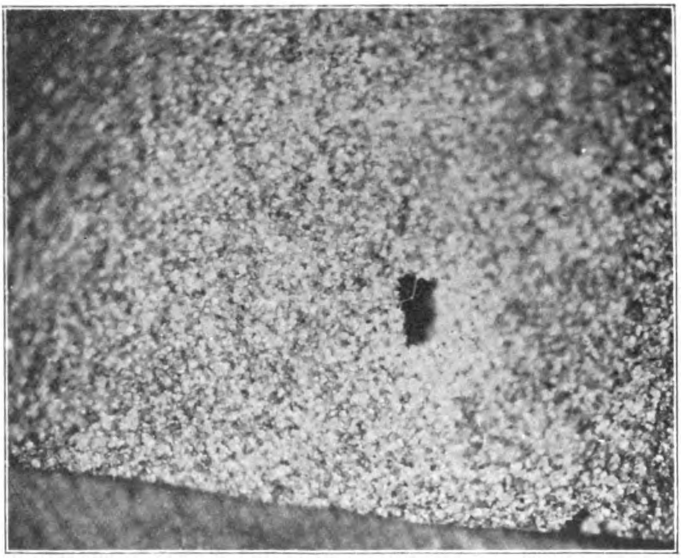

Fig. 25 Microphotograph of Core showing Hole where Unbonded Sand flowed out

122 Heavy open-hearth steel work requires the best materials. Both the mold and the cores must be made of silica sand and nothing that has a tendency to fuse at low temperatures can be employed. At the same time the cores must be of such a nature that they will crush readily before the metal as it shrinks. This has brought into use many different mixtures all having the same object in view. Flour or flour and molasses are sometimes used as binders and the cores baked until the bond is practically destroyed so that the core is rotten. Core arbors and core rods are relied on to hold the mate-

rial together and the surface is thickly coated with a silica wash which gives a strong skin to the core. Such a core will usually resist the action of the molten metal and crush readily when the casting shrinks.

TABLE 6 SOME OF THE BINDERS TESTED

| NAME | SHIPPED BY |
|---|---|
| Boiled linseed oil | Spencer Kellogg and Sons, Buffalo, N. Y. |
| Raw linseed oil | Spencer Kellogg and Sons, Buffalo, N. Y. |
| Fish oil | Young & Kimball, Boston, Mass. |
| Paraffine oil | Standard Oil Co., Cleveland, Ohio |
| Corn oil | Standard Oil Co., Cleveland, Ohio |
| Cottonseed oil | Standard Oil Co., Cleveland, Ohio |
| Parolite (pitch) | Standard Oil Co., Cleveland, Ohio |
| Light tar oil | Atlantic Turpentine Co., Savannah, Ga. |
| Heavy tar oil | Atlantic Turpentine Co., Savannah, Ga. |
| Resin oil | Atlantic Turpentine Co., Savannah, Ga. |
| Resin oil | Pensacola Tar & Turp. Co., Gull Point, Fla. |
| Molasses | Hill & Griffith Co., Cincinnati, Ohio |
| Flour | Hill & Griffith Co., Cincinnati, O. |
| China wood oil | L. G. Gillespie & Son, New York |
| Blending oil | Sun Oil Co., Toledo, Ohio |
| Crude oil of tar | Pine Turpentine Co., New York |
| Silicate of soda | Philadelphia Quartz Co., Chester, Pa. |
| Foundry dextrine | V. C. Bloede, Baltimore, Md. |
| Special dark dextrine | Corn Products Refining Co., Waukegon, Ill. |
| Special canary dextrine | Corn Products Refining Co., Waukegon, Ill. |
| Filtered whale oil No. 1 | Harvey & Outerbridge, New York |
| Filtered whale oil No. 2 | Harvey & Outerbridge, New York |
| Filtered whale oil No. 3 | Harvey & Outerbridge, New York |
| Special varnish gum | L. G. Gillespie & Son, New York |
| Michigan resin | Cadillac Turpentine, Co., Cadillac, Mich. |
| Oil No. 1 filtered and blown whale | Harvey and Outerbridge, New York |
| Raw pitch | Westinghouse Electric Co., Cleveland, Ohio |
| Distillery slop | Cutter Wood Supply Co. |
| Hydrol | Corn Products Refining Co., Argo, Ill. |
| Starch | Corn Products Refining Co., Argo, Ill. |
| Starch | B. Remmers & Sons, Bourse Bldg., Philadelphia. |

123 Others use both clay and sawdust in their core mixtures, the sawdust burning out and allowing for shrinkage and the clay acting as a binder. The burning of the sawdust frees the clay and permits the cleaning of the core. In one light-work steel foundry shop a core made of silica sand Welsh Mountain clay and sawdust is used, the core being baked until the sawdust is partially charred.

124 For work with core mixtures in which a binder like glutrin will sweat to the surface such a mixture could be developed to good advantage for steel foundry work, as a core of this kind has a hard skin and a rotten or soft interior. All such cores, however, have to be baked carefully at a certain temperature for if the skin is burned there is nothing left of the core. Glutrin is used in steel facing sand and in many clay and silica sand core mixtures.

125 *Cores for Brass, Bronze and Aluminum.* The other extreme in the core field is found in the brass and bronze foundry. Here the temperatures encountered by the cores are much lower, and greater diversity of sands and binders can be employed. In a case of this

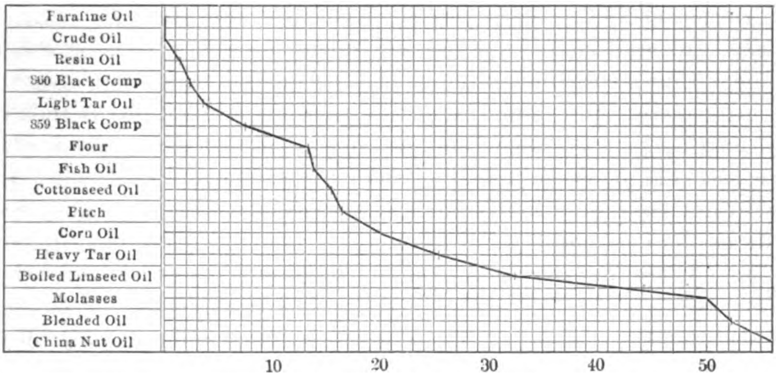


FIG. 26 DIAGRAM SHOWING RELATIVE STRENGTH OF A NUMBER OF BINDERS

kind what is needed is a core with a close surface which is still free venting enough to permit the mold to be filled quickly and the gases to escape readily.

126 Clay is out of place as a binder in brass and bronze work and the material used should be of such a nature as to burn out at a rather low temperature.

127 In dealing with aluminum a metal with maximum shrinkage and minimum hot strength is encountered. This requires a core that yields readily and softens as quickly as the metal strikes it. Two courses are open: to use a mixture giving a core with a soft interior and practically all the binder on the surface so that as quickly as the surface is disintegrated the core can be readily crushed; or to use a binding material which softens as soon as heat strikes it whether it burns or not. Resin is the only binder which fully meets this latter

requirement, and it is frequently used to good advantage in aluminum work. These cores clean out readily if the castings are taken from the mold hot and cleaned out at once, but if they are allowed to get cool the resin cores harden once more and it is almost impossible to get them out.

128 *Cores for Grey Iron and Malleable Iron.* For grey iron or malleable work the core problems to be met are almost infinite. In the radiator shops and in stove foundries producing gas range burners it is necessary to have cores which are exceedingly strong and free-venting and which will stand being entirely surrounded by metal with the exception of a small print. This means a core made from sharp sand and at present all such are of oil or mixtures of oil and glutrin as binders.

129 Oil-sand cores have one advantage possessed by few other binders, that a core made from clean sand and oil has no tendency to absorb moisture and can be kept without losing strength for an indefinite length of time. The writer has cores in his possession, now nearly five years old, made of linseed oil and clean sand, some of which were used after they were four years old and seemed to give as good results as the new ones.

130 A core for the most exacting requirements met by oil-sand mixtures must have a tensile strength of at least 75 lb. per sq. in. In such mixtures it is usually the most economical to employ only high-grade materials and particular care must be taken to see that the sand contains no loam which will destroy the bonding value of the oil. Linseed oil at $1 per gal., as it has been this past year, makes the cost of the old standard binder almost prohibitive and has led foundrymen to look for cheaper materials. All of the paint and varnish oils, including China wood, Soya bean, corn and cottonseed oils have found a place in the core-oil trade. The regular blended oil, on the market also carry resin and neutral oil. As a rule the neutral oil does not add appreciably to the binding power of the compound but it does serve to carry the resin into the mixture and to give a waterproof oil of sufficient strength for ordinary work at a much lower cost per gallon than the old standby linseed. As linseed oil, however, is the ultimate standard of excellence for all core oils, some firms prefer to use it and either to dilute it themselves or to use glutrin in the mixture with it. In many grey iron and malleable foundries flour or dextrine is used as a binder and for some classes of work they give entire satisfaction.

131 *Cost of Strength in a Core.* In solving any core-binder problem the ultimate cost is the guiding factor. To determine the cost of a cubic foot of core several points must be considered: (1) the strength of the core mixture both green and dry; (2) the character of the surface which the core presents to the metal; (3) the question of the percentage of vent area in the core; (4) the ability of the core to resist moisture; (5) the ease with which the core can be cleaned from the casting; (6) the character of the fumes or gases given off during the baking of the core and when the mold is poured; (7) the number of cores which a man can make in a day from a given mixture; (8) the cost of drying; (9) the expense of the rigging involved with the use of a given binder.

132 The strength of the green mixture is important in cases where cores must stand at a considerable height above the plate during drying, and if the core has any overhanging bodies it must possess sufficient green strength to carry these. Green strength may be afforded by using a bonded sand, that is, a sand containing clay, or by using flour, dextrine or some other glutinous or starchy material in the mixture. The strength of the dry core is governed by the amount of pressure it must resist as the metal enters the mold. All cores tend to float as the metal enters and if not sufficiently rigid to resist this tendency, are likely to be broken or displaced.

133 Cores must also have sufficient strength to enable them to resist handling. The strength of core mixtures in use in the foundries in which we have carried on experiments varies from less than 5 to over 100 lb. per sq. in. The proper strength for a given condition can be determined only by experience, but after this has been decided, any other sand or binder mixtures can easily be compared with the standard by suitably testing the new one. Foundrymen have generally adopted a bar 1 in. sq. and broken it on supports 12 in. apart. This is suitable for oil-sand and fairly strong mixtures, but does not give good results for mixtures having low strength. For these the tensile method using a delicate machine is to be preferred or bars 4 or 6 in. long and 1 in. sq. may be made and broken in the middle.

134 Under the second heading must be considered the character of the surface presented to the metal, its ability to carry off the air or gases displaced by the metal as it enters the mold, its ability to resist the cutting action of the metal as it flows into the mold, and the freedom with which the burned core separates from the surface of the interior of the casting. As has already been stated, in the case of metals which have extreme fluidity and a tendency to search out all

small openings in the core, it is necessary to use a mixture which will present a close uniform texture, the voids or spaces of which are so fine that the metal cannot flow into them. In the case of such metals it may be necessary to use some facing or blacking on the core to close partially the spaces or voids and also to make the core clean out more readily. Cores for cast-iron water pipe and a large variety of similar grey iron work are given a coating of blacking and the interior faces of the mold made to peel just as well as the exterior. If the core itself does not present a proper surface to the metal it must be considered whether it would be cheaper to select a material which does or to treat the surface of the core in such a way as to improve it.

135 Under the third heading, the percentage of venting area, must be considered the size of the sand grains and their character; also the character of the bond and the extent to which it blocks the vent. In the case of castings which are entirely surrounded by metal with the exception of a small print, as for instance, gas stove burners, the sand mixtures must have a maximum amount of vent and a minimum amount of gases to be driven out, while in the case of aluminum the metal solidifies so quickly that a very small amount of gases has to be taken care of. The thickness of the casting that is to surround the core also has an influence on this as it determines the duration of the high degree of heat.

136 Under the fourth heading, the resistance to moisture, must be considered the length of time the cores remain in the molds and the manner of handling and storing them. If high-grade oil-sand cores are used, their moisture-resisting properties are such that no ill effects need be feared from leaving them in the mold several hours before it is poured or in connection with their storage, but many other binders show a tendency to absorb moisture. Where this is the case, if there is a considerable saving in the use of one which absorbs moisture, it may be necessary to see if some means cannot be found for so handling the cores as to minimize their exposure to moisture. If they are kept in a dry place and are introduced into the mold only a short time before pouring, there will be no trouble on account of dampness and the saving in the cost of binder may more than compensate for the additional handling.

137 The fifth heading, ease of cleaning, is one of the important problems in the expense of making castings. A proper core mixture should rattle out without any difficulty, leaving a good smooth interior surface. If this is not so, some means must be secured of free-

ing the surface from the metal or of making the entire core of such a nature that it will soften under the action of the heat. In the case of brass and bronze cores, they are very largely blown out by dipping the hot castings into water, the steam formed blowing out the core. Iron castings cannot be so treated, hence the core must be compounded and baked so as to clean freely. One of the most common causes of difficulty in the cleaning room is the use of an excess of binder in the core room, or the use of sands which are too heavily bonded, that is, contain too much clay.

138 Under the sixth heading, the character of fumes, must be considered both the effect of fumes in the core-room and foundry. With regard to the character of fumes, certain oil mixtures give off very disagreeable odors after the cores are withdrawn from the oven and placed in the racks to cool. If less offensive mixtures which are equally efficient can be found it will greatly improve the working conditions of the core-room men; if not, ventilating devices should be provided to draw these fumes away from the coremakers. In the foundry the importance of this question depends to a large degree upon the volume of the cores used for each individual casting. If there are only a few small cores in each mold the volume will not be sufficient to trouble the workman, no matter what binder is used, but if the mold is largely composed of cores it becomes an important item in the comfort of the molders at pouring-off time, a great many castings having been lost on account of careless pouring of a molder in hurrying from the stifling fumes of the surrounding molds. Whale oil and fish oil give particularly bad fumes in these cases, though they form excellent binders. By lighting the gases as they come from the vents in the mold the disagreeable odors can frequently be reduced, but even then they may be sufficient to make a change of binding materials desirable. More and better work will result.

139 The number of cores per man per day is influenced by the character of the binder, since if the material tends to stick to the core box, the workman cannot produce as many cores as in a free working material. In many binders the trouble with the sticking was found to be due to too strong a core mixture and as soon as the proportion of binder was reduced the trouble disappeared. In the cost of drying, the length of time it takes to dry each different class of cores when using different binders determines the capacity of the core ovens, their fuel consumption, and the floor space which must be devoted to equipment of this kind. Quick drying core mixtures increase this capacity and so decrease the plant expense.

140 High-grade oil-sand cores made from clear sand and oil have no green binding power and hence they must all be provided with driers which support the core throughout its entire length, or the cores must be bedded in open, clear, sharp sand containing no binder. One of these procedures requires a considerable outlay for driers and the other an expenditure of time for bedding in. If the output from a given core box or pattern is to be limited, it may pay better to use a mixture having some green bond, so that the cores may be allowed to stand on one end on the plate or be supported in some other convenient manner which will avoid the making of driers. If very large outputs are required the driers will be found the most economical course.

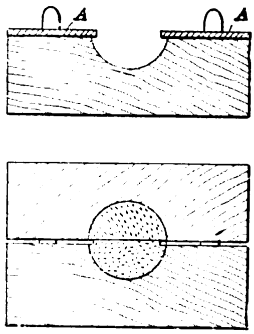


FIG. 27 CORE BOX WITH LINER FOR MAKING SELF-PASTING CORES

141 *Self-Pasting Cores.* Many intricate cores must be made in halves and then either dried on flat plates and pasted, or the two halves rocked together before pasting. If the latter is done, the binder must be of such a nature that it will form a self-pasting core. High-grade core oils when used in fairly large proportions will generally bind the two halves together in cases of this kind. In some cases, however, the expedient shown in Fig. 27 must be resorted to. One-half of the box is provided with a thin metal sheet shown at *A* which projects slightly over the edge of the box.

142 After the two half cores are made in the boxes the metal plate *A* is lifted off and the two halves of the box closed together. When the halves first meet, the condition will be as represented in the lower portion of Fig. 27. As the box is closed together, the projections of sand left by the opening in the plate *A* will crush into the faces of each half of the core so as to bond thoroughly the sand

in the two parts. This device, the writer believes, was patented some years ago by Mr. Lee, superintendent of a department of the Crane Company. In other cases the coremaker is careful to leave the sand projecting slightly above the face of the box when he strikes it off and then when the boxes are closed together there is sufficient pressure to make the sand along the faces of the core adhere. These rock-over boxes are now used in a number of different classes of work either

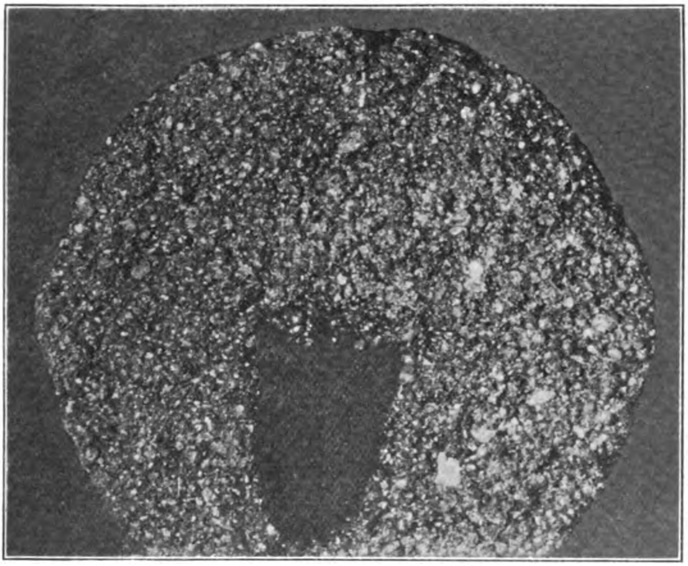

FIG. 28 MICROPHOTOGRAPH OF SELF-PASTING CORE WHICH HAS BEEN VENTED WITH A PRESS VENT

When the block for forming the press vent was forced into the lower half of the core the sand on each side of the box was forced up. When the second half of the box was placed on top of the first the sand over the vent crowded down slightly as shown and the ridges of sand at the side of the vent caused the material to blend along the parting so that the core became one homogeneous mass when baked.

with or without the stripping device and their use simplifies the making of intricate cores and at the same time permits the drying of the entire core in one piece.

143 Where cores are made in halves as shown in Fig. 27 and then rocked together, some form of block is generally employed for pressing a vent into the face of one-half of the core. The introduction of this vent block swells the sand on both sides of the vent, and this is usually sufficient to make the core self-pasting. A section of a core similarly made is shown in Fig. 28, where the use of the vent

block in the lower half has forced up two ridges of sand, causing the two halves of the core to unite.

144 *Grinding Experiments.* Concerning the compounding of core mixtures the writer has tried a great many experiments, and was aware that the grinding of molding sands greatly increased their strength, and under the impression that a similar grinding would aid core sands. In this connection a series of tests were run at the plant of the Lumen Bearing Company in Buffalo. A Wadsworth mixing and compounding mill was used, having a pair of small rollers running around on an annular track, following which are scrapers that turn the sand over first one way and then the other. A number of different classes of mixtures were put through the mill. In the case of sharp sands mixed with oil, grinding in the mill from 1 to 2 minutes was found to be a decided advantage over hand-mixing. After 5 minutes, however, there was a marked falling off of the strength of the core, due evidently to grinding the sand in such a way as to form dust which absorbed the oil and prevented its acting as a binder between the sand grains. One of the mixtures tested consisted of 120 parts of Lake sand, 60 parts of Del Ray bank sand, 5 parts by volume of No. 1 Peterson's core oil, and 1 part by volume of flour. Cores made from this mixture showed a strength of over 60 lb. per sq. in. after a grinding of 2 minutes. A large batch was made up, thoroughly mixed with the shovel, and then succeeding parts of it put through the mill, grinding the first 2 minutes, the second 5, then 15, 20, and 30 minutes. Several series of this kind were run and in each case the initial strength of the material was about 60 lb. per sq. in., while the final strength ground 30 minutes averaged less than 30 lb. per sq. in.

145 An experiment was then made by grinding a facing-sand mixture for dry sand molds. This was composed of four parts of new Zanesville molding sand, 52 parts of heap sand, $\frac{1}{4}$ part of glutrin, and $\frac{1}{2}$ part of dextrine. With this the strength increased slightly for the first 10 minutes' grinding and then remained constant for grinding up to 30 minutes. In it there is no bond that would be injured by fine material as in the case of the oil-sand cores already described. It is evident therefore, that in the case of oil-sand cores all that is required is a thorough mixing or blending of the ingredients. The hand-mixing experiments tried at the same time showed conclusively that if the oil and water were not ground together in contact with the sand so as to form an emulsion and to bring it in contact with the grains, the core would have unbonded spots.

146 The writer has also had access to the records of several foundries using mixing and compounding mills of various types and found that in all cases the oil-sand mixes require thorough blending, but are the better for not being ground with heavy rollers. Loam-sand mixtures require more grinding and in this respect are similar to molding sand. In one foundry two types of mills were in use, one a Wadsworth mill like that used in tests referred to later, at the Lumen Bearing Company and the other one having 900-lb. crushing wheels. The latter was found to be best for making a mixture with a bonded sand and black compound. When it was first installed practically all of the old core sand had been hauled to the dump. The common practice then was to mix the sand by hand with shovels and put it through a pneumatic riddle two or three times. From 10 to 20 per cent of old sand was used in the mix. When the mill was first put in they were able to use a mix composed of the following: 25 parts of old sand, 5 parts of new molding sand, ¾ part black core compound, and 18 parts of coke breeze. This was the refuse coke cleaned out of cars in which the cupola coke was received. The coke was first shoveled into the mill, ground for between 1 and 2 minutes, and then the other material was thrown in, wet down with water and glutrin, and ground for 5 minutes.

147 After continuing this practice for a short time it was found that the sand was growing weaker. At first there was the advantage of a large amount of unburned pitch in the black compound which remained in the old core sand, but with the continued re-use of the old sand this proportion was decreased and so the following mixture was finally adopted: 20 parts of old core sand, 3 parts of new molding sand, 2 parts of sharp sand, 6 parts of refuse coke, and 1½ parts of black core compound. This was run through a ½-in. riddle at the mill and then used for making the largest of coarse cores. Some of it was subsequently run through a ¼-in. riddle and used for a facing sand in the large cores.

148 The selection of core materials will probably remain for some time largely in the hands of the core-room foreman, but the writer confidently expects to see all of the larger concerns and the more progressive foundries throughout the country placing the control of these supplies in the hands of the laboratory, just as they have placed the control of their metals and fuels in the hands of the laboratory.

## CORE OVENS AND CORE DRYING

149 The baking or drying of a core is a complex process, depending upon the character of the sands and the nature of the binders used. Where flour, starch or dextrine are used, the moisture is first driven out and then the starch or flour compound is baked, as in any ordinary bread-baking process. To develop the greatest strength the material must not be charred, but should be carried simply to the condition of ordinary bread crust. For this purpose the temperature should be between 350 and 375 deg., and under no circumstances should it be allowed to rise above 400 to 410 deg. If flour or starch bonds are charred they immediately lose strength. Such a core taken from the oven at its condition of maximum strength will still contain some moisture in the starch or flour compounds, this moisture being mechanically combined, and naturally gives off a great deal of smoke when the mold is poured.

150 In the baking of resin or pitch cores it is necessary only to heat the material to such a temperature as to cause the resin or pitch to flow and unite the grains of sand. Practically all black core compounds contain a considerable percentage of dextrine and on this account the baking partakes both of the nature of the process already described and of the melting of the pitch, causing it to flow through the sand. This requires only a temperature of 350 to 400 deg., and if heated much above 410 deg., the dextrine contained in the black compounds will be burned out or, in the case of the resin core, some of the resin oils will be distilled off and the material will lose in binding power. Most of the resin oil, however, does not distill off below 550 deg., but at 640 deg. fahr. over 90 per cent of it can be driven off.

151 In both of these classes of cores described, the first operation is to drive out the water, and the second simply a baking or melting as the case may be. In both cases, during the first part the core oven should have ample ventilation so as to drive out the steam as it is formed. During the latter part a free circulation of air is not needed and in fact not desirable, as it would tend to oxidize or burn the compounds forming the bonds if the temperature of the oven got a little too high.

152 With oil-sand cores an entirely different proposition is encountered. The active bonds are the drying oils with the exception of resin, which is sometimes blended with the core oil. The drying or paint oils all require a good circulation of air through the oven. As in the previous cases, the first action which takes place is the driving

out of the moisture contained in the core and the second largely the oxidation of the oil. If a blended or compounded oil is being used which contains mineral or tar oil, or any similar compound, there will be some volatile hydrocarbons which will be driven out. After this it is necessary to continue a good circulation of air through the oven to oxidize the oils.

153 The process going on in the core oven during the latter part of the drying of an oil-sand core is similar to that of drying oil-skin clothing. This clothing is made by dipping cloth in a mixture of oils and drying it in a current of warm air. If the rooms containing the clothing to be dried are shut up so that there is no current of air, the oil will remain moist for days, even though the temperature may be much above that ordinarily employed for the purpose. With a good circulation of air, however, the clothing will dry rapidly to a firm hard skin. In like manner oil-sand cores must be given plenty of oxygen if they are to be properly dried.

154 Very few of the bonding oils will be burned at temperatures below 500 deg., and hence when they are being used core ovens can be driven at a higher temperature than with flour or starch. There is no need, however, of carrying the temperature above 400 to 410 deg., and the writer believes that the best results are obtained at about this range. If the temperatures reach 600 deg., all forms of carbon used in core binders begin to char and the strength of any carbon bond is reduced. The cores already spoken of, composed of silica sand, Welsh mountain clay and sawdust, were baked at about 600 deg., for the purpose of charring the last ingredient. With ordinary binders, however, this would not be a proper procedure.

155 As a rule a foundryman keeps no record as to the part of his oven in which certain cores were baked and may be wholly unaware of the fact that from 10 to 30 per cent of the product is seriously damaged every day and that in many cases castings are lost on account of being baked at too high a temperature in hot parts or not thoroughly baked by being left in cold parts. With a realization of these great differences in temperature a series of experiments has been tried with a pair of recording thermometers furnished by the Bristol Company of Waterbury, Conn. Before taking up the matter of recording thermometers, however, it may be interesting to speak of one piece of bad core-oven practice which came under the writer's attention in this investigation. The ovens were simply iron boxes having bars across them to support the core plates. In the bottom of each box there was an open coke fire with no baffle plates between the fire and the core

plates. Flour cores were being made at the ratio of one part of flour to nine parts of sand, and core plates were pulled from directly over the fire with the edges of the plate at a dull red heat, showing a temperature of at least 900 deg. fahr. The cores on these plates were black on the outside and smoking as though they were on fire and were being at once put in the molds by the molders to whom they were taken and the molds poured. One of the smoking hot cores was taken from one of these lower plates and broken, showing that the outer $\frac{1}{4}$ in. was burned while the inside of it was still in the condition of

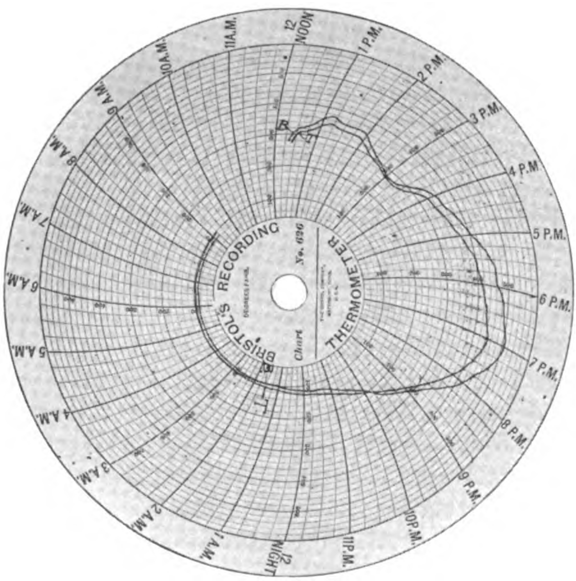


FIG. 29 DIAGRAM ILLUSTRATING DIFFERENCE IN TEMPERATURE IN A PORTABLE CORE OVEN

dough. The only wonder is that their casting loss was not greater than their report showed. The top of these ovens was probably below 550 deg. fahr.

156 The first ovens in which the writer tested the difference in temperature between the shelves was the Wadsworth oven used in experimental work at Covington and the first diagram taken is shown in Fig. 29. This heat was not used to bake cores but simply to try out some fuels and also to find the difference in temperature between the top and bottom. The curve for the lower thermometer which is placed just above the bottom shelf is marked *B*, while that

for the top thermometer which is placed just beneath the top shelf is marked *T*. In this oven the bottom shelf was the hottest while the oven was being fired. When it cooled off at night, however, the temperature of the lower thermometer fell below that of the upper. From 12.25, when the thermometers were coupled, until 2 p.m., the writer was firing with coke and trying to get the temperature up to 400 deg. At that time the coke fire was raked down and a fire of anthracite coal put in. The temperature fell from 2 to 3.10, when it commenced to rise, and at 7 p.m. the lower thermometer

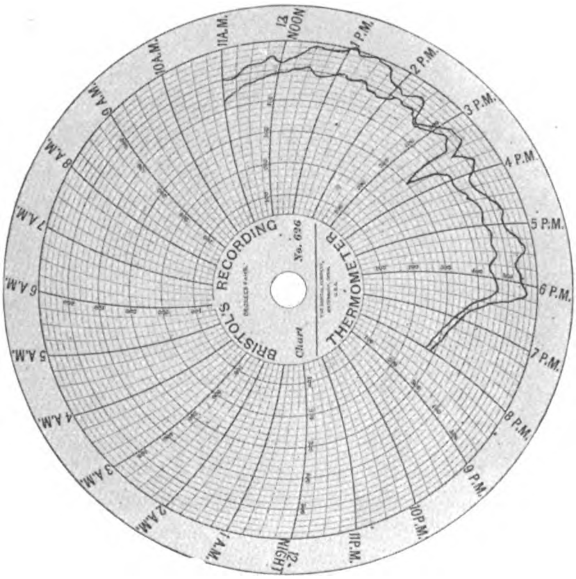


FIG. 30 DIAGRAM ILLUSTRATING DIFFERENCE IN TEMPERATURE IN AN OIL-FIRED CORE OVEN AND ALSO THE EFFECT OF OPENING DOORS AND IMPROPER CONTROL OF HEAT

had reached 510 deg. and the upper one 450 deg., there being a difference of 60 deg. between the top and the bottom of the oven. After this anthracite coal was used in this oven and the curves were kept very close to 400 deg. A difference was found between the top and bottom shelves which was rarely less then 30 deg. and under working conditions sometimes 40 deg. When the oven contained cores no difference was experienced as great as that indicated at 7 p. m. on the chart shown in Fig. 29.

157 The diagram shown in Fig. 30 was taken on a set of ovens without changing their ordinary core-room practice, the men being

allowed to open and shut doors or control the temperature as they saw fit. The ovens were of the oil-fired type and the oil came from a pipe line which also supplied a battery of oil-fired furnaces. The pressure in the line varied greatly when these furnaces were started or stopped, and unless corresponding changes were made in the control valves on the core oven, the temperatures of the core oven would increase or decrease in accordance with the varying oil pressure in the line. The oven was watched closely so that the line on the chart

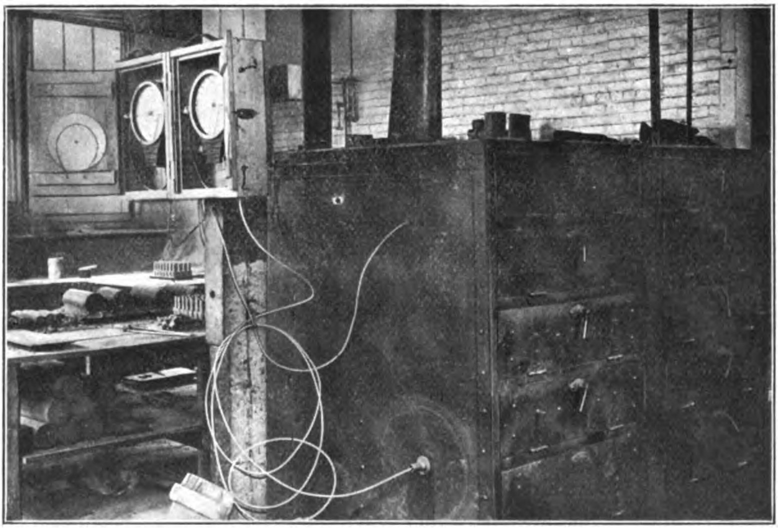

FIG. 31 OIL-FIRED CORE OVEN SHOWING MANNER OF ATTACHING THE BRISTOL RECORDING THERMOMETERS FOR ASCERTAINING DIFFERENCES IN TEMPERATURE

could be interpreted very accurately. The record for each thermometer was recorded on a separate chart but is here drawn on one chart to make comparisons more apparent. In this oven the upper thermometer, the location of which is clearly shown in Fig. 30, registered the highest temperature. At 11.50 one of the men opened one of the upper doors to take out cores and left it open for several minutes. This made a rather sharp drop in the line for the upper thermometer without any corresponding drop in the record of the lower thermometer. At 12.30 a man opened one of the lower doors opposite the lower thermometer and this resulted in a sharp drop of nearly 30 deg. in the lower thermometer. At 1.10 a door located about midway between the two thermometers was opened and both fell, the upper one showing the greatest difference of a fall of over 20 deg. while the lower one fell 15 deg. From 11 a.m. until 1.30 p.m. melting furnaces were being shut off and the oil pressure in the line was increased so that the general trend of both curves was upward, the sharp local conditions being due to the opening and closing of doors. At 1.45 two of the upper doors were opened and a lot of heavy green cores were put in. Cores were also placed on the third or middle shelf. This caused the upper thermometer to show a drop in temperature continuing until

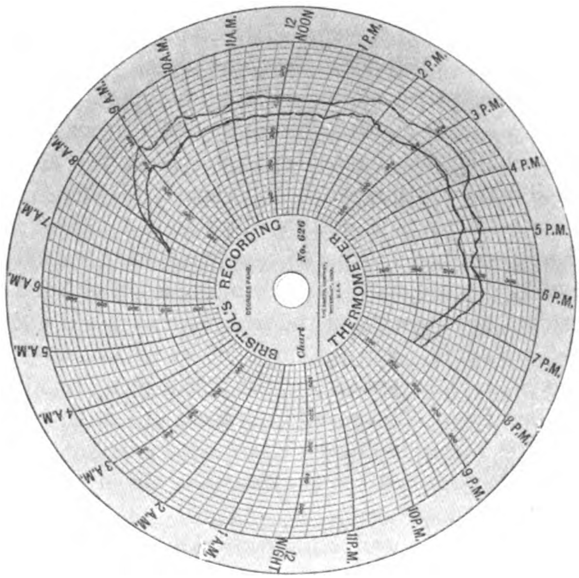


FIG. 32 DIAGRAM ILLUSTRATING DIFFERENCE IN TEMPERATURE IN AN OIL-FIRED CORE OVEN OBTAINED ON THE SECOND DAY THE THERMOMETERS WERE ATTACHED

2.10. About this time the lower door was opened giving a slight fluctuation. Just before 2.30 both upper and lower doors on the back side of the oven were opened and left open for some time and green cores put in. This resulted in a sharp drop of both thermometers. After this there was a gradual increase until 3.10 when one of the lower doors on the front side of the oven was opened and left so. The temperature fell gradually for the first few minutes and then rapidly until the lower thermometer showed a drop of over 200 deg. The upper thermometer at the same time fell about 65 deg. In like manner the various humps of the curve can be explained throughout the day. About 4.15 the melters commenced to cut off furnaces and the oil pressure gradually rose driving the temperature up until 6.10, when the oil was shut from the oven, and the curves for both thermometers fell. On the day the chart shown in Fig. 30 was made a very large number of cores was lost on account of being burned. The next day an attempt was made to control the temperature of the oven and keep it as near 400 deg. for an average as it was possible to do. The two curves for this day have been plotted together as shown in Fig. 32. In the morning when the oven was first started the temperature was allowed to rise until the upper thermometer registered 460 and the lower one 385. The oil supply was then checked giving a quick drop in the temperature of both thermometers. The temperature picked up once more, however, until at 9.50 it was again at the same figures which it had reached at 9. Here the oil supply was again checked when the temperatures dropped slightly and continued fairly uniform until 1 p.m. Between 11.30 and 1 it was necessary to regulate the oil supply a number of times to hold the curve as uniform as it appears in this record. At 1 o'clock the writer left the oven to look after some other work and the man in charge did not regulate it as closely as he should. He did, however, check the supply at 2 p. m. and again at 3.30, thus preventing the curve rising as high as it did on the previous day. The results obtained by baking the cores at the temperatures recorded on the chart shown in Fig. 32 were much better than those obtained the previous day when the temperatures varied as shown in chart 29.

158 If all core ovens were equipped with recording thermometers and account taken of the time different cores were placed in the oven, the foundryman would have a record of the baking temperature of each batch of cores and would thus be able to trace irregularities in the quality of the cores to the baking temperatures, if variations in these temperatures were to blame. When workmen know that a recording instrument is watching them and drawing a record of just how they maintain the temperature in the oven they will look after the fire and the drafts and see that the record is a credit to them. The writer believes it is a good thing to put the recording thermometers where the foreman can see them and then hold him responsible for the results, for many castings are ruined through bad cores and the trouble laid at the molder's door or considered a mysterious dispensation of providence.

159 *Core-Oven Design.* It is not intended in this paper to go into an exhaustive discussion of core-oven construction, but the underlying principles of core-oven design will be stated. If it is to be efficient it must be so constructed as to maintain a practically uniform temperature throughout the entire drying chamber. For the best results the extreme variations between different parts of this chamber should not exceed 60 deg. fahr. There also should be a proper circulation through the oven to insure the carrying off of any steam generated during the first period of drying of cores and to afford an ample amount of oxygen for oxidizing and drying oil binders. Where no oil binders are used and the cores are dried in batches it is advisable to vary the amount of circulation through the oven at different periods of the drying process so as to avoid undue oxidation of certain classes of binders toward the end of the drying period.

160 The most common mistake made in core-oven design is that of locating the firebox too close to the oven and of discharging the products of combustion into the core-drying chamber at too high a temperature. This practice renders certain portions of the oven inoperative for efficient baking on account of the fact that if any cores were located in these hot parts they would be burned. In the oven there should be ample space between the combustion chamber, or firebox, and the oven, or drying chamber, for the mixing of the products of combustion so that they will have a uniform temperature when entering the oven, and this should be the maximum baking temperature of the oven. The most efficient ovens that have come under my attention have all had their firebox located at some distance from the oven proper, or else have had a large mixing chamber introduced in the flue between the oven and the firebox. In one case there is a battery of ovens constructed with fireboxes in the basement and the ovens are located two stories above. The flues are so arranged and provided with dampers as to make it possible to control the temperature and volume of the incoming gases entering each oven or oven compartment. A provision of this kind insures rapid drying without any danger of burning the cores.

161 *Steam-Heated Core Ovens.* For some classes of binders steam-heated ovens are excellent since they insure control of the temperature and preclude any possibility of its rising above the desired maximum. The fuel economy of the steam-heated oven, however, is very low, and hence some form of direct firing by carbonaceous fuel is generally depended upon.

162 *Core-Oven Fuels.* The fuel used must be one that does not give a smoky flame which would cover the cores with soot. In consequence, anthracite coal, coke, fuel oil, and gas, are the fuels commonly employed. The products of combustion from anthracite coal and coke are carbon dioxide with possibly a little carbon monoxide if there is imperfect combustion. With these are mingled a large amount of nitrogen which is passed through the oven with the air supply to provide oxygen for the combustion of the solid carbon. All of these gaseous products are efficient drying agents and have the power of absorbing moisture and carrying it from the core oven with them.

163 Turning to fuel oil or gas as a means of heating the oven, an entirely different set of fuels is encountered. Both of these fuels contain larger percentages of hydrocarbons, all of which burns to water, which passes off as steam and as its temperature falls in the core oven it tends to saturate the air with steam and hence is not efficient as a means of carrying moisture from the oven. In other words, while all of the combustible material in oil or gas produces heat when it is first burned, the products of combustion are of such a nature that much of the heat is carried through the oven locked up in the steam resulting from the burning of the hydrocarbon compounds and so is not available for the drying of cores. The exceedingly high thermal efficiency of gas and oil, however, and the fact that the use of fuels of this kind does away with the handling of coal or ash may make it advisable to use such material though it is not the most efficient fuel.

164 *Continuous Core Ovens.* In the case of continuous ovens where the cores are carried by mechanical means, care should be taken to see that there is no hot spot in the ovens where the temperature exceeds the safe drying limit for the binder in use. Cores may be made to resist high temperatures by spraying the surface of the cores to increase the percentage of binder in the surface, but this is expensive since in spraying cores much of the material is wasted, and the operation itself takes time. It is far more economical to design the oven so that it will bake the cores with the maximum degree of rapidity and at the proper temperature, than to try to utilize improperly designed ovens by doctoring the core-room practice. One advantage of continuous ovens over many of the other types is that the temperatures of the different parts may be controlled so as to give the most rapid and efficient drying possible, but this is true only where the cores are approximately uniform.

165 *Chamber Ovens with Shelves.* For chamber ovens in continuous use, the cores being dried on individual shelves, it is necessary to determine the condition of the drying by inspecting the cores. In such ovens the products of combustion usually rise and pass out of the top and if there are partially baked cores on the upper shelves and subsequently green cores beneath them, the steam driven out of the green cores passes over the dry cores and the moisture may, to some extent, be absorbed by the dry cores, thus retarding their baking. In any case the presence of steam in the ascending current of air will retard the baking on the upper shelf. This is one reason why the lower shelves of a drying oven frequently bake faster than the upper shelves, even when the temperature of the incoming gases is kept well below the maximum allowable for the oven.

166 *Distortion of Metal Parts of Core Ovens.* Core ovens have been arranged in many cases so that the fire was 1 to 3 ft. from the cores being dried. The core cars have often been warped and bent out of shape by the fact that the flame from the fireboxes played against them. Iron will not be distorted at any temperature that is safe for the baking of cores, hence any warping of any metal work in the oven is evidence of too high temperature. For the proper regulation of the temperatures in core ovens, recording thermometers should be applied not only to the ovens themselves but to the main heat flues.

167 *Core-Oven Cars.* For efficient core-oven work the car must be designed so that it will support the cores without any danger of being distorted. The tracks for supporting the car must also be rigidly supported and kept in perfect condition. Too little attention is given to the design of this part of the core-room rigging. A firm installing a core oven will frequently order from the lowest bidder. From the day such an oven comes into commission it is a constant expense in the way of spoiled cores and time expended in unnecessary manipulation in getting the work to and from the oven. The core trucks or cars should run into the oven as easily as any other part of the industrial transportation system, and there is no need of having to bring a 25-ton travelling crane to the front of the core oven and couple it to the truck by an intricate system of chains and blocks in order to shove 5 tons of cores into the oven.

## CORE PASTING, HANDLING, AND STORAGE

168 With the increasing demands from the designing department for greater accuracy in finished castings, it has been necessary to

improve the core-room rigging to insure the accurate fit and location of the cores. For convenience many cores are made in halves so that they can be dried on flat plates. This method also affords an opportunity for the forming of vent passages on the parting. Fig. 33 shows a pair of half cores and the vent block which was used in pressing vents in the cores. The horizontal strips attached to the blocks press grooves in the face of the cores that lead the vent to the face of the print and the vertical or projecting pins press vents into

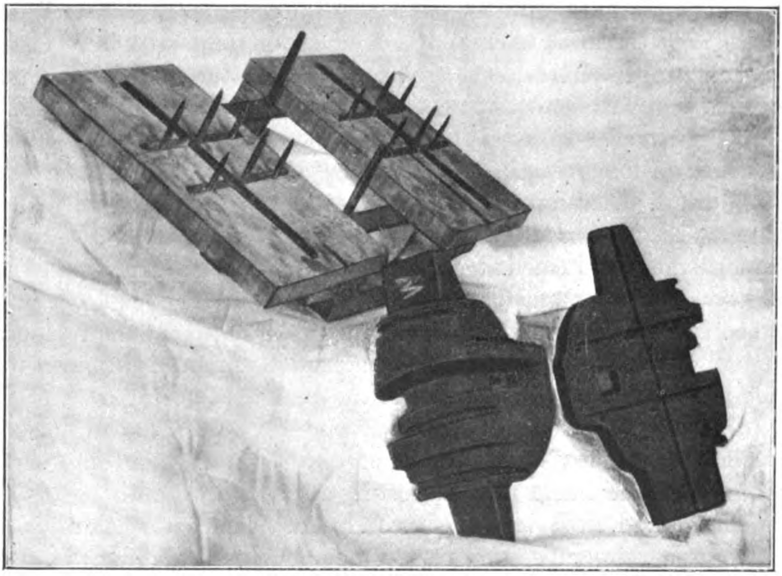

Fig. 33 Block for forming Press Vents in Cores and Press-Vented Cores

the pockets of the core. After baking they must be assembled and pasted together.

169 *Core-Pasting Device.* John Gow of the General Electric Company has contrived and patented the device for core-pasting shown in Fig. 34. It consists of a shallow wooden box made of pine, well protected with shellac. Through the bottom of this box is cut a series of grooves corresponding to the line of paste required to unite the parts. The core shown at the left is laid in the box, being guided into place by the three guide blocks. The box with the core in place is then placed in a tank containing 2 or 3 in. of liquid paste. The box

is pressed into the paste so as to force it up through the groove into contact with the face of the core. When the box is lifted out once more and the core removed there will be long narrow strips of paste where they are required on the face of the core. The two halves of the core are then assembled and placed in the drying oven to dry the paste. This method is economical of paste and applies the material very much more rapidly than it could be done by hand. It also

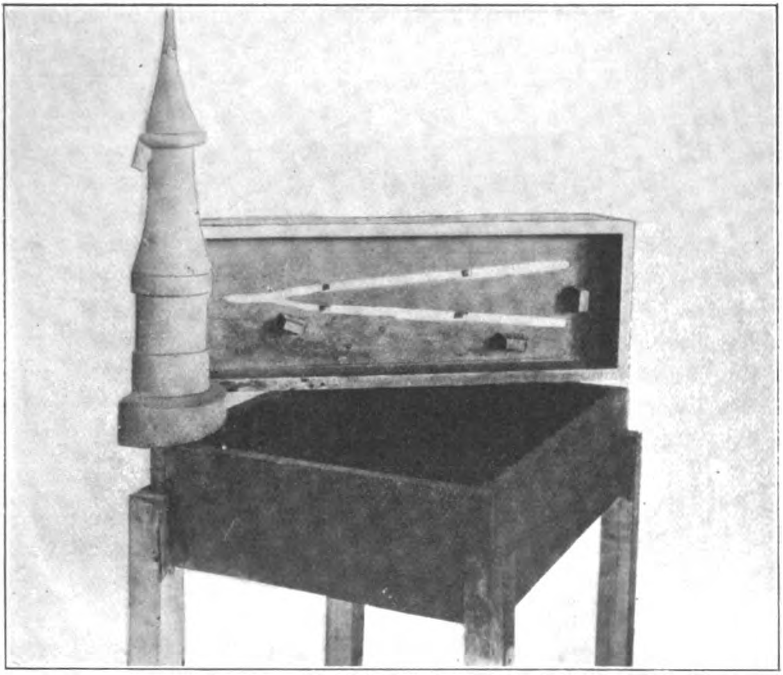

Fig. 34 Pasting Device for pasting Split Cores

avoids all possibility of getting paste into the vents. Where duplicate work is to be done it has proved an excellent time saver.

170 *Drying Pasted Cores.* After the cores are pasted it is necessary to dry the paste before introducing the cores into the molds. In some cases a torch is used to dry the paste near the edges of the parting and the cores sent directly to the mold, but the maximum adhesion of the paste has not been developed and the core is likely to shift. Generally a regular core oven is used for drying, the pasted cores being placed on plates and introduced on to core-oven cars or placed in drawer ovens.

171 A device for pasting and drying cores in large quantities is shown in Fig. 35. The table supporting the core plates consists of angle iron legs which carry angle iron rails running along the sides. These in turn support cross bars carrying a pair of ordinary railroad rails upon which the core plates may be placed. The hood is lifted off while the cores are being assembled. The cores are pasted on the plates with the use of suitable portable pasting jigs. As soon as one entire bench of cores has been pasted the hood *C* is dropped over

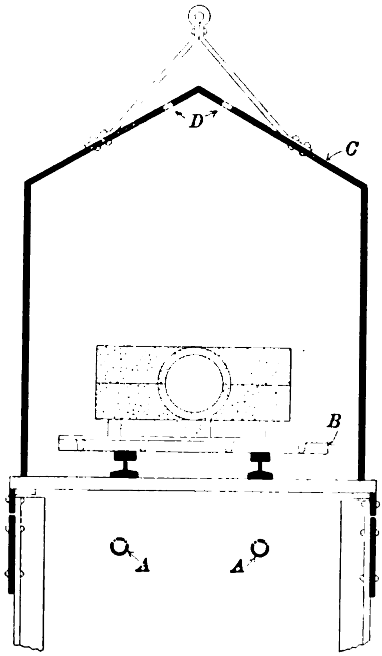


FIG. 35 PORTABLE HOOD USED IN DRYING PASTED CORES

the structure as shown. The gas pipes *AA* are provided with perforations through their entire length and when *C* is dropped in position the gas is turned into the pipes and lighted. The heat from the gas jets issuing from the pipes *AA* rising under the core plates *B* is deflected by them to the sides of the hood, and surrounds the cores with hot air so as effectually to dry the paste. For ventilation a series of small holes near the top of *C* is arranged as shown at *D*. As soon as one bench full of cores is covered with its hood and the cores are drying the workmen pass to the next bench and begin to paste cores on it. By the time they have pasted them on four or five benches those on the first are dried, so that the gas can be turned off, the hood lifted and the cores removed. This scheme does away with the handling of the cores while the paste is green and avoids possibilities of cores shifting.

172 *Core-Assembling Jigs.* For assembling automobile cores various types of jigs have been devised. The principle on which these jigs work is well illustrated in Figs. 36 to 40. Fig. 36 represents a jig for filing the pasting faces of cores. The upper edges of this jig are protected with pieces of tool steel which have been made as hard

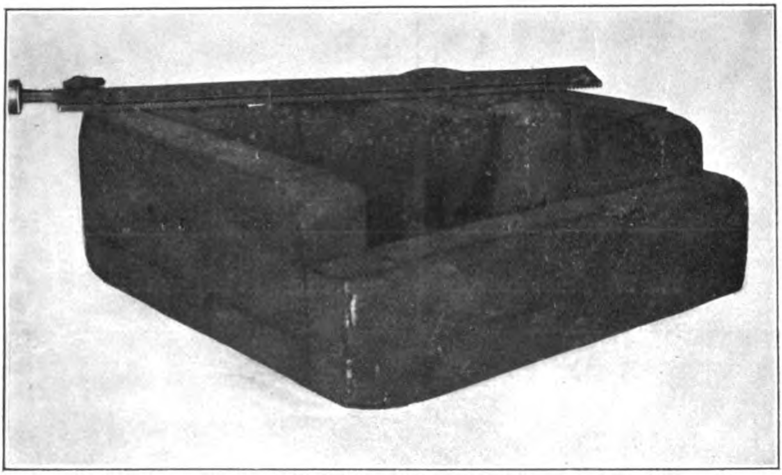

FIG. 36 JIG FOR FILLING PASTING SURFACE OF JACKET CORES

as fire and water could make them, so that they will not be affected by passing a file over them. The core is dropped into the jig shown in Fig. 36 and a coarse file passed over the pasting face so as to bring it to a uniform surface. The core boxes are so constructed as to allow about 0.01 in. on the core face for filing. The lower half of the core is then placed in a jig as shown in Fig. 37. The paste is applied to the surface and the next section of the core placed in position as shown in Fig. 38. In this case it was a small section at the back of the core. The paste is then applied to the next surface and the upper half of the core is introduced as shown in Fig. 39. In taking the illustration a set of unfiled cores were assembled in the jig so that the parting is not perfect, as it would be in the case of filed cores. After the cores have been assembled in the jig they may be removed and placed on the core plate for drying in the oven or the entire jig may be placed in the oven and the cores dried in the jig. Where a limited number of

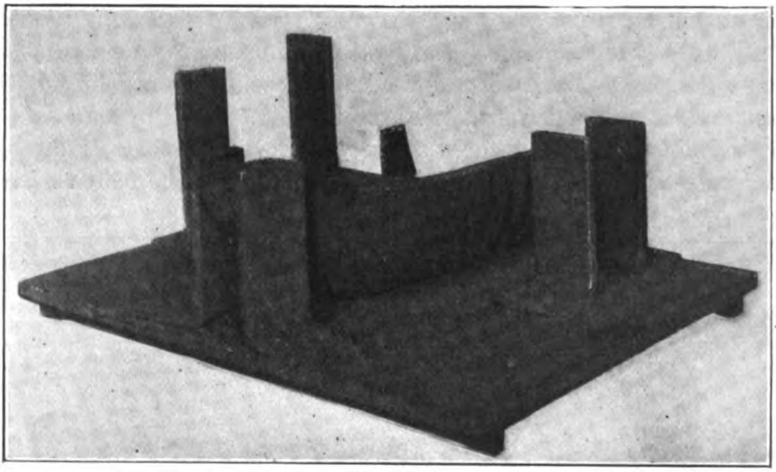

FIG. 37 FIRST SECTION OF CORE PLACED IN PASTING JIG

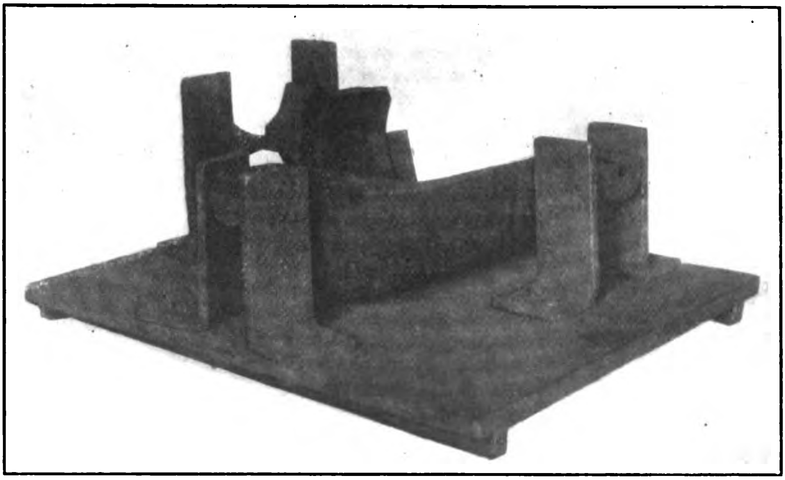

FIG. 38 PASTING JIG SHOWING SECOND SECTION OF CORE IN PLACE

cores is required it is best to dry the cores in the jig, but with a large number the amount of equipment in the shape of jigs would be prohibitive, and hence the cores are removed before drying.

173 *Core-Testing Gages.* After the cores have been dried they are tested by means of various gages, a set of which is shown in Fig. 40.

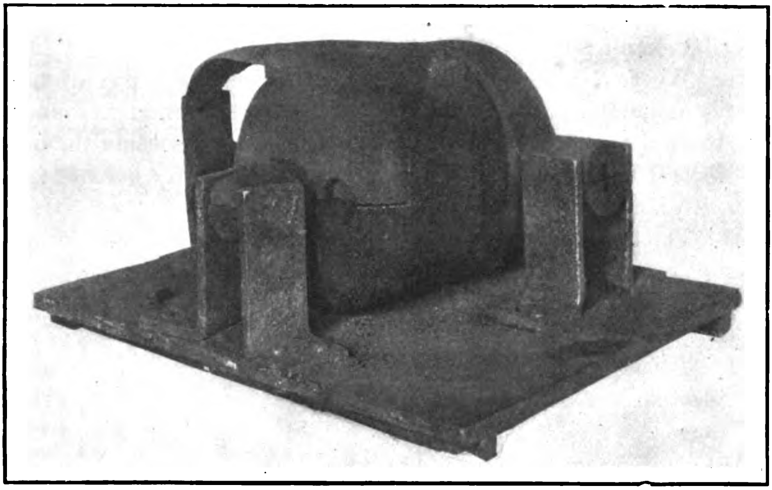

FIG. 39 PASTING JIG SHOWING COMPLETED CORE IN PLACE

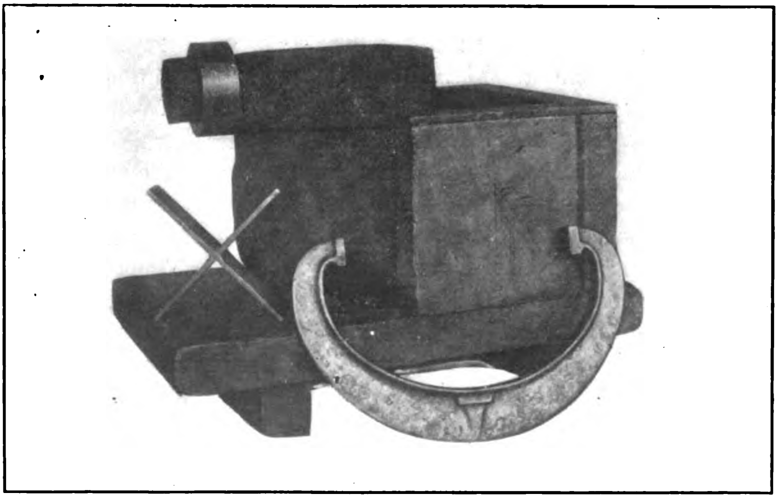

FIG. 40 GAGES FOR TESTING CORE

The core is placed on a steel plate and the shoulder at the right is filed off by passing a file over the hardened steel plates surrounding this portion of the core. This insures the proper length of the core from shoulder to shoulder. The interior diameter of the core is tested with the star gage shown at the left; the exterior diameter with the caliper gage shown at the right; and the print by the ring gage shown at the upper left-hand portion of the illustration.

174 Where a large output of cores is required these jigs are made entirely of metal, and it is no uncommon thing for the modern foundryman to hold his core work within limits of a few thousandths of an inch for medium sized cores and within 0.01 in. for cores 1 ft. or more in diameter or length.

175 The use of core jigs is not confined to small work such as cores in connection with automobile castings, but may be applied to steam engines or any large work. A wooden or metal frame may be constructed with bearing points corresponding to the bearing points which carry the cores in the mold. The cores to be tested can be lowered into one of these jigs with the crane and then by means of suitable gages the metal thickness that will be left at all points can be ascertained before the core is placed in the mold.

176 *Core-Setting Jigs and Gages.* It is also possible to use setting jigs for placing cores in the mold to insure the proper fit of the various parts. Fig. 41 represents the drag half of a cylinder mold for a large gas engine. In this case the cores are supported on arbors which fit in prints at the ends of the molds, the prints being shown at the front and back of the mold. Fig. 42 illustrates the same mold with the main barrel cores in place and the core jig located over the top of the barrel cores to measure the setting of the barrel cores. This jig may be placed anywhere along the length to see if they are straight and properly set at all points. The illustration shows a type of cylinder for a 2-cycle engine, the compression cylinder being at the right and the ordinary working cylinder at the left. The compression cylinder does not need water jacketing.

177 The drag half of the mold with all of the cores assembled is shown in Fig. 43. After the upper half of the jacket core is in place a caliper gage may be used to see that the space between the barrel and the jacket is correct and a gage similar to that shown in Fig. 42 may be used to test the outside of the jacket core if desired.

178 *Handling the Dry Cores.* The handling of cores is of importance. Every time a core must be picked up and set down there is danger of its being broken and an expense for the labor involved. Cores should pass from the oven to the molder with the fewest handlings consistent with the maintenance of a sufficient stock of cores to

insure continuous work in the foundry and also with distribution of the work in the core room so as to allow the coremakers to complete batches of a given style of cores in the most efficient manner.

179 Where the operations are such that a constant number of standard cores are required they should be taken from the core-oven trucks, and placed directly on some form of carrier which will deliver them to the molders. In the case of small chunky cores such as are used in fitting shops the cores are often piled into boxes and these in

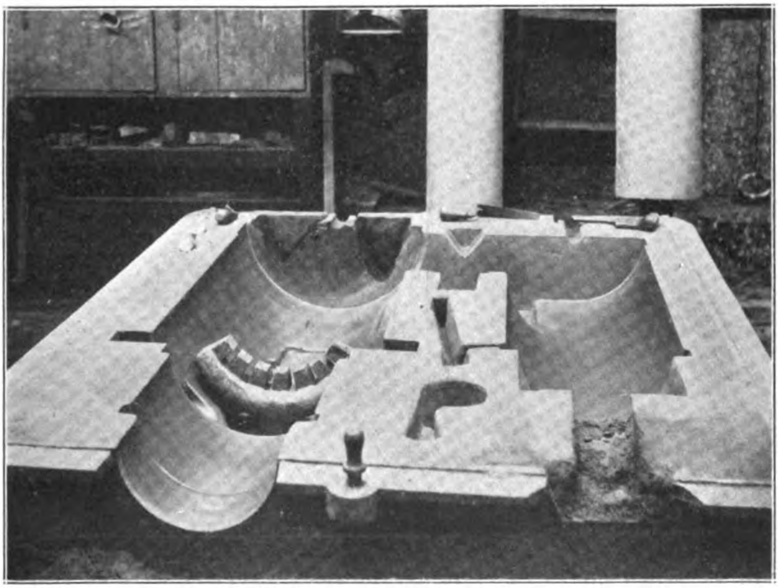

FIG. 41 MOLD FOR LARGE 2-CYCLE GAS-ENGINE CYLINDER WITH PORT CORES IN PLACE, SHOWING SUPPORTS FOR CORE ARBORS

turn laid on the trucks or on racks supported from overhead trolleys and then transported to the molders. Where cores must be passed to a storage or must be pasted subsequently to drying, they can be taken from the core-oven trucks, laid on industrial railway cars and delivered to the storage or pasting departments and to the foundry as required.

180 *Handling Green Cores.* Where possible the coremaker should place the plate carrying the green cores either on the shelves of the core-oven truck in which it is to be dried or on a conveyor which will carry the cores to the core oven. For medium sized plants one

of the most efficient methods is to have the core-oven trucks so designed that they will run on tracks between the coremaker's benches. The coremakers place the cores on the shelves of the truck and laborers then run it out from between the benches to a transfer car which delivers it to the oven in which the cores are to be baked. After the cores are dried the truck carrying the dry cores may be taken to the core storage or the dry cores may be placed on

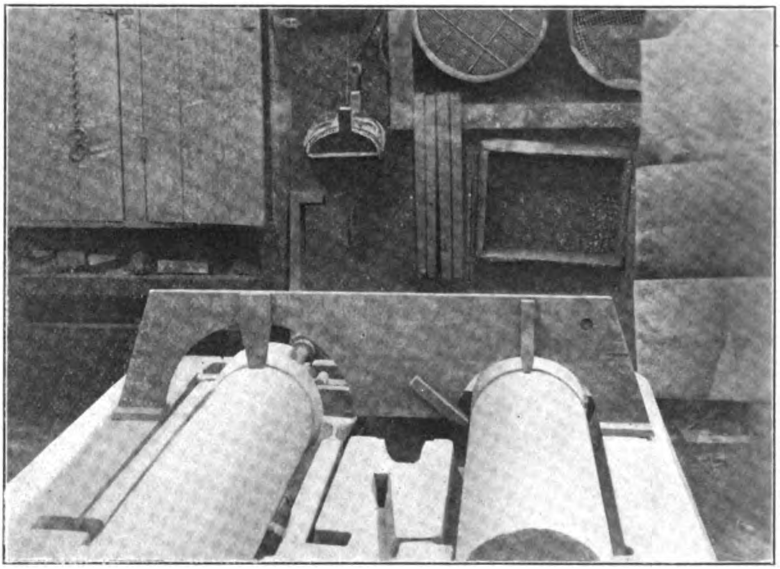

FIG. 42 MOLD FOR 2-CYCLE GAS-ENGINE SHOWING LOWER HALF OF JACKET, CORES AND BARREL CORES IN PLACE, WITH GAGE FOR TESTING CORE SETTING

industrial railway trucks or carriages supported from a trolley system and carried either to the storage or the foundry.

181 *Protecting Cores from Dampness.* Complaints are constantly made to the effect that flour, starch, dextrine, or glutrin cores become soft if left in storage. The reason for this is that if exposed to moisture-ladened air these cores will absorb moisture. The author has seen a core storage located in a cold unheated building with the exhaust from an engine playing past the unclosed windows so that the exhaust steam came in over the cores in clouds. They might just as well have played water from a hose over them so far as the effect was concerned.

182 On the other hand, there are a good many heated core storages. In most cases these are located over the core ovens and take advantage of the waste heat from the core ovens. In other cases they are located over malleable annealing ovens or in any place where there is waste heat available. In some other cases they are heated with steam coils or stoves fired with coke or natural gas. The author has seen flour cores taken from such a heated storage and used after they had been in storage for three years, and they were

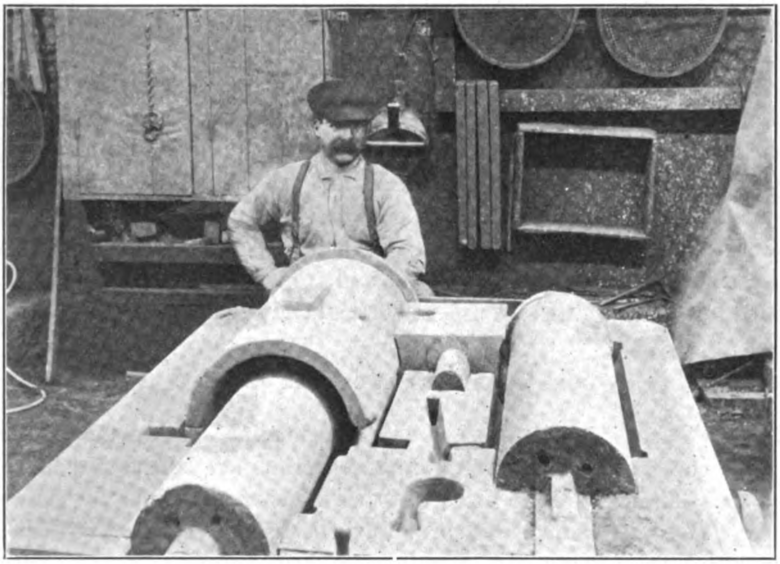

FIG. 43 MOLD FOR 2-CYCLE GAS-ENGINE CYLINDER, CORES SET

just as good as the day they were made. Glutrin cores made with gangway sand have been used after they were many months old.

183 In many plants it is the practice to leave cores standing upon the molders' floor from one to three days before they are used or to introduce them into molds long before they are used.

184 *Moisture in Molding Sand.* In order to ascertain the moisture conditions that the core must meet in the mold, samples of the molding sand were taken from many foundries in different parts of the country and moisture determinations made. The amount of moisture used in molding sand was found to vary from less than 5 per cent to over 10 per cent, and in the same foundry it will frequently vary 3 per cent in a single day. By watching the molding operations

the author has been able to predict which molds would be lost before they were poured, and these predictions were verified when a badly blown casting was shaken out. In one case the foundryman had been blaming first the iron and then the coremaker, it was proved conclusively that the trouble lay in the too free use of the swab on certain molds. A core made from any of the standard binders should be able to remain in the mold from morning until afternoon without any danger of its absorbing an excessive amount of moisture, providing the core has not been subjected to undue moisture in the storage or the molding sand has not been worked too wet or overswabbed.

185 *Location of Core Storage.* The core storage in any plant should be so designed and located that the cores can be handled with the least amount of labor and also so that the number of cores of any given kind on hand may be ascertained readily at any time. The placing of the core storage on the second floor usually makes it possible to utilize some waste heat for the protection of the cores, and the transportation of the cores to and from the storage by elevator adds but little to the expense, as vertical transportation is very cheap.

## CORE MACHINES AND CORE RIGGING

186 *Types of Core Machines.* Core machines in so far as they affect core sands and core-binding materials are considered in this paper. There are four distinct types of core machines in general use. The best known and probably the oldest type is that which corresponds to the hand-rammed molding machine. In this case the core boxes are simply attached to a molding machine, the core sand rammed in the boxes and the machine used for rolling over and drawing the boxes away from the finished core.

187 Another type of machine which has long been in use is the screw-feed machine forming a core through a die. The plunger-feed machine works on the same principle so far as the die is concerned. In a machine of this kind the core mixtures must be forced through a die and on to a plate. Such a mixture must contain sufficient green binder to make the core stand up on the plate and sufficient oil to make it slip on the plate without being torn up. These conditions are antagonistic, as the green binder depended upon is usually flour and the core oil neutralizes much of the effect of the flour. Core mixtures for use in machines in which the core is forced through a die must contain an excess of binder, but the capacity of the machines is usu-

ally sufficient to more than pay for the excess of binder used. Such cores usually vent fairly freely in spite of the excessive amount of binder and the reason for this is that the large amount of flour used shrinks greatly during drying, thus giving added vent space.

188 Where silica sand or a good sharp sand is used as a base with a proper binder the cores will neither shrink nor swell appreciably during baking, and in fact, George H. Wadsworth has succeeded in producing both square and round cores which were kept within limits of 0.004 in. over or under a given size. This is a total allowable variation of less than 0.01 in. Machines of this type, that is, either the screw-feed or plunger-feed machine, are extensively used for forming parallel sided stock cores.

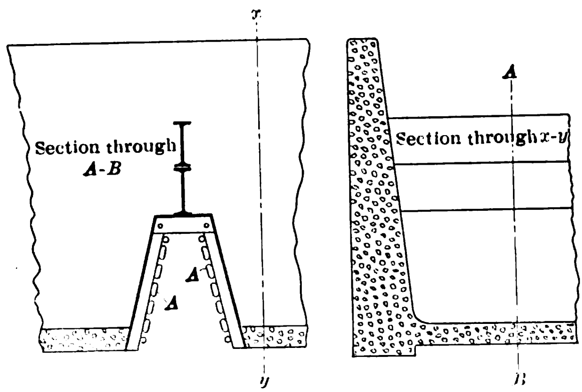


FIG. 44 SECTIONS OF BIN FOR STORING LARGE QUANTITIES OF SAND

189 For forming irregular cores a new type of machine has come on the market within the last few years. This is known as the Hulet machine, manufactured at Kankakee, Ill. In this the core mixture is blown into the core box by compressed air and the packing accomplished by the impact of the sand as it enters.

190 The jar-ramming molding machine was very promptly applied to core making, and a large variety of special jar-ramming machines have been developed for this purpose. Jar-rammed cores vent more freely than hand-rammed cores on account of the fact that hand ramming tends to form hard faces which effectually block the flow of the gases through the mold and so interfere with the vent. In the case of automobile cylinder jacket cores and other intricate work made from silica sand and oil mixtures jar ramming has almost eliminated the use of artificial vents.

191 In the case of large cores made from pitch or black compound mixtures or from any mixtures suitable for heavy work the jar-ramming machine can be used with special or ordinary standard boxes. A layer of facing sand is first shoveled in next the core box, the core arbors, and the core bars are introduced together with any coke or other material that may be required to form vent passages, the remainder of the sand is then introduced and the whole mass jar-rammed, the core arbors and core bars settling down into the sand as it is rammed. This results in a uniformly rammed core which does not have a tendency to swell and become irregular in drying as is often the case with hand-rammed cores. Such a core also vents more freely than a hand-rammed core.

192 These advantages alone would be sufficient to induce foundrymen to introduce core machines into their foundries, but there is the additional advantage of larger output and the author is convinced that in the future there will be an increasing use of machines for forming cores in the foundry. In addition to the types of machine already specially referred to nearly every type of molding machine has found its application in the making of some kind of special cores. The roll-over molding machine is being used extensively for the production of automobile jacket cores.

193 *Sand-Handling Equipment.* Particular attention should be given to the storage, preparation and mixing of core sands. The sand should be put into storage at the time of year when it is driest, as this saves freight and also insures sand in better condition for core work. Core sand should always be kept under shelter.

194 The method of storing sand will depend largely upon the size of the plant. For comparatively small plants a series of covered bins may be arranged in the basement and the sand introduced into them through chutes in the side of the building from a switch outside or dumped into them through hatches in the roof.

195 For the storage of large quantities of sand, concrete bins are best. Fig. 44 illustrates the bin construction which has been used in a large steel foundry. The bins are separated by division walls, the lower part of which are made of steel plates supported on angle irons as shown. Inside of these low walls are steam coils *AA*, through which steam is circulated so as to dry and thaw out any excessively damp or frozen sand which may be received in bad weather. The upper part of the wall between the bins is simply composed of I-beams bolted one on top of the other. In a case of this kind the sand can be handled into the bins and from there to the foundry by means of a grab bucket operated by means of an electric crane.

196 For smaller plants some conveyor system is advantageous, the sand being conveyed from the bins to the mixing machinery by means of a belt conveyor. Where the cores are made by hand the core sand can be delivered to the operators' benches either by means of boxes carried on trucks or supported from overhead trolleys, or by a conveyor system, but in most cases the latter is more complicated, and for this reason not desirable. Another objection to it is that in most plants several core mixtures are in use and in some cases the same operator may work on different mixtures during different parts of the day. For moderate sized plants working only from four to ten bench coremakers, a mill of the Wadsworth type, that is, a small mixing and compounding mill with small rollers gives excellent results. The centrifugal core-mixing machine made by William Sellers & Company, Inc., of Philadelphia, has a larger capacity and is used in many plants.

197 The experiments tried in the mixing of sands at different foundries indicate that for all sharp sand mixtures the sands should be thoroughly mixed but not ground, and for this reason a paddle mixer working on the principle of the ordinary pug mill used in brick manufacture is suitable. The Standard Sand and Machine Company of Cleveland, Ohio, were pioneers in the making of this class of machinery and have developed combination paddle mixing and grinding machines suitable for various core mixtures and various capacities. In any case the plant should be equipped with some kind of mixing machinery, for hand mixing is not only expensive, but is not capable of uniform production and hence an excessive amount of binder would be used.

NOTE OF ACKNOWLEDGMENT

The apparatus comprising the equipment of the laboratory at Covington, Va., was furnished by the following firms: Wadsworth Core Machine and Equipment Co., of Akron, O.; The Acme Core Machine Co., of Cuyahoga Falls, O.; Detroit Core Machine Co., Detroit, Mich.; The Robson Process Co., Covington, Va.; Bristol Co., Waterbury, Conn.; W. S. Tyler Co., Cleveland, O.; The lenses were loaned by Spencer Lens Co., Buffalo, N. Y., and Sauveur and Boylston, Boston, Mass.

To test the advantage of milling core sands the Lumen Bearing Company of Buffalo, N. Y., placed at the author's disposal their Wardsworth compounding mill and core-room equipment. The author is also indebted to the Detroit Testing Laboratory for assistance in the examination of sands and advice in regard to methods, to Prof. Geo. W. Cravanaugh for work done on sands at Cornell University, and to many foundrymen throughout the country who have assisted in the work by furnishing information concerning their experiments or by carrying on experiments at his suggestion.

The micrographic investigation into the structure of cores was one of the most difficult phases of the work which was taken up. In this work assistance was received from the Detroit Testing Laboratory, of Detroit, Mich.; the Spencer Lens Co., of Buffalo, N. Y., and from Sauveur & Boylston, of Boston, Mass.

In connection with the investigation into the colloidal properties of sands the author wishes to express his indebtedness to George K. Elliott, of the Lunkenheimer Co., of Cincinnati, Ohio, to Prof. Edward Orton,, of the Ohio State University, and to the Agricultural Department and the Geological Survey at Washington.

The following manufacturers of foundry supplies have furnished standard core compounds or have given valuable suggestions and hints for the conducting of the work: The National Core Oil Co., Buffalo, N. Y., Spencer Kellog and Sons, Buffalo, N. Y., and The C. E. Mills Oil Co., Syracuse, N. Y. A number of chemists and metallurgists in different parts of the country have also co-operated by supplying information or advising as to the methods of procedure. Among these are William M. Davis, Lubrication Engineer, Boston, Mass., Alex. E. Outerbridge, of William Sellers & Co., Philadelphia, Pa., N. W. Shedd, of The Buffalo Foundry Co., Buffalo, N. Y.; also the chemists in connection with the Forest Testing Laboratories, of the United States Forest Service, at Madison, Wis.

# GAS POWER SECTION

## PRELIMINARY REPORT OF LITERATURE COMMITTEE

## (X)

### ARTICLES IN PERIODICALS[1]

CARBURADOR, EL. *El Comercio, June 15, 1911.* ¼ p.

On a method of obtaining the best results from carburetors.

COMBUSTIBLE PARA CALDERAS, EL GAS COMO. *El. Comercio, August 15, 1911.* ½ p. *f.*

Gas as a fuel for steam boilers.

COSTS OF GAS-ENGINE OPERATION, DISCUSSION ON, John H. Norris, *Proceedings of A.I.E.E., September 1911.* 5 pp.

COST COMPARISON OF SMALL GAS ENGINE AND STEAM PLANTS. *Electrical World, August 26, 1911.* ¾ p., 4 tables. *a.*

DIESELMOTORBAUES UND DIE VERSORGUNG MIT FLÜSSIGEN BRENNSTOFFEN, UEBERLICK UEBER DEN HEUTIGEN STAND DES, R. Diesel. *Zeitschrift des Vereines deutscher Ingenieure, August 12, 1911.* 9 pp., 2 curves. *f.*

Review of the present day status of Diesel motor construction and the present liquid fuel supply.

ELECTRIC VERSUS THE GASOLINE VEHICLE, THE, Hayden Eames. *Electrical World, August 26, 1911.* 2 pp. *a.*

ENCENDIDO DE LOS MOTORES, REGLAS PARA EL. *El Comercio, July 15 and August 15, 1911.* 1 p. *f.*

Rules to be observed in the matter of ignition with gas engines.

GASOLINA PARA REGADIOS, MERITO DEL MOTOR DE. *El Comercio, June 15, 1911.* ½ p. *f.*

The value of the gasolene motor in irrigation problems.

[1] Opinions expressed are those of the reviewer not of the Society. Articles are classified as *a* comparative; *b* descriptive; *c* experimental; *d* historical; *e* matematical; *f* practical. A rating is occasionally given by the reviewer, as *A*, *B*, *C*. The first installment was given in The Journal for May 1910.

Irrigación, Motores de Gasolina para la. *El Comercio, July 15, 1911.* 2 pp. *f.*

On gasolene engines for irrigation.

Kraftversorgung unserer Hüttenwerke durch Gichtgase, Wichtige Fragen aus der, Hubert Hoff. *Stahl und Eisen, July 13, 1911.* 12½ pp., 2 figs., 3 tables, 3 curves.

Important questions on the production of power for steel mills from blast-furnace gases.

Marine Motor, another French Diesel. *The Engineer (London), August 25, 1911.* 3 pp., 5 figs. *bfB.*

Describes a 420-b.h.p. 4-cycle Diesel type, reversible marine motor, built by Normand et Cie, Havre.

Molestias que Facilmente Pueden Remediaose en los Motores a Gas. *El Comercio, August 15, 1911.* 1 p. *f.*

Easily remedied troubles in gas engines.

Moteurs à Combustion Interne et en particulier le Moteur Diesel, Les, P. de Bousquet. *Bulletin de la Societé des Ingenieur Civil, April 1911.* 12 pp., 2 figs., 4 tables. *B.*

General description of combustion engines, in particular Diesel motors.

Moteurs à Gaz

———Robinets Oscillants, G. Richard. *Revue de Mécanique, June 31, 1911.* 2 pp., 8 figs. *bf.*

Copiés of letters of patents. Design and construction of oscillating valves for gas engines.

———Distributions sans Soupapes, G. Richard. *Revue de Mécanique, June 31, 1911.* 21 pp., 68 figs. *bf.*

Copies of letters of patents. Design and construction of piston valves for gas engines, valveless gas engines.

———Mises en Train et Changements de Marche, G. Richard. *Revue de Mécanique, July 31, 1911.* 2½ pp., 11 figs. *bf.*

Copies of letters of patents. Design and construction of attachments to reverse the revolution of gas engines.

———Réglages. *Revue de Mécanique, July 31, 1911.* 7 pp., 24 figs. *bf.*

Copies of letters of patents, articles from technical press. Design and construction of admission valves, mixing chambers for gas engines.

———Distribution par Soupapes. *Revue de Mécanique, July 31, 1911.* 9 pp., 33 figs. *bfA.*

Copies of letters of patents, articles from technical press. Design and construction of exhaust and admission valves for gas and gasolene motors.

———PISTONS. *Revue de Mécanique, July 31, 1911.* 1 pp., 3 figs. *bf.*

From Engineering, December 1910. Design and construction of gas engine pistons.

———INJECTION D'EAU. *Revue de Mécanique, July 31, 1911.* 2 pp., 4 figs. *bf.*

From Engineering Laboratory (Cambridge). Design and construction of a gas engine (Hopkinson) with water injection into the cylinder.

MOTOR BOAT FOR CHINA, COMMERCIAL. *Engineering, August 11, 1911.* 1½ pp. 5 figs. *b.*

Machinery consists of a 6-cycle 45-h.p., 800-r.p.m., Djinn petroleum engine.

OELMASCHINE, DIE NEUERE ENTWICKLUNG DER ORTFESTEN, A. Nägel. *Zeit, schrift des Vereines deutscher Ingenieure, August 12, 1911.* 26½ pp., 78 figs., 3 tables, 67 curves. *bdf.*

An exhaustive and very interesting article on the later development of the stationary oil engine.

PIEDRA DE CAL EN LA PRODUCCIÓN DEL GAS, LA. *El Comercio, June 15, 1911.* $\frac{1}{12}$ p.

Brief reference to certain experiments at Pittsburgh on using a mixture of coke and limestone in a gas producer.

RAILWAY MOTOR CAR, PETROL-ELECTRICAL. *The Engineer (London), August 4, 1911.* 2 pp. 5 figs. *bfB.*

Interesting in that it describes the Thomas system of transmission, which claims that at any time not more than one-third of the power is electrically transmitted.

ROHOEL MOTOREN, NEUERE, Ch. Pohlmann. *Dinglers Polytechniches Journal, July 8, 22, 1911.* 10 pp., 7 figs. *bf.*

Describes new types of crude oil engines.

SCHIFFS-SAUGGASMASCHINE DES EMPIRE OIL SYNDICATE, LONDON, EINE DOPPELTWIRKENDE. *Dinglers Polytechnisches Journal, August 12, 1911.* 3 pp. 4 figs. *B.*

Describes the construction of a 2-cycle suction gas engine with 3 double-acting cylinders.

SCHUTZE DER GAS UND WASSERRÖHREN GEGEN SCHÄDLICHE EINWIRKUNGEN DER STRÖME ELEKTRISCHER GLEICHSTROMBAHNEN, DIE DIE SCHIENEN ALS LEITER BENUTZEN. *Journal für Gas und Wasserversorgung, June 10, 1911.* 8 pp., 2 figs. *fA.*

From Verein deutscher Gas und Wasser Fachmänner. Laws and regulations for the protection of gas and water pipes against the deteriorating influence of the electric current. Direct current for surface car using the rails as a leader for the current.

Steigerung der Spezifischen Leistung von Viertakt-gasmaschinen mit Druckluftspülung, W. Hellmann. *Zeitschrift des Vereines deutscher Ingenieure, July 29 and August 5, 1911.* 11 pp., 14 figs., 3 tables, 6 curves. *bef.*

On the increased efficiency of 4-cycle gas engines using compressed air rinsing. Also extracted in Stahl und Eisen, August 10, 1911.

Turbine Problem, A Suggested Solution of the Gas., B. H. Blaisdell. *Power, September 5, 1911.* 2 pp., 1 fig., 1 table. *c.*

Describes a combustion chamber which fills with the combustible mixture before ignition, and when combustion occurs it is so rapid as to be practically an explosion.

Valve for Large Engines, Precision Mixing. *Engineering, September 1, 1911.* 1 p., 2 figs. *b.*

# GENERAL NOTES

## NEW ENGLAND WATER WORKS ASSOCIATION

The annual convention of the New England Water Works Association was held at Gloucester, Mass., September 13–15, 1911, with headquarters at the Hawthorne Inn. The following papers were presented and discussed: Coming Efficiency in Water Works Management, W. H. Richards; The Filtration of Salt Water, R. S. Weston; Hudson River Crossing of the Catskill Aqueduct, Robert Ridgway; A Short Account of Some Purification Experiments with a Surface Water in Queenland, Australia, Hardolph Wasteneys; Organization and Efficiency; E. M. Peck; Protection of Steel Pipes in the Catskill Aqueduct.

## INTERNATIONAL CONGRESS OF THE APPLICATIONS OF ELECTRICITY

An International Congress of the Applications of Electricity was held at Turin, Italy, September 9–20, 1911, on the initiative and under the auspices of the Italian Electrotechnical Association and of the Italian Electrotechnical Committee, during the period of the International Exhibition of Industry and Labor. Among the subjects presented for discussion were: Electrical and mechanical characteristics of modern electric generators, with special reference to very high-speed machines, Underground high tension networks in metallic connection with overhead lines; The problem of frequency transformation; Overhead line construction for electric railways; Rational methods of commercial measurement of electric power; Automatic telephone exchanges as a means of economy and improvement in telephonic communication in large cities; Distribution of electric power for agricultural purposes.

## INSTITUTE OF OPERATING ENGINEERS

The first annual meeting of the Institute of Operating Engineers was held in the Engineering Societies Building, New York, September 1–3, 1911. Short addresses were made by the following: F. R. Low, Mem. Am. Soc. M. E., The Operating Engineer's Future; D. B. Heilman, The Engineer's Place in the Community; A. C. Dougall, The Employer and the Engineer; James A. Pratt, Mem. Am. Soc. M. E., A Method of Teaching Operating Engineering; also by W. D. Ennis, Mem. Am. Soc. M. E., and F. H. Sykes. The following papers were presented for discussion: Temperature Changes and Heat Transmission, V. P. Rupp; A Boiler Room Analysis of Coal, J. P. Fleming; Cooling Towers vs. Steam Pumps, H. B. Geare; Engine Lubrication, R. D. Tomlison; Reduction of Lubricating Costs in Smelter Power Plants, G. L. Fales; Removing Emulsified Oil from Condensed Water, Darrow Sage.

## AMERICAN SOCIETY OF CIVIL ENGINEERS

A paper by G. B. Francis and J. H. O'Brien on The New York Tunnel Extension of the Pennsylvania Railroad: Certain Engineering Structures of the New York Terminal Area, was presented at the opening meeting of the season of 1911–1912 of the American Society of Civil Engineers in New York, September 6. Mule-Back Reconnaisances and Economics Canal Location in Uniform Countries was presented for discussion at the September 20 meeting.

## AMERICAN PEAT SOCIETY

The annual meeting of the American Peat Society was held at Kalamazoo, Mich., September 21–23, 1911. The papers described the Canadian Government fuel plant at Alfred and those interested inspected a peat fuel plant in operation. The work of draining 300,000 acres of swamp land in North Carolina was also described in a paper by Joseph H. Pratt.

## ROADMASTERS' AND MAINTENANCE OF WAY ASSOCIATION

The annual convention of the Roadmasters' and Maintenance of Way Association was held at the Southern Hotel, St. Louis, Mo., September 12–15, 1911. The subjects for committee reports were as follows: Use of manganese steel for frog, switches and crossings; Is it economy to use soft ties for track and at switches; How to remedy soft spots in roadbed; Motor cars for section work; Concrete and steel ties; Treated wood ties; Emergency stock of tools; New appliances for track and maintenance work.

## AMERICAN ASSOCIATION FOR LABOR LEGISLATION

A conference was held under the auspices of the American Society for Labor Legislation at the Auditorium Hotel, Chicago, Ill., September 15–16, 1911. One of the subjects was the Standardization for Accident Prevention in which the following took part: John Calder, Mem. Am. Soc. M. E., on Scientific Accident Prevention; Edgar T. Davis, Safety Standards through State Inspection; Robert J. Young, Practical Safety Devices. This was followed by discussions on Administration by Commissions, Uniform Accident Reports, Administration of Workmen's Compensation Acts. A business meeting of the general administrative council of the association for the discussion of an immediate legislative program closed the conference and was as follows: (*a*) Prohibition of poisonous phosphorus in the manufacture of matches; (*b*) Investigation of occupational diseases; (*c*) Reporting of industrial accidents and injuries; (*d*) Enforcement of labor laws. A special feature of all the sessions was exhibits of photographs and charts illustrating the topics discussed.

# PERSONALS

Charles U. Carpenter, formerly president of the Herring-Hall-Marvin Safe Co., Hamilton, O., has been elected president of the Fire-Proof Furniture and Construction Co., Miamisburg, O., and vice-president of the Republic Motor Car Co., Hamilton, O.

Henry R. Cornelius who was connected with the Southward Foundry, and Wisconsin Engine Companies, in the capacity of sales manager, has accepted a similar position with the Mesta Machine Co., Pittsburgh, Pa.

Charles I. Corp has been appointed associate professor of mechanical engineering, University of Kansas, Lawrence, Kan.

Ed. G. BuBarry has accepted a position with the Minneapolis Steel and Machinery Co., Minneapolis, Minn. He was formerly identified with the Duquesne Steel Works, Duquesne, Pa., in the capacity of draftsman.

Walter B. Gump has been placed at the head of the electrical school which has been started by the Young Men's Christian Association at Los Angeles, Cal.

Edwin M. Herr, who since 1905 has been vice-president in active charge of the manufacturing and commercial operations of the Westinghouse Electric & Manufacturing Co., was elected permanent president of the corporation.

Winslow H. Herschel has been appointed assistant professor of mechanical engineering, University of Maine, Orono, Me.

James D. Hoffman, formerly professor of engineering design of Purdue University, Lafayette, Ind., has become connected with the University of Nebraska, Lincoln, Neb.

O. P. Hood, head of the departments of mechanical and electrical engineering of the Michigan College of Mines, Houghton, Mich., has accepted an appointment as chief mechanical engineer of the United States Bureau of Mines, and will make his headquarters in Pittsburgh, Pa.

John H. Kelman has become identified with the Witherbee Igniter Co., Springfield, Mass. Mr. Kelman was formerly superintendent of construction of the National Electric Signaling Co., Brant Rock, Mass.

James Lyman has become associated with Sargent & Lundy, Chicago, Ill. He was until recently district engineer of the General Electric Co., Chicago, Ill.

Horace J. Macintire has been appointed instructor of mechanical engineering, Carnegie Technical Schools, Pittsburgh, Pa. He was formerly instructor in the engineering department of Harvard University, Cambridge, Mass.

F. M. Marquis, formerly associated with the railway engineering department of the University of Illinois, Urbana, Ill., has accepted a position in the turbine research department of the General Electric Co., West Lynn, Mass.

Robert F. Massa has entered the service of H. W. Johns-Manville Co., New York. He was formerly associated with the Creamery Package Manufacturing Co., Albany, N. Y.

J. E. Powell of Washington, D. C., has resigned his position of chief mechanical and electrical engineer in the office of the supervising architect, Treasury Department. Mr. Powell's resignation was due to ill health.

H. F. J. Porter has been appointed expert adviser on fire prevention to the Factory Investigation Commission appointed by the New York State Legislature, as a result of the Asch building fire in Januaiy last.

Manning E. Rupp has accepted a position as mechanical engineer with Stanley G. Flagg & Co., Philadelphia, Pa. Mr. Rupp was formerly in the department of construction and engineering of the Isthmian Canal Commission, at Panama and later associated with John W. King, consulting engineer, New York.

Walter G. Scott has assumed the duties of factory manager and production engineer with the Jenkins Motor Car Co., Rochester, N. Y. He was until recently connected with the Cyclone Drill Co., Orville, O., in the capacity of production engineer and systematizer.

Harry E. Smith has been appointed assistant professor of mechanical engineering of the Agricultural and Mechanical College of Texas, College Station, Tex. Mr. Smith was formerly professor of mechanical engineering of the James Milliken University, Decatur, Ill.

Charles E. Torrance, formerly instructor of experimental engineering, Sibley College, Cornell University, Ithaca, N. Y., has become associated with the Northampton Emery Wheel Co., Leeds, Mass.

K. O. Truell has entered the service of the Virginia Portland Cement Co., Fordwick, Va. He was until recently associated with the Colloseus Cement Co., New York.

Geo. L. Watson has resigned as chief engineer of the United Paving Co., Atlantic City, N. J., and as superintendent for Lockwood & Cherry of the same city, and has opened an office as consulting civil engineer in the Land Title Building, Philadelphia, Pa.

Burt C. Wear has entered the employ of the Youngstown Sheet and Tube Co., Youngstown, O. He was formerly connected with the Steel Roof Truss Co., St. Louis, Mo.

W. H. Whiteside, formerly president of the Allis-Chalmers Co., Milwaukee, Wis., was elected president of the Stevens-Duryea Automobile Co. of Chicopee Falls, Mass.

# ACCESSIONS TO THE LIBRARY

### With Comments by the Librarian

This list includes only accessions to the library of this Society. Lists of accessions to the libraries of the A. I. E. E. and A. I. M. E. can be secured on request from Calvin W. Rice, Secretary, Am. Soc. M. E.

Architecture, Engineering and the Building Law, D. H. Ray. (Reprinted from School of Mines Quarterly, vol. 32, no. 4). Gift of the author.

Automobile Engineering 1911. Annual. *London, 1911.*

Berechnen und Entwerfen der Schiffskessel. Hugo Buchholz and Hans Dieckhoff. *Berlin, 1910.*

Bureau of Railway Economics. Capitalization and Dividends of the Railways of Texas, 1909. Bull. no. 18. *Washington, 1911.*

——Comparative statement of physical valuation and capitalization. *Washington, 1911.*

——Conflict between federal and state regulation of the railways. Bull. no. 15. *Washington, 1911.*

——Railway wage increases for the year ending June 30, 1911. Retrenchment in the Railway Labor force in 1911. Bull. no. 17. *Washington, 1911.*

——Summary of revenues and expenses of steam roads in the United States for May 1911. Bull. no. 16. *Washington, 1911.* Gift of the bureau.

Die Dampfturbinen, A. Stodola. Ed. 4. *Berlin, 1910.*

Entwerfen und Berechnen der Dampfmaschinen, H. Dubbel. Ed. 3. *Berlin, 1910.*

Flies and Mosquitoes as Carriers of Disease, W. P. Gerhard. *New York, 1911.* Gift of the author.

Conference faite a l'Aero-Club de France la 27 Mai 1911 sur la Resistance de l'Air et l'Aviation, G. Eiffel. (Extrait de l'Aerophile. June 15, 1911.) *Paris, 1911.* Gift of the author.

Government Contracts. The decision of the Boston Dry Dock Case. (Reprinted from Engineering Record, March 11, 1911). *Washington.* Gift of Messrs. King and King.

Handbuch über Triebwagen für Eisenbahnen, C. Guillery. *München, 1908.*

Imperial College of Science and Technology and City and Guilds of London Institute. Calendar of the Imperial College (Engineering). Pt. 4, 1911. *London, 1911.* Gift of the college.

Indikator und seine Hilfseinrichtungen, Anton Staus. *Berlin, 1911.*

Institution of Civil Engineers. Report of the Conference held June 28, 29, 1911. Education and Training of Engineers. (Reprinted from The Times, July 5, 1911). *London, 1911.*

International Railway Fuel Association. Proceedings of the 3d annual convention. *Chattanooga, 1911.* Gift of the association.

KONDENSATION, F. J. Weiss. Ed. 2. *Berlin, 1910.*

KONDENSATION DER DAMPFMASCHINEN UND DAMPFTURBINEN, Karl Schmidt. *Berlin, 1910.*

LOUISIANA STATE UNIVERSITY. Announcement of the College of Engineering for 1911–1912. *Baton Rouge, 1911.* Gift of the university.

MCGILL UNIVERSITY, MONTREAL. Announcement of the Faculty of Applied Science, 1911–1912. *Montreal, 1911.* Gift of the university.

MARINE ENGINEER. Vol. 23, nos. 271–276; vol. 24, nos. 277–284; vol. 25, nos. 292-300; vols. 26–32. *London, 1901-1910.* Gift of T. J. Smith.

MASSACHUSETTS BOARD OF RAILROAD COMMISSIONERS. 39th Annual Report, 1907. *Boston, 1908.* Gift of the board.

MONTHLY OFFICIAL RAILWAY LIST. August 1911. *New York, 1911.* Gift of the Railway List Company.

MUNICIPAL ENGINEERS OF THE CITY OF NEW YORK. Proceedings, 1910. *New York, 1911.* Gift of the Municipal Engineers of the City of New York

NEW YORK CITY DEPARTMENT OF DOCKS AND FERRIES. Report on Physical Characteristics of European Seaports, 1911. *New York, 1911.* Gift of the Commissioner of Docks.

THE RUDDER. Vols. 12–15. *New York, 1901-1904.* Gift of T. J. Smith.

TESTING OF ENGINES, BOILERS AND AUXILIARY MACHINERY, W. W. F. Pullen. Ed. 2. *Manchester, Scientific Publishing Co., 1911.*

The first edition of this work was published in 1900. The progress of engineering since that time has necessitated an almost entire re-writing of the text, and the addition of a large number of illustrations. The volume is devoted to methods and apparatus, no references being given to tests which have been made. The last chapter treats of the methods of testing internal-combustion engines. Frequent acknowledgment is made of indebtedness to the publications of The American Society of Mechanical Engineers for descriptions of testing methods.

DIE THEORIE DER WASSERTURBINEN, Rudolf Eacher. *Berlin, 1908.*

TRAVELING ENGINEERS' ASSOCIATION. Committee Reports and Subjects for Discussion. 19th Annual Meeting, 1911. Gift of the association.

WERKSTATT-BETRIEB UND ORGANISATION MIT BESONDEREM BEZUG AUF WERKSTATT-BUCHFÜHRUNG, P. R. Grimshaw. Ed. 3. *Hannover, 1908.*

WORLD TRADE DIRECTORY FOR THE PROMOTION OF AMERICAN EXPORT TRADE. 1911. *Washington, 1911.*

## EXCHANGES

AMERICAN SOCIETY OF CIVIL ENGINEERS. Transactions, vol. 73. *New York, 1911.*

AMERICAN SOCIETY OF HEATING AND VENTILATING ENGINEERS. Transactions, vol. 15. *New York, 1909.*

INSTITUTION OF CIVIL ENGINEERS. Minutes of Proceedings, vol. 184. *London, 1911.*

WESTERN SOCIETY OF ENGINEERS. Constitution, List of Members and Officers, 1911. *Chicago, 1911.*

## UNITED ENGINEERING SOCIETY

RHODESIA CHAMBER OF MINES. 16th Annual Report, 1910. *Cape Town, 1911.* Gift of the Rhodesia Chamber of Mines.

## TRADE CATALOGUES

Butterfield & Co., *Derby Line, Vt.* Taps, screw plates, reamers, discs and tools, 96 pp.

Cutler-Hammer Co., *Milwaukee, Wis.* The Thomas meter for recording the quantity of flow of gases, 32 pp.

Duncan Elec. Mfg. Co., *Lafayette, Ind.* Bull. no. 20, Duncan direct-current watt-hour meter, 24 pp.

General Electric Co., *Schenectady, N. Y.* Bull. no. 4802, Type H transformer, 16 pp.; Bull. no. 4818, Couplings, 9 pp.; Bull. no. 4829, Electric locomotives for industrial railways, 17 pp.; Bull. no. 4382 Commutating pole generators, 6 pp.; Bull. no. 4835, Electrically driven pumps, 18 pp.; Bull. no. 4836, General Electric steam flow meter, 16 pp.; Bull. no. 4845, Curtis steam turbine generators of 100-1000 kw. capacity at 3600 r.p.m., 15 pp.; Bull. no. 4846, Alternating-current switchboard panels, 18 pp.; Bull. no. 4847, Belt-driven alternators, form B, 5 pp.; Bull. no. 4848, Automobile instruments, 3 pp.; Bull. no. 4849, Motor-generator sets, 19 pp.; Bull. no. 4850, Edison Mazda lamps, 26 pp.; Bull. no. 4851, Electricity in the service of steam railroads, 47 pp.; Bull. no. 4852, 50-ton electric locomotives, 11 pp.; Bull. no. 4853, Electric arc headlights, 14 pp.; Bull. no. 4855, Gas-electric motor car, 29 pp.; Bull. no. 4856, U. S. 13 roller-bearing trolley bases, 3 pp.; 4 stereofotos of electrical instruments, 4 pp.; Bull. no. 4863, Metallized filament lamps, 9 pp.; Bull. no. 4866, Thompson horizontal edgewise instruments for switchboard service, 15 pp.; Bull. no. 4867, Electric locomotives of 25-ton type, 15 pp.; Bull. no. 4870, 100-ton electric locomotives 18 pp.; Bull. no. 4872, Transformer, oil dryer and purifier, 9 pp.; Bull. nos. 4837–4842, Infolder of circuit brakes of various types, 147 pp.

Goulds Mfg. Co., *Seneca Falls, N. Y.* Bull. no. 105, Single-stage suction centrifugal pump, 16 pp.

Hess-Bright Mfg. Co., *Philadelphia, Pa.* Index cards for the Hess-Bright ball bearing data sheets, 10 cards.

Vulcanite Portland Cement Co., *Philadelphia, Pa.* Concrete in the country 112 pp.; Hair cracks or crazing on cement surfaces, 8 pp.; Suggestions on cement sidewalk paving, 32 pp.; Reinforced concrete for houses, 26 pp.; Concrete surface finishes, 12 pp.

# EMPLOYMENT BULLETIN

**The Society has always considered it a special obligation and pleasant duty to be the medium of securing better positions for its members. The Secretary gives this his personal attention and is most anxious to receive requests both for positions and for men available. Notices are not repeated except upon special request. Copy for notices in this Bulletin should be received before the 12th of the month. The list of men available is made up of members of the Society and these are on file, with the names of other good men not members of the Society, who are capable of filling responsible positions. Information will be sent upon application.**

## POSITIONS AVAILABLE

0117 Wanted by Ohio company building stationary engines, an energetic and competent engineer to take charge of the shop as superintendent. Must be familiar with modern methods of turning out work and able to put them into practice. Good opportunity for right party.

0118 Mechanical engineer, college graduate, three years' experience or more in general industrial plant engineering, machine and building design, concrete and steel construction. State salary, age and qualifications. Location within 75 miles of New York. No one who can not make good need apply.

0119 Three or four men for selling end, principally in vicinity of Boston, Chicago and Saint Louis; must have had actual engineering experience around steam plants as well as selling.

0120 Designer for automobile bodies. Salary $25 week to start. Communicate directly with Employment Bureau, Pierce-Arrow Motor Car Co., Buffalo, N. Y.

0121 Master mechanic capable of handling repair department of finishing works. Must be first-class executive, good disciplinarian and able to turn out the work at minimum cost; only thoroughly equipped and experienced man need apply. State fully, qualifications, experience, age and salary desired.

## MEN AVAILABLE

280 Member, extensive experience as superintendent and works manager desires position with machine shop, foundry, etc., making engines, turbines, pumps, air compressors or similar lines.

281 Member, 20 years' experience in engineering educational work, including shops, drafting, lectures, laboratory and administration, with special reference to mechanics, steam, hydraulic and industrial engineering and power plants; open for engagement at close of present term of contract.

282 Student member, mechanical engineer, at present employed as chief draftsman, desires position with consulting engineer. Four years' drafting experience in automatic, conveying, automobile and clay-working machinery, also plant design and some civil engineering. Good references.

283 Associate member, 20 years' experience selling machinery, wishes to represent manufacturer whose product is marketable in southern California.

284 Chief draftsman on steam design of power stations desires position with firm of consulting engineers. Experience in designing, construction, inspection and testing. Age 29 years.

285 Mechanical engineer, graduate Mass. Inst. Tech., eight years' experience in designing and manufacturing feed-water heaters, coiled and bent pipe, also several years' experience in manufacture and sale of radiators and sheet metal parts for automobiles.

286 Competent commercial engineer, age 35, Member, at present engaged as manager of industrial plant, desires new connection; experienced organizer and systematizer; 14 years' experience embracing mechanical, electrical, hydraulic and gas engineering. Successively and successfully held positions of assistant superintendent, superintendent, general superintendent and manager of industrial plants.

287 Graduate of Cornell. Twenty-five years' broad experience in manufacturing and steam engineering, including design, installation and contracting for power and heating plants.

288 Junior, would like to connect with manufacturing company as superintendent or assistant of plant, being responsible for up-keep, design and construction of additions or changes, or position with contracting engineer with an opportunity to form partnership.

289 Member, technical education and training, 12 years' experience, machine, mill, and power-house design, inspecting, estimating, corresponding, office work, etc. Desires change of position.

290 Associate, technical graduate, 12 years' wide and general experience designing and constructing factory and miscellaneous railway buildings, power and industrial plants. Familiar with street railway engineering work. Location preferably New York or vicinity.

291 Member, technical graduate, present position factory superintendent, desires to make a change; prefers East or Middle West. Twelve years' supervision of work, thoroughly familiar with locomotive construction and design, some experience with gas engine and general machine work. Familiar with modern shop organization, piece work and bonus systems.

292 Associate, desires to locate in the East, preferably near Philadelphia or New York. Fifteen years' experience as draftsman, squad foreman and checker, on blast furnaces, steel, rolling, pipe and tube mills, coke ovens and chemical apparatus.

293 Mechanical engineer, nine years' varied experience along mechanical and electro-metallurgical lines, associated with steel mills and structural works, also gas and electric furnace work, in capacities of supervision and trust, desires association with production or the engineering department of some reliable company, preferably in the vicinity of Philadelphia or New York.

294 Member, wide experience in design and manufacture of power plants; successfully developed sales organization, desires to meet considerable concern in the engineering field on strictly result basis, preferably to represent them in New York and develop their export possibilities. Good connection abroad and conversant with principal languages.

295 Associate, 35, graduate Mass. Inst. Tech., experienced in design and erection of special machinery and hoisting and material handling machinery, both with manufacturers and with large coal mining company.

296 Junior, experience in drafting room, construction and engineering office work in connection with power and industrial plant installations, desires to make a change.

297 Cornell graduate, ten years' practical experience in factory superintendence and maintenance, building construction, including reinforced concrete, and the installation and operation of power plant and factory machinery. Desires position with consulting or contracting engineers, or as executive engineer in manufacturing concern.

298 Member, technical graduate, 30 years' experience as machinist, toolmaker, designer and chief draftsman, mostly on improvement and design of manufacturing machinery, desires position as shop engineer or chief draftsman.

299 Member, owning basic patents, desires to offer his services in connection with the building and leasing of road paving machines of exceptional efficiency and corresponding economy.

## CHANGES IN MEMBERSHIP

### CHANGES IN ADDRESS

ABORN, George P. (1889; 1892), Mgr., Blake & Knowles Steam Pump Wks., East Cambridge, and *for mail*, 50 Garrison Rd., Brookline, Mass.

BENDIT, Louis (Associate, 1905) Mgr. West. Office, The Hope Engrg. & Supply Co., 504 N. Y. Life Bldg., Kansas City, and *for mail*, 134 W. Sea Ave., Independence, Mo.

BENNETT, Joseph A. (1907), Ch. Engr., Studebaker Bros. Mfg. Co., and *for mail*, 902 Riverside Drive, South Bend, Ind.

BERRYMAN, Wilson G. (Junior, 1905), Engr., Combustion Utilities Corp., 60 Wall St., New York, and *for mail*, 40 Murray St., Flushing, N. Y.

BRECKENRIDGE, C. E. (Associate, 1904), 232 State St., Flushing, N. Y.

BURGESS, Chas. Munroe (1897), Life Member; Galena, Kan.

CARPENTER, Charles U. (1907), Pres., Fire-Proof Furniture & Constr. Co., Miamisburg, and V. P., The Republic Motor Car Co., Hamilton, O.

CHACE, William W. (1908), Mech. Engr., Cleveland Twist Drill Co., Cleveland, and *for mail*, Beachland, Nottingham, O.

CLARK, Frank S. (Associate, 1909), Asst. Engr., Ohio Elec. Ry. Co., Springfield, O.

CLAYTON, J. Paul (Junior, 1911), 205 W. Hill St., Champaign, Ill.

COOK, Harry Hall (Junior, 1910), Ch. Engr., Coffin Valve Co., Boston, and *for mail*, 44 Massachusetts Ave., Springfield, Mass.

COOLEY, Hugh Nelson (Associate, 1910), 3414 Cedar St., Milwaukee, Wis.

CORP, Charles I. (Junior, 1904), Assoc. Prof. Mech. Engrg., Univ. of Kan. Engrg. Bldg., Lawrence, Kan.

CREELMAN, Frank (1894), The St. Agnes, Convent Ave., and 130th St., New York, N. Y.

DOOLITTLE, Harold Lukens (Junior, 1910), Ch. Designer, So. Cal. Edison Co., Los Angeles, and *for mail*, 127 N. Catalina Ave., Pasadena, Cal.

DOWNES, Nate Worswic (Junior, 1911), Ch. Draftsman, J. H. Brady, Cons. Engr. and Ch. Engr., Kansas City Sch. Dist., and *for mail*, Rm. J, Public Library, Kansas City, Mo.

DU BARRY, Ed. G. (Junior, 1910), Minneapolis Steel & Mchy. Co., and *for mail*, 2731 12th Ave., S., Minneapolis, Minn.

FLICKINGER, Harrison William (Junior, 1911), St. James Park, Dawson, Pa.

FREDERICK, Floyd W. (1907), Mech., Engr. Natl. Bd. of Fire Underwriters, 135 William St., New York, N. Y., and *for mail*, 315 S. 2d St., Bangor, Pa.

GATH, Andrew L. (Associate, 1906), Pres., Gath Mch. Tool Co., 61 Terrace, and *for mail*, 354 Franklin St., Buffalo, N. Y.

GREEN, John Stevenson (Junior, 1909), Eddystone Dept., Baldwin Loco. Wks., Philadelphia, and *for mail*, Box 171, Moore, Delaware Co., Pa.

HALL, Robert E. (1898; 1905), V. P. and Treas., The Goulds Mfg. Co., 58 Pearl St., Boston, and 1558 Beacon St., Waban, Mass.

HERR, Edwin M. (1891), Vice-President, 1911–1913; Pres., Westinghouse Elec. & Mfg. Co., East Pittsburgh, and *for mail*, 140 Hutchinson Ave., Edgewood Park, Pittsburgh, Pa.

HERSCHEL, Winslow Hobart (1910), Assst. Prof. Mech. Engrg., Univ. of Me., Orono, Me.

HOFFMAN, James David (1894; 1903), Univ. of Neb., Lincoln, Neb.

HONSBERG, August A. (1901), Engrg. Dept., East Ohio Gas Co., and *for mail*, Sta. B, Box 54; also, 5 Euclid Windsor Pl., Cleveland, O.

HOOD, Ozni Porter (1904), Ch. Mech. Engr., U. S. Bureau of Mines, 40th and Butler Sts., and *for mail*, Old Heidelberg Cottage No. 4, Braddock Ave. and Waverly St., Pittsburgh, Pa.

JACKSON, Dugald C. (1890), 84 State St., and Mass. Inst. of Tech., Boston, Mass.; also, D. C. & Wm. B. Jackson, 111 W. Monroe St., Chicago, Ill.

JACOBI, Albert W. (1885), Life Member; Cons. Engr., 192 Market St., and 20 Fabyan Pl., Newark, N. J.

JOHNSON, Bradley S. (Associate, 1909), Rep., The T. H. Symington Co., 623 Peoples Gas Bldg., Chicago, Ill.

JONES, John Emlyn (1907), Engineers Club, 32 W. 40th St., New York, N. Y.

KELMAN, John H. (1904), Witherbee Igniter Co., Springfield, Mass.

LAND, Frank (1900), Secy. and Treas., Land-Wharton Co., 912 Pa. Bldg., Philadelphia, Pa., and *for mail*, care of Mrs. C. L. Land, 205 W. 57th St., New York, N. Y.

LAPE, Willard E. (1890), Mech. Engr., 5 Cleveland Terrace, East Orange, N. J.

LEACH, William H., Jr. (1905), Crow Point, Hingham, Mass.

LEIGHTON, Edward I. (1892), V. P., The Cleveland Mch. & Mfg. Co., 4946 Hamilton Ave., and *for mail*, 1183 East Blvd., Cleveland, O.

LIBBY, Malcolm M. (1902; 1905; 1909), Canadian Fairbanks Co., 28 W. Front St., and *for mail*, 786 Keele St., Toronto, Ont., Canada.

LYMAN, James (1899), Sargent & Lundy, cor. Jackson and Michigan Blvds., Chicago, and 1308 Maple Ave., Evanston, Ill.

MACINTIRE, Horace Jas. (Junior, 1907), Instr. Mech. Engrg., Carnegie Tech. Schs., Pittsburgh, Pa.

MARQUIS, Franklin Wales (Junior, 1908), Turbine Research Dept., Genl., Elec. Co., West Lynn, and *for mail*, 173 N. Common St., Lynn, Mass.

MASSA, Robert F. (1904), H. W. Johns-Manville Co., 100 William St., New York, N. Y.

MAYHEW, Ray (Associate, 1910), Asst. Ch. Draftsman Mech. Dept., Minneapolis Steel & Mchy. Co., and *for mail*, 4500 36th Ave., S., Minneapolis Minn.

MEYER, C. Louis (Junior, 1909), Engr. and Sales Agt., Trussed Concrete Steel Co., 604 Wilson Bldg., Dallas, Tex.

MURRAY, Warren Edwards (1910), Ch. Engr., West. Sugar Refining Co., 23d and Louisiana Sts., San Francisco, Cal.

NEWBURY, George K. (Junior, 1904), 1514 S. 12th St., Harrisburg, Pa.

ORD, Henry C. (1905), Ch. Draftsman Mech. Dept., Dominion Bridge Co., Ltd., and *for mail*, 46 Bishop St., Montreal, P. Q., Canada.

RANSOM, Allan (Associate, 1903), Beverly Hills, Los Angeles, Cal.

REILLY, Wm. J. (1901), Dist. Sales Mgr., The Babcock & Wilcox Co., 435 17th St., and Shirley Hotel, Denver, Colo.

RICHARDS, Chas. Russ (1892; 1901), Univ. of Ill., Urbana, Ill.

RICHARDSON, George Edward (Associate, 1910), Genl. Elec. Co., Empire Bldg., Atlanta, Ga.

ROBESON, Anthony Maurice (1895), Somerville Hotel, St. Aubins, Jersey Island, England.

SALTZMAN, Auguste L. (1908), Asst. Ch. Engr., The Edison Cos., Edison Lab., Orange, and *for mail*, 53 Wilcox Ave., East Orange, N. J.

SARENGAPANI, T. S. (Junior, 1903), Head Draftsman, Pub. Wks. Dept., Madura, Madras, India.

SCOTT, Charles Felton (1911), 284 Orange St., New Haven, Conn.

SCOTT, Walter G. (Junior, 1909), Factory Mgr. and Production Engr., The Jenkins Motor Car Co., and 571 Park Ave., Rochester, N. Y.

SEAWELL, Bert W. (Associate, 1907), 186 State St., Brooklyn, N. Y.

SHAW, Arthur Derwood (Associate, 1905), Mgr., Francis Bros. & Jellett, 315 N. 15th St., Philadelphia, and 246 W. Johnson St., Germantown, Pa.

SHERMAN, W. D. (1907), Inventor, Cons. Engr., Arlington, Riverside Co., Cal.

SHERWOOD, Mather W. (1909), 1406 Liberty St., Franklin, Pa.

SMITH, Harry E. (1894; 1903), Asst. Prof. Mech. Engrg., Agri. and Mech. College of Tex., College Station, Tex.

SPURLING, O. C. (1907), West. Elec. Co., Hawthorne Sta., Chicago, Ill.

STEVENS, Alfred H. (1898; 1903), Engr. and Contr., 149 Broadway, New York, and *for mail*, 400 Ninth St., Brooklyn, N. Y.

TORRANCE, Chas. Everett (Junior, 1909), Northampton Emery Wheel Co., Leeds, and *for mail*, 15 Forbes Ave., Northampton, Mass.

TRUELL, Karl O. (Associate, 1906), Va. Portland Cement Co., Fordwick, Va.

WATSON, George Linton (Junior, 1905), Cons. Civ. Engr., Engineers Club, Philadelphia, Pa.

WEAR, Burt C. (Junior, 1905), Youngstown Sheet & Tube Co., and *for mail*, 272 Arlington St., Youngstown, O.

## NEW MEMBERS

COWGILL, Paul Everett (Junior, 1910), Instr. Engr. Dept., N. C. College of Agri. and Mech. Arts, West Raleigh, N. C.

GORDON, Albert Anderson, Jr. (1911), Supt., Crompton & Knowles Loom Wks., Worcester, Mass.

HOUCHIN, Ernest A. (1911), Pres., Houchin Aiken Co., 35-45 53d. St., Brooklyn, N. Y.

SAWYER, Luke Eugene (Junior, 1911), Apprentice, Babcock & Wilcox Co., and *for mail*, 137 Broadway, Bayonne, N. J.

WILKIE, Donald Cook (1911), Supt. Engr., Linggi Plantations, Ltd., Seremban, Federated Malay States.

## DEATHS

CANNIFF, William Lester, August 29, 1911.
CHRISTIE, James, August, 24, 1911.
HOPTON, Lemuel Robert, September 5, 1911.
McLAUGHLIN, James, August 18, 1911.
STRANAHAN, O. A., September 8, 1911.

# COMING MEETINGS

## October-November

**Advance notices of annual and semi-annual meetings of engineering societies are regularly published under this heading and secretaries or members of societies whose meetings are of interest to engineers are invited to send such notices for publication. They should be in the editor's hands by the 15th of the month preceding the meeting. When the titles of papers read at monthly meetings are furnished they will also be published.**

AMERICAN ELECTRIC RAILWAY ASSOCIATION
October 9–13, annual convention, Atlantic City, N. J. Secy., H. C. Donecker, 29 W. 39th St., New York.

AMERICAN GAS INSTITUTE
October 18–20, annual convention, St. Louis, Mo. Secy., A. B. Beadle, 29 W. 39th St., New York.

AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS
October 13, monthly meeting, 29 W. 39th St., New York. Secy., R. W. Pope.

AMERICAN INSTITUTE OF MINING ENGINEERS
October 10–17, annual convention, San Francisco, Cal., followed by trip to Japan. Secy., Joseph Struthers, 29 W. 39th St., New York.

AMERICAN RAILWAY BRIDGE AND BUILDING ASSOCIATION
October 17–19, annual convention, St. Louis, Mo. Secy., C. A. Lichty, C. & N. W. Ry., Chicago, Ill.

AMERICAN SOCIETY OF CIVIL ENGINEERS
October 4 and 18, bi-monthly meetings, 220 W. 57th St., New York. Secy., C. W. Hunt.

THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS
Monthly Meetings: New York, October 9; Boston, October 18; New Haven, November 15. Secy., Calvin W. Rice, 29 W. 39th St., New York.

ASSOCIATION OF RAILWAY ELECTRICAL ENGINEERS
November 6–10, annual convention, Chicago, Ill. Secy., J. A. Andreucetti, C. & N. W. Ry.

LAKES-TO-THE-GULF DEEP WATERWAY ASSOCIATION
October 12–14, annual convention, Chicago, Ill. Secy., Thos. H. Lovelace, Bank of Commerce Bldg., St. Louis, Mo.

LEAGUE OF AMERICAN MUNICIPALITIES
October 4–6, annual convention, Atlanta, Ga. Secy., John MacVicar, Dept. of Streets, Des Moines, Iowa.

IRON AND STEEL INSTITUTE
October 2–16, autumn meeting, Turin, Italy. Secy., G. C. Lloyd, 28 Victoria St., London, S. W., England.

NATIONAL ASSOCIATION OF RAILWAY COMMISSIONERS
October 10, annual convention, Washington, D. C. Secy., Wm. H. Connolly.

NATIONAL COMMERCIAL GAS ASSOCIATION
October 23-28, annual convention, Denver, Colo. Secy., Louis Stotz, 29 W. 39th St., New York.

NATIONAL MACHINE TOOL BUILDERS ASSOCIATION
October 10-12, annual convention, New York. Secy., Chas. E. Hildreth, 134 Gold St., Worcester, Mass.

RAILWAY SIGNAL ASSOCIATION
October 10-12, annual convention, Colorado Springs, Colo. Secy., C. C. Rosenberg, Bethlehem, Pa.

SOUTHERN ASSOCIATION OF CAR SERVICE OFFICERS
October 20, annual convention, Atlanta, Ga. Secy., E. W. Sandwich, A. & W. P. Ry., Montgomery, Ala.

## MEETINGS IN THE ENGINEERING SOCIETIES BUILDING

| Date | Society | Secretary | Time |
|---|---|---|---|
| October | | | |
| 5 | Blue Room Engineering Society | W. D. Sprague | 8.00 p.m. |
| 10 | American Society of Mechanical Engineers | C. W. Rice | 8.15 p.m. |
| 12 | Illuminating Engineering Society | P. S. Millar | 8.00 p.m. |
| 13 | American Institute of Electrical Engineers | R. W. Pope | 8.15 p.m. |
| 17 | New York Telephone Society | T. H. Lawrence | 8.00 p.m. |
| 20 | New York Railroad Club | H. D. Vought | 8.15 p.m. |
| 25 | Municipal Engineers of New York | C. D. Pollock | 8.00 p.m. |
| November | | | |
| 2 | Blue Room Engineering Society | W. D. Sprague | 8.00 p.m. |
| 9 | Illuminating Engineering Society | P. S. Millar | 8.00 p.m. |
| 9 | Institute of Operating Engineers | H. Collins | 8.00 p.m. |
| 10 | American Institute of Electrical Engineers | R. W. Pope | 8.00 p.m. |
| 13 | American Society of Mechanical Engineers | C. W. Rice | 8.00 p.m. |
| 16 | American Society of Engineer Draftsmen | H. L. Sloan | 8.00 p.m. |
| 16–17 | Society of Naval Architects and Marine Engineers | W. J. Baxter | All day. |
| 17 | New York Railroad Club | H. D. Vought | 8.15 p.m. |
| 21 | New York Telephone Society | T. H. Lawrence | 8.00 p.m. |
| 22 | Municipal Engineers of New York | C. D. Pollock | 8.00 p.m. |

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F. J. MILLER (4)

Note—Numbers in parentheses indicate number of years the member has yet to serve.

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*Sub-Committee on Steam of Research Committee*

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J. M. SMITH, *Temp. Chmn.*
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*Power House Piping*

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*Involute Gears*

W. LEWIS. *Chmn.*
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E. R. FELLOWS
C. R. GABRIEL
G. LANZA

*Engineering Standards*

HENRY HESS, *Chmn.*
H. W. SPANGLER
CHAS. DAY
J. H. BARR

*Standardization of Catalogues*

WM. KENT, *Chmn.*
M. L. COOKE
W. B. SNOW
J. R. BIBBINS

*Pipe Threads*

E. M. HERR, *Chmn.*
W. J. VALDWIN
G. M. BOND
S. G. FLAGG, JR.

*Society History*

J. E. SWEET
H. H. SUPLEE
F. R. HUTTON

*Tellers of Election*

W. T. DONNELLY
T. STEBBINS
G. A. ORROK

*Nominating*

R. C. CARPENTER
New York, *Chmn.*
R. H. FERNALD
Cleveland, O.
E. G. SPILSBURY
New York
A. M. HUNT
San Francisco, Cal.
C. J. H. WOODBURY
Boston, Mass.

*Committee to Formulate Standard Specifications for the Construction of Steam Boilers and other Pressure Vessels and for Care of Same in Service*

E. F. MILLER
C. L. HUSTON
C. H. MEINHOLTZ
R. C. CARPENTER
W. H. BOEHM
R. HAMMOND

NOTE—Numbers in parentheses indicate number of years the member has yet to serve.

## OFFICERS OF THE GAS POWER SECTION

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R. H. FERNALD

*Secretary*
GEO. A. ORROK

*Gas Power Executive Committee*

F. H. STILLMAN (5). *Chmn.*
G. I. ROCKWOOD (1)
C. J. DAVIDSON (1)
E. D. DREYFUS (1)
F. R. HUTTON (2)
H. H. SUPLEE (3)
F. R. LOW (4)

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WM. T. MAGRUDER, *Chmn.*
W. H. BALUVELT
E. D. DREYFUS
A. H. GOLDINGHAM
NISBET LATTA
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S. S. WYER

## OFFICERS OF STUDENT BRANCHES

| INSTITUTION | DATE AUTHORIZED BY COUNCIL | HONORARY CHAIRMAN | PRESIDENT | CORRESPONDING SECRETARY |
|---|---|---|---|---|
| Stevens Inst. of Tech. | Dec. 4, 1908 | Alex. C. Humphreys | A. E. Bauhan | A. D. Karr |
| Cornell University | Dec. 4. 1908 | R. C. Carpenter | F. E. Yoakem | D. S. Wegg, Jr. |
| Armour Inst. of Tech. | Mar. 9, 1909 | G. F. Gebhardt | C. E. Beck | F. H. Griffiths |
| LelandStanfordJr.Univ. | Mar. 9, 1909 | C. H. Shattuck | H. H. Blee | C. W. Scholefield |
| Brooklyn Poly. Inst. | Mar. 9, 1909 | W. D. Ennis | A. L. Palmer | R. C. Ennis |
| Purdue University | Mar. 9, 1909 | L. V. Ludy | L. Jones | H. E. Sproull |
| University of Kansas | Mar. 9, 1909 | P. F. Walker | W. H. Judy | M. C. Conley |
| New York University | Nov. 9, 1909 | C. E. Houghton | Harry Anderson | Andrew Hamilton |
| Univ. of Illinois | Nov. 9, 1909 | W. F. M. Goss | F. J. Schlink | E. J. Hasselquist |
| Penna. State College | Nov. 9, 1909 | J. P. Jackson | J. A. Kinney | H. S. Rodgers |
| Columbia University | Nov. 9, 1909 | Chas. E. Lucke | N. E. Hendrickson | J. L. Haynes |
| Mass. Inst. of Tech. | Nov. 9, 1909 | Gaetano Lanza | J. A. Noyes | R. M. Ferry |
| Univ. of Cincinnati | Nov. 9, 1909 | J. T. Faig | C. J. Malone | J. H. Schneider |
| Univ. of Wisconsin | Nov. 9, 1909 | H. J. B. Thorkelson | F. B. Sheriff | L. F. Garlock |
| Univ. of Missouri | Dec. 7, 1909 | H. Wade Hibbard | F. T. Kennedy | Osmer N. Edgar |
| Univ. of Nebraska | Dec. 7, 1909 | C. R. Richards | W. O. Forman | C. A. Bennett |
| Univ. of Maine | Feb. 8, 1910 | Arthur C. Jewett | A. H. Blaisdell | W. B. Emerson |
| Univ. of Arkansas | Apr. 12, 1910 | B. N. Wilson | W. Q. Williams | H. W. Barton |
| Yale University | Oct. 11, 1910 | L. P. Breckenridge | F. M. Jones | W. St. C. Childs |
| Rensselaer Poly. Inst. | Dec. 9, 1910 | A. M. Greene, Jr. | G. K. Palsgrove | H. J. Parthesius |
| State Univ. of Ky. | Jan. 10, 1911 | F. P. Anderson | G. C. Mills | H. L. Moore |
| Ohio State University | Jan. 10, 1911 | W. T. Magruder | H. A. Shuler | H. M. Bone |
| Washington University | Mar. 10, 1911 | | | F. E. Glasgow |
| Lehigh University | June 2, 1911 | | | |

## MEETINGS OF THE SOCIETY

*The Committee on Meetings*

L. R. POMEROY (1), *Chmn.*
C. E. LUCKE (2)
H. DE B. PARSONS (3)
W. E. HALL (4)
C. J. H. WOODBURY (5)

*Meetings of the Society in Boston*

I. N. HOLLIS, *Chmn.*
I. E. MOULTROP, *Secy.*
E. F. MILLER
R. E. CURTIS
R. H. RICE

*Meetings of the Society in New York*

W. RAUTENSTRAUCH, *Chmn*
F. A. WALDRON, *Secy.*
F. H. COLVIN
E. VAN WINKLE
R. V. WRIGHT

*Meetings of the Society in St. Louis*

E. L. OHLE, *Chmn.*
F. E. BAUSCH, *Secy.*
M. L. HOLMAN
R. H. TAIT
J. HUNTER

*Meetings of the Society in San Francisco*

A. M. HUNT, *Chmn.*
T. W. RANSOM, *Secy.*
T. MORRIN
W. F. DURAND
E. C. JONES

*Meetings of the Society in Philadelphia*

T. C. McBRIDE, *Chmn.*
D. R. YARNALL, *Secy.*
W. C. KERR
A. C. JACKSON
J. E. GIBSON
J. C. PARKER

*Meetings of the Society in New Haven*

E. S. COOLEY, *Chmn.*
E. H. LOCKWOOD, *Secy.*
L. P. BRECKENRIDGE
F. L. BIGELOW
H. B. SARGENT

### SUB-COMMITTEES ON

*Textiles*

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JOHN ECCLES, Taftville, Conn.
EDW. W. FRANCE, Philadelphia, Pa.
EDWARD F. GREENE, Boston, Mass.
FRANKLIN W. HOBBS, Boston, Mass.
C. R. MAKEPEACE, Providenec, R. I.
C. H. MANNING, Manchester, N. H.
HENRY F. MANSFIELD, Utica, N. Y.
EDWARD W. THOMAS, Lowell, Mass.

Note—Numbers in parentheses indicate the number of years the member has yet to serve.

# THE JOURNAL

OF

# THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS

VOL. 33 NOVEMBER 1911 NUMBER 11

## THE ANNUAL MEETING

The Society is again looking forward to its Annual Meeting which will as usual be held in the Engineering Societies Building, New York, in December, opening on Tuesday the 5th, and closing on Friday the 8th.

Some noteworthy papers have been secured by the Committee on Meetings and the professional program will shortly be announced. An important feature this year will be contributions by three of the first sub-committees appointed by the Committee on Meetings, those on Textiles, Cement Manufacture and Machine Shop Practice. One session is to be devoted to Foundry Practice, another to Steam Boiler Performance. The Gas Power Section will as usual have a session, at which Oil Engines, at present a subject of so much importance, will be discussed.

The entertainment features which are so prominent a part of annual gatherings, will be in the hands of the Committee on Meetings in New York, who have always provided so successfully for the pleasure and comfort of the members and their guests. The principal events will be the President's reception on Tuesday evening in the rooms of the Society, George J. Foran acting as chairman of the sub-committee in charge; and the annual reunion of the membership of New York in honor of the newly-elected officers and visiting members, at the Hotel Astor on Thursday evening, F. A. Scheffler having been appointed chairman of the sub-committee in charge of that occasion. Luncheon will be served as usual on Wednesday and Thursday during the convention. While the program as announced is similar to that of last year, many interesting features will be found which, in combination with the finish of detail for which the meetings have already become noted, ought to make the entire convention one of profit and enjoyment. There will be a number of excursions, prominent among which will be an inspection of the S. S. Olympic. The Society will be the guests on that occasion of the White Star Line. The Olympic will be in port on her first trip since her recent accident, and the repairs are being hastened in order that the membership may not be disappointed in its plans to visit this great floating palace. There will also be trips to the Brooklyn Navy Yard, the Sims Magneto Company in Bloomfield, N. J., the Bush Terminal Buildings in Brooklyn, E. W. Bliss Company, Brooklyn, and the Hotel Astor. In general the Committee will be glad to arrange special visits on request if sufficient notice be given.

The welcoming of the visiting ladies will again be in charge of the ladies of New York who have organized a committee to plan for trips and entertainment of various descriptions, Mrs. Jesse M. Smith acting as chairman. The headquarters of the committee will be in the rooms of the Society on the eleventh floor. The ladies of the Society and their guests will be received by the Ladies' Committee on Wednesday afternoon at four o'clock.

### RAILROAD TRANSPORTATION

Arrangements for hotel, transportation and Pullman car accommodations should be made personally.

For members and guests attending the Annual Meeting in New York, December 5–8, 1911, the special rate of a fare and three-fifths for the round trip, on the certificate plan, is granted when the regular fare is 75 cents and upwards, from territory specified below.

*a* Buy your ticket at full fare for the going journey, between December 1 and 7 inclusive, and get a certificate, *not a receipt*, securing these at least half an hour before the departure of the train.

*b* Certificates are not kept at all stations. If your station agent has not certificates and through tickets, he will tell you the nearest station where they can be obtained. Buy a local ticket to that point and there get your certificate and through ticket.

*c* On arrival at the meeting, present your certificate to the registration desk at the Headquarters. A fee of 25 cents will be collected for each certificate validated. No certificate can be validated after December 8.

*d* An agent of the Trunk Line Association will validate certificates, Dec. 6, 7, 8. No refund of fare will be made on account of failure to have certificate validated.

*e* One-hundred certificates and round trip tickets must be presented for validation before the plan is operative. This makes it important to show the return portion of your round trip ticket at Headquarters.

*f* If certificate is validated, a return ticket to destination can be purchased, up to Dec. 12, on the same route over which the purchaser came, at three-fifths the rate.

This special rate is granted only for the following:

Trunk Line Association:

**All of New York east of a line running from Buffalo to Salamanca, all of Pennsylvania east of the Ohio River, all of New Jersey, Delaware and Maryland; also that portion of West Virginia and Virginia north of a line running through Huntington, Charleston, White Sulphur Springs, Charlottesville, and Washington, D. C.**

## CURRENT AFFAIRS OF THE SOCIETY

### STUDENT BRANCHES

The movement to affiliate student engineering societies had its inception in the fall of 1908, when the Stevens Engineering Society applied for affiliation and was accorded privileges by the Council. A month later the Cornell Student Branch was formed. In the three years intervening the number has grown to twenty-four, with a total membership of more than half a thousand.

According to the basis adopted by the Council in December 1908, these student branches, while maintaining their autonomy and independence, are offered many of the privileges of the Society. The Journal is sent as a subscription to ali affiliates, and all other publications of the Society are supplied to the students at members' rates. Each organization holds independent meetings, monthly or bi-monthly, and reports of these are published in The Journal from time to time. Members of the Society frequently address the branch meetings, and the Secretary has personally visited many of them in order to convey the Society's greetings and to express its cordial interest. Many graduates are now among the Society's Junior members and promise to become prominent in its service. Branch meetings offer to the students practical opportunities for public speaking, for the presentation and discussion of papers, and for a widening of acquaintanceship likely to be of value professionally. The training received, modelled as each branch is on the lines of the larger organization of which it is a part, thus fits the students to undertake, immediately after leaving college, activities which they would otherwise have to forego.

### TECHNICAL SEARCHES

The Society has for years put the contents of its library within the reach of every member, no matter how far situated from headquarters, through technical searches. An especially able staff is maintained and that the service is being appreciated is evidenced by recent requests for data upon the following subjects, among many which might be named: steel belts, combustion of coal dust, efficiency tests of pumps for waterworks, bearings, ball and roller, making of brass tubes, care of belting, size of drums for wire rope, design of hooks for cranes, automatic stops, fire hose pressure, high-speed tools, drying lumber in kilns, permanent molds, manufacture and properties of phosphor bronze, comparative value of various methods of power transmission, engineering standards and specifications, smoke abatement, composition and heat treatment of steel, steam meters, high-pressure turbo-compressors, tap drills for various metals, manufacture of seamless steel tubes, and shop costs. In some instances typewritten copies of complete articles have been furnished as well as translations. We are equipped to make translations from any language.

This is an especially valuable side of the work being done by the library and ought to appeal to members who lack the time to make such searches for themselves. Unless the work is extensive no charge is made and in any event the cost of copying or translation is gaged by the time required and is slight in proportion to its value. Members are invited to make use of the library in this way.

### STANDARDIZATION OF FLANGES

An important work of the committees has been the formulation of standards and the effort has always been to secure results which would be mutually acceptable to the designers, manufacturers, and users of the apparatus to which the standards applied. The Society does not adopt standards in the usual sense, the procedure being instead for a committee authorized by the Council to investigate and report, and at a suitable time the report is brought up for discussion at a meeting of the Society. When issued in its final form it is simply ordered printed by the Council.

In 1894 a committee of the Society coöperated with one from the National Association of Master Steam and Hot Water Fitters in the preparation of standards for pipe flanges for low-pressure work. These have been very largely adopted by manufacturers, although certain manufacturers' standards have also been employed.

Recently the matter has been taken up again by the National Association of Master Steam and Hot Water Fitters, and a committee of The American Society of Mechanical Engineers, H. G. Stott, chairman, has coöperated with them in preparing a report, a preliminary draft of which was submitted for discussion at the Spring Meeting at Pittsburgh and later was favorably considered by the Master Steam and Hot Water Fitters. This report is both for standard weight and extra heavy flanged fittings, and in the larger sizes, that is 9 inches and above, it represents the investigation and work contributed in a large measure by our own committee. For these sizes the flanges were drawn on paper, full size, and the bolt holes laid out and tested to insure that there would be no trouble in using wrenches or through other interferences. The effort was especially made to secure ample strength in the bolts, inasmuch as in some of the flanges as now used, the bolts are stressed beyond what is considered by our committee to be a safe working strength.

Another step in the preparation of the schedule has been the holding of a joint meeting of these two committees and representatives of manufacturers of pipes and fittings. Obviously the manufacturers' interests are very great, not only because of the large stock of fittings which must be regularly carried and which become obsolete if radical changes in design were made, but because the equipment in the way of patterns, flasks, etc., is an enormous item, as well as the carrying of stock of both styles for old and new work. The efforts of the Society may always be depended upon to be directed toward the securing of results mutually advantageous to the manufacturer and user, in so far as this is practicable without sacrificing the obvious responsibility of the Society to advocate only what can be considered sound engineering practice.

## THE ANNUAL MEETING

The Annual Meeting to take place in December, beginning on Tuesday evening the 5th, and ending on Friday the 8th, is the 32d in the history of the Society. In 1905 when the Engineering Societies Building was in immediate prospect, the interest in the Society and its activities very naturally increased, and the attendance of members at the Annual Meeting of that year was 50 per cent larger than it had been at any previous meeting. Since that time the attendance has continued to be large, averaging more than 700 members, thus affording an unusual opportunity for engineers to meet others in the profession from different sections of the country.

The preparation of the program of these meetings which is in the hands of the Committee on Meetings, involves a great amount of painstaking work, extending over a long period of time. The meeting this year will be notable because it represents the beginning of a new era in the meetings of the Society, wherein contributions will be made from widely different fields of engineering by groups of men who are specialists in the subjects brought up for discussion. This is the result of the plan of the Committee on Meetings, which has also received the enthusiastic approval of the Council, to organize subcommittees of specialists who will assist in securing papers, present annual reports of the state of the art, and otherwise bring to the attention of members in other fields the important engineering problems that are to be solved. They will in return receive the benefit of discussion by the entire membership who may have had similar problems in their own particular fields.

It is no small problem, moreover, to arrange the entertainment program for these Annual Meetings, even in a city with the resources of New York. The Committee on Meetings in New York took this matter in hand early for the coming meeting and have arranged excursions to points so far as possible not before visited by the Society as a body, and they have also introduced new features which should add to the pleasure of those who have been regular attendants of these meetings.

CALVIN W. RICE, *Secretary.*

## COMING MEETINGS

### NEW YORK MEETING, NOVEMBER 14

On account of the wide interest in the subject of Welding, Autogenous, and Electric, the Committee on Meetings of the Society in New York has arranged for its presentation at the monthly meeting on November 14 in the Engineering Societies Building. The material already in hand is replete with valuable information concerning the latest developments in apparatus and applications of these processes. For various reasons the possibilities of these processes have not been taken advantage of. They are by no means limited to repair work, important as it is, and if employed would revolutionize many practices in manufacturing. The subject well deserves the investigation of those not fully acquainted with it. Representatives of both the makers and users of the apparatus will participate in the discussion.

The subject will be introduced by H. R. Cobleigh, Mem.Am. Soc.M.E., publicity manager of the International Steam Pump Company, New York, in a general paper dealing with the apparatus used in the different processes. The origin and principles of each process, with considerable stress on the flame processes, will be given. This will be followed by two special papers, one on Thermit Welding, by G. E. Pelissier, Assoc.Am.Soc.M.E., superintendent of the Goldschmidt Thermit Company, New York, and one upon Electric Welding, by C. B. Auel, assistant manager of works of the Westinghouse Electric & Manufacturing Company, East Pittsburgh, Pa.

The discussion will, in the main, be divided as follows:

*a* Electric resistance welding
*b* Electric arc welding
*c* Thermit welding
*d* Oxy-acetylene welding
*e* Oxy-hydrogen welding

The fields of application, costs of work, how difficult work may be accomplished and advantages of special features of apparatus will be taken up under each of these divisions. The speakers will not be limited to these particular phases but it is hoped that information along these lines may be brought out. Among those who are expected to participate are W. R. Noxon, of the Davis-Bournonville Company; Nelson Goodyear, of Nelson Goodyear, Inc.; G. E. Kershaw, Linde Air Products Company; W. H. Levin, of the International Oxygen Company; Henry Cave, of the Autogenous Welding Equipment Company, B. Morgan, Newport, R. I.; and L. P. Alford, Mem.Am.Soc.M.E., editor-in-chief of The American Machinist, New York.

The papers and many of the discussions will be illustrated by lantern slides and it is expected that one process will be shown with moving pictures.

## BOSTON MEETING, NOVEMBER 15

A meeting of the members of the Society, the American Institute of Electrical Engineers and the Boston Society of Civil Engineers coöperating, will be held in Boston, on November 15 in the rooms of the Boston Society of Civil Engineers. A paper on Some Refractory Substitutes for Wood, by Charles L. Norton, Mem.Am.Soc.M.E., associate professor of physics of the Massachusetts Institute of Technology, will be presented.

## NEW HAVEN MEETING, NOVEMBER 15

The Society will hold a meeting in New Haven in the Mason Laboratory of Mechanical Engineering, on November 15, commencing at 3 p.m., with afternoon and evening sessions. E. S. Cooley, of the Connecticut Company, chairman of the Committee on Meetings of the Society in New Haven, will act as chairman of the afternoon session, when the Cost of Power will be the topic considered. The subject will be introduced by several papers describing plants now in operation in New Haven and vicinity, using power from steam engines, steam turbines, gas and oil engines. At the close of the session the new Mason Laboratory will be open for inspection.

Dinner will be served in the Yale Dining Club at 6 p. m. and the meeting will be resumed at 8 p.m., Lester P. Breckenridge, professor of mechanical engineering of the Sheffield Scientific School, presiding. Col. E. D. Meier, President of the Society, will make an informal address, and an illustrated lecture will be delivered by Chas. F. Scott, Past-President A.I.E.E. and Mem.Am.Soc.M.E., professor of electrical engineering of the Sheffield Scientific School, upon the Hartford Electric Light Company, its Power Plant, Distribution System, and Public Service.

# REPORTS OF MEETINGS

## NEW YORK MEETING, OCTOBER 9

The monthly meeting of the Society in New York, held in the Engineering Societies Building on October 9, had for the topic of the evening Reinforced Concrete Construction. A paper on Factory Construction and Arrangement was presented by L. P. Alford, Mem. Am.Soc. M.E., editor-in-chief of The American Machinist, and H. C. Farrell, Mem.Am.Soc.M.E., mechanical engineer of the United Shoe Machinery Company, Beverly, Mass., in which the latter company's plant was described. This factory was one of the first to be constructed entirely of reinforced concrete and is an example of its most extensive use for machine-shop purposes.

The discussion centered particularly about the phases of factory arrangement, covering the different methods of arranging machinery for manufacturing; artificial shop lighting, dealing with the advantages of diffused illumination versus individual lights at each machine, and the best types of lamps for each; factory floors, giving the relative advantages of concrete, composition and wood. Those who participated either orally or by means of written contributions were: Alexander Taylor, Mem.Am.Soc.M.E., manager of the Westinghouse Electric & Manufacturing Company, East Pittsburgh, Pa.; L. D. Burlingame, Mem.Am.Soc.M.E., chief draftsman for the Brown & Sharpe Manufacturing Company, Providence, R. I.; G. H. Stickney, General Electric Company, Schenectady, N. Y.; H. M. Lambourn, superintendent of power plant, Yale & Towne Manufacturing Company, Stamford, Conn.; Henry Hess, Mem.Am.Soc.M.E., president Hess-Bright Manufacturing Company; Gilbert Arnold, Stamford, Conn.; George Parsons; L. C. Wason, president of the Aberthaw Construction Company, Boston, Mass.; and F. A. Waldron, Mem.Am.Soc.M.E., industrial engineer, New York.

The paper and many of the discussions were illustrated by lantern slides, some of them in color.

## SAN FRANCISCO MEETING, OCTOBER 17

The members of the Society in San Francisco held a dinner at the Fairmont Hotel, San Francisco, on October 17, to meet Col. E. D.

Meier, President of the Society. A. M. Hunt, chairman of the Committee on Meetings of the Society in San Francisco, presided. Society matters were discussed and George W. Dickie, Edward C. Jones and T. W. Ransom were appointed a committee to confer with the representatives of other engineering organizations with regard to the engineering congress projected for 1915.

The next meeting of the Society for the presentation of professional papers and discussion will probably be held in December.

## BOSTON MEETING, OCTOBER 18

The Society coöperated with the American Institute of Electrical Engineers and the Boston Society of Civil Engineers in a meeting held in Boston on October 18, under the auspices of the last organization. The paper of the evening, Power System of the Pacific Mills: Methods, Rules and Cost of Operation, by F. A. Wallace, Assoc.Am.Soc.M.E., master mechanic of the Pacific Mills, Lawrence, Mass., was presented by Mr. Robinson, a member of his staff, and was illustrated by lantern slides.

The Pacific Mills Corporation operates several properties, the largest of which is the group of mills and works on the north side of the Merrimac River at Lawrence, Mass., motive power for which has in the past been obtained from a variety of steam engines supplemented by waterwheels. Recently a power house with turbo-generators, concrete coal pocket, etc., has been provided, and an electric transmission system extending throughout the property. The paper included a very full description of the plant, transmission system and motor drives, as well as of the methods and organization for operation and inspection, and considerable information as to costs. An interesting incident was the reference to a high-pressure high-speed steam engine, built in 1847, to take steam at 30-lb. gage, and running 30 r.p.m., which in its later years of service has been run on exhaust steam from other sources.

The paper was followed by an extended discussion, participated in by C. R. Manning, Mem.Am.Soc.M.E., superintendent of the Amoskeag Manufacturing Company, Manchester, N. H.; A. G. Hosmer, Mem.Am.Soc.M.E., mechanical superintendent of the Lancaster Mills, Clinton, Mass.; Chas. T. Main, Mem.Am.Soc.M.E., Boston, Mass.; W. L. Puffer, Mem.A.I.E.E., Boston, Mass.; R. A. Fessenden, Mem.A.I.E.E., Boston, Mass.; G. A. Burnham, Assoc.A.I.E.E., assistant engineer, Condit Electric Manufacturing Company, Boston, Mass.; F. M. Gunby, member Boston Society of Civil Engineers, with Chas. T. Main, Boston, Mass.; and others.

## PHILADELPHIA MEETING, OCTOBER 18

A meeting of the Society in coöperation with the Franklin Institute was held in Philadelphia on October 18, in the hall of the Institute. The Practical Application of Scientific Management to Railway Operation was presented in a paper by Wilson E. Symons, consulting engineer, Chicago, Ill. Mr. Symons combated the theory that by scientific management in the operation of railways a saving of $1,000,000 a day could be effected, and said practical railroad men who know more about the economic operation of railroads than theorists, had already reduced maintenance and operating expenses to a minimum. The paper contained many statistics and took up in detail a consideration of employees and compensation, operating revenues and expenditures, division of expenditures and balance sheet, efficiency, staff officers, efficiency engineers, the question of over-expenditure on oil, all of which, the author believed, gave evidence for a decision against the adoption of the plan.

Railroad experts as well as men eminent in scientific management were present and the paper was thoroughly discussed in the open meeting which followed. Among the discussors were Webb C. Ball, chief time inspector for the New York Central Lines, Cleveland, Ohio; F. H. Clark, Mem.Am.Soc.M.E., general superintendent of motive power, Baltimore & Ohio Railway, Baltimore, Md.; A. L. Conrad, assistant general auditor for the Atcheson, Topeka & Santa Fé Railway; Charles Day, Mem.Am.Soc.M.E., of Dodge, Day & Zimmerman, Philadelphia; Harrington Emerson, Mem.Am.Soc.M.E., and Frank B. Gilbreth, Mem.Am.Soc.M.E., New York City, both noted exponents of scientific management; George R. Henderson, Mem.Am.Soc.M.E., mechanical engineer for the Baldwin Locomotive Works, Philadelphia; B. B. Milner, mechanical engineer, Pennsylvania Railroad, Wilmington, Del.; Jas. Shirley Eaton, New York; Walter V. Turner, chief engineer of the Westinghouse Air Brake Company, Pittsburgh, Pa., and S. M. Vauclain, Mem.Am.Soc.M.E., superintendent of the Baldwin Locomotive Works, Philadelphia. Mr. Emerson who is the author of the statement that $1,000,000 could be saved daily by the railroads under a system of scientific management, declared that since making that statement he had increased the amount to $2,000,000. He cited figures to show how one railroad had decreased operating expenses and increased its efficiency since adoption of the plan.

## STUDENT BRANCHES

### LELAND STANFORD JR. UNIVERSITY

On October 4, the Stanford Mechanical Engineering Association held its opening meeting of the year, on which occasion Prof. W. F. Durand gave an interesting and instructive talk on the Los Angeles Aqueduct. This was followed by an open discussion by the members present.

### STATE UNIVERSITY OF KENTUCKY

At the first meeting of the year of the State University of Kentucky Student Branch, October 6, William Gibson delivered an address on the Industrial Efficiency and the Attitude of Labor Regarding It. Frederick P. Anderson, professor of mechanical engineering at the University was elected honorary chairman.

### MASSACHUSETTS INSTITUTE OF TECHNOLOGY

The Mechanical Engineering Society of the Massachusetts Institute of Technology held a dinner on October 19, at which Fred R. Low, Prof. J. C. Riley and E. F. Miller, the new head of the mechanical engineering department, were among the speakers. After the dinner J. A. Noyes outlined the Society's plans for the coming year, which are to include excursions, and lectures by professional men of wide experience and reputation, as well as by members of the senior class.

### STEVENS INSTITUTE OF TECHNOLOGY

The first regular meeting of the Stevens Engineering Society was held on October 12, for the election of new members and the discussion of the year's activities. Seventy students were admitted, making the total active membership 132.

The following lectures are scheduled to be delivered before the society during the coming year: October 19, Calvin W. Rice, Secretary of the Society, will extend the greeting of The American Society of Mechanical Engineers, and Charles Whiting Baker will speak on a subject to be announced; November 9, James Hartness, Some Non-

Technical Phases of Machine Design; December 7, Arthur H. Elliott, The Comparative Economics of Coal Gas and Water Gas; December 14, William D. Ennis, Vapor for Heat Engines; January 11, Charles Kirchhoff, Factors in the Development of the Iron Industry; February 8, Charles N. Chadwick, The Catskill Water Supply; February 15, Thomas Travis, The Criminal from the Scientific Standpoint; February 29, Col. E. D. Meier, Modern Boiler Practice; March 14, Worcester R. Warner, What are the Astronomers Doing; April 18, Charles P. Steinmetz, Phenomena Beyond the Elastic Limit, with Special Reference to Electrical Effects.

### UNIVERSITY OF CINCINNATI

The University of Cincinnati Student Section held its regular monthly meeting, October 12, at which Augustus Davis, of the Ohio Welding & Manufacturing Company, lectured on the Oxy-Acetylene Process of Welding & Cutting Metals. His demonstrations were practical and showed the engineering possibilities of the process.

### UNIVERSITY OF MISSOURI

At the meeting of the Student Section of the Society at the University of Missouri held October 2, the following officers were elected for the first semester: G. D. Mitchell, president; J. H. Pound, secretary-treasurer; P. A. Tanner, corresponding secretary; and H. S. Philbrick, A. C. Edwards, F. J. King, governing committee.

Prof. H. W. Hibbard spoke on the value of The Journal, and A. J. Hecker presented a paper on Troublesome Questions in Brake Design, which was further discussed by Prof. E. A. Fessenden.

On October 16, Professor Hibbard and C. A. Olson spoke on Power Forging and a general discussion of power hammers, rolls and presses followed.

### YALE UNIVERSITY

On October 10, the Yale Mechanical Engineers Club held a most successful meeting at which 21 new members were enrolled. Prof. L. P. Breckenridge made a short address in which he set forth the advantages to be derived from a student branch, and subsequently by joining The American Society of Mechanical Engineers.

## NECROLOGY

### HENRY A. FERGUSSON

Henry A. Fergusson was born in Philadelphia, Pa., December 1869, and received his technical training at the Spring Garden Polytechnic Institute and at Cornell University. In September 1887, he began an apprenticeship at the Baldwin Locomotive Works, Philadelphia, and from 1888 to 1902 was employed by the Pennsylvania Railroad Company at Altoona, Pa., holding successively the positions of assistant foreman of car shops; assistant master mechanic at the Meadows shops; assistant road foreman of engineers of the New York division, in sole charge of tonnage, rating and tests of locomotives; and assistant engineer of motive power. He resigned from the company to become assistant superintendent of motive power of the Chicago Great Western Railroad, St. Paul, Minn., and in 1904 entered the employ of J. T. Ryerson & Sons, Chicago, Ill., as engineer. At the time of his death on April 22, 1911, he had been consulting engineer and general manager for The Steel Roof Truss Company, Valley Park, Mo., for several years.

### WILLIAM S. McKINNEY

William S. McKinney was born in Troy, N. Y., August 11, 1844. He removed with his parents to Cincinnati, Ohio, in 1861, where his father engaged in the manufacture of hardware in partnership with Miles Greenwood. At the age of twenty, after the sudden death of his father, he assumed entire charge of the factory, continuing to carry on the business until the expiration of the partnership agreement with Mr. Greenwood. He then, together with his brother J. P. McKinney, built a small works for the manufacture of hardware, making a specialty of strap and tee hinges and butts. Recognizing the advantages to be found in Pittsburgh for a business of this character, they removed the works to Allegheny, Pa., and organized the McKinney Manufacturing Company, of which he was president until his death. His engineering work was confined mainly to the designing, building and improving of machinery adapted for the manufacture of heavy hardware. He died at his home in Pittsburgh, August 30, 1911.

# RATIONAL PSYCHROMETRIC FORMULAE

## THEIR RELATION TO THE PROBLEMS OF METEOROLOGY AND OF AIR CONDITIONING

By Willis H. Carrier

ABSTRACT OF PAPER

In many industries such as the manufacture of textiles, food products, high explosives, photographic films, tobacco, etc., regulation of the humidity of the atmosphere is of great importance. This paper deals with the subject of the artificial regulation of atmospheric moisture, technically known as air conditioning. It gives a theoretical discussion of the subject in which formulae are developed for the solution of problems. These formulae are based upon the most recently determined data and in order to establish a logical basis for the presentation of these data and the derivation of the formulae, the principles governing atmospheric moisture are reviewed and the present methods of determining atmospheric humidity are discussed.

# RATIONAL PSYCHROMETRIC FORMULAE

## THEIR RELATION TO THE PROBLEMS OF METEOROLOGY AND OF AIR CONDITIONING

By Willis H. Carrier, Buffalo, N. Y.

Associate Member of the Society

A specialized engineering field has recently developed, technically known as air conditioning, or the artificial regulation of atmospheric moisture. The application of this new art to many varied industries has been demonstrated to be of greatest economic importance. When applied to the blast furnace, it has increased the net profit in the production of pig iron from $0.50 to $0.70 per ton, and in the textile mill it has increased the output from 5 to 15 per cent, at the same time greatly improving the quality and the hygienic conditions surrounding the operative. In many other industries, such as lithographing, the manufacture of candy, bread, high explosives and photographic films, and the drying and preparing of delicate hygroscopic materials, such as macaroni and tobacco, the question of humidity is equally important. While air conditioning has never been properly applied to coal mines, the author is convinced that if this were made compulsory, the greater number of mine explosions would be prevented.

2 Although of so much practical as well as scientific importance the laws governing many of the phenomena of atmospheric moisture are but partially understood, while the present engineering data pertaining thereto are both inaccurate and incomplete. Accepted data used in psychrometric calculations are based largely on empirical formulae, which are incorrect as well as limited in their range. Recent investigators have determined the most important properties of water vapor with final accuracy. At the same time, sufficient error has been shown in previous steam data, especially at atmospheric temperatures, to warrant the revision of all calculations based thereon.

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The American Society of Mechanical Engineers, 29 West 39th Street, New York. All papers are subject to revision.

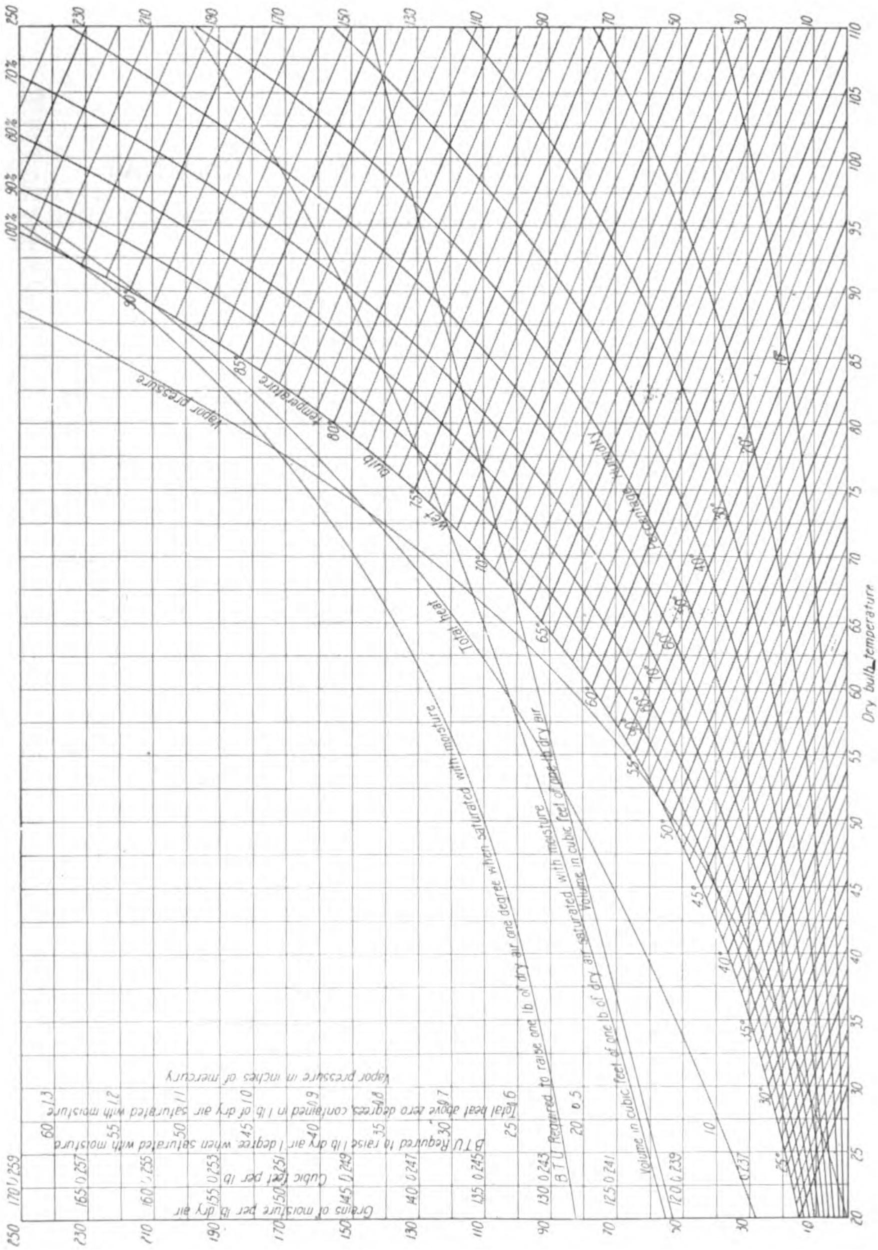


**FIG. 1 PSYCHROMETRIC CHART**

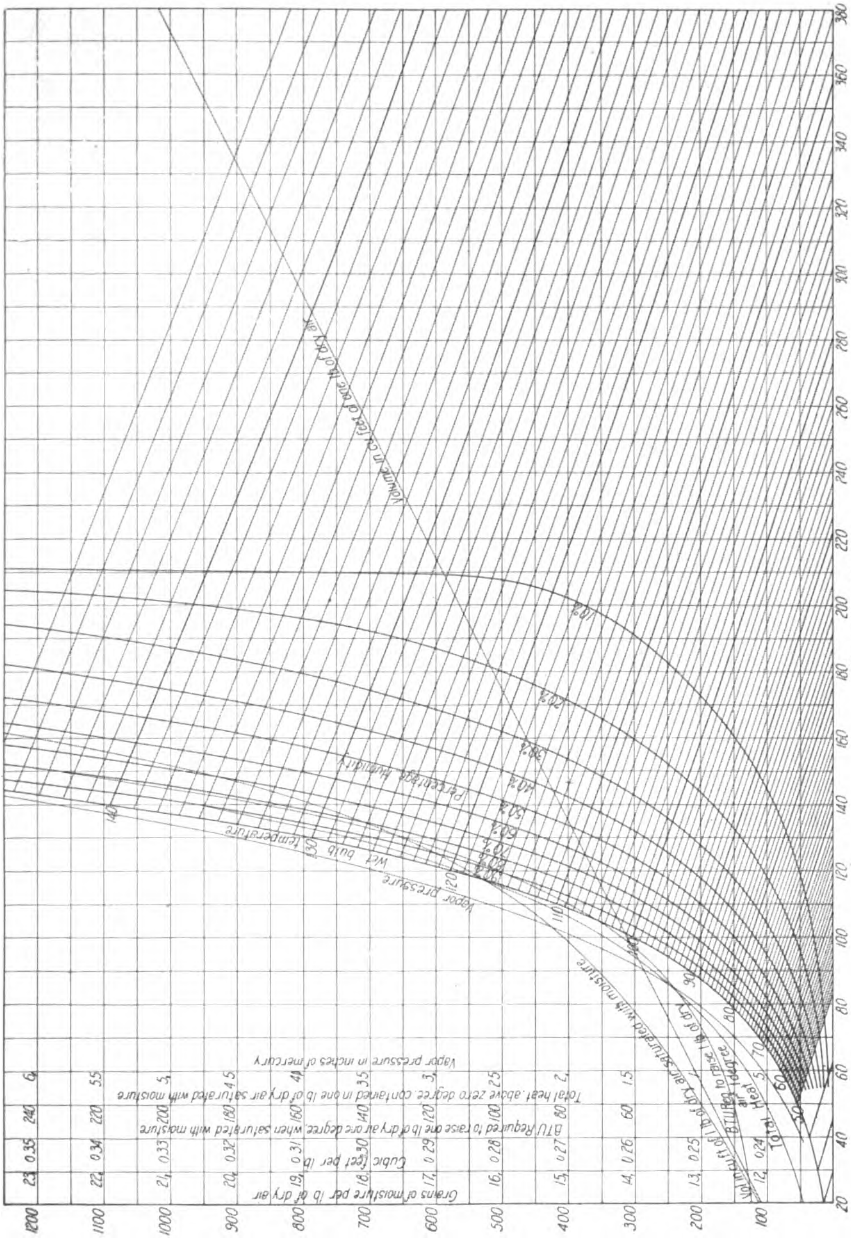


**Fig. 2 Psychrometric Chart**

3 It is the purpose of this paper to apply these final data to the development of rational formulae for the solution of all problems pertaining to the phenomena of atmospheric moisture as related to psychrometry and to air conditioning. Original data are given in proof of fundamental relations as well as in determination of errors in standard psychrometric instruments. The author hopes these results may prove to be of permanent value.

4 In order to establish a logical basis for the presentation of these data and the derivation of the rational formulae, the established principles and laws governing atmospheric moisture will be reviewed and the present methods of determining atmospheric humidity discussed.

### VAPOR PRESSURE AND LAW OF PARTIAL PRESSURES

5 Water vapor exists in the air purely as a mixture in relation to its other elements. This vapor, according to Dalton's law, is capable of exerting a certain maximum vapor pressure dependent entirely on its temperature and regardless of the presence of other gases or vapors. For example, assume 1 cu. ft. saturated with vapor of alcohol at 100 deg. cent. having a vapor pressure of 1697.6 mm., and add isothermally to this 1 cu. ft. saturated with water vapor at 100 deg. cent. having a vapor pressure of 760 mm. This will give 1 cu. ft. of the mixture saturated with both water vapor and alcohol vapor at 100 deg. cent., having as a total pressure the sum of the two separate saturated vapor pressures, or 2457.6 mm. Similarly, an equal volume of a third saturated vapor might be added without affecting the other two. But if, on the other hand, it is attempted to include isothermally an additional amount of either of the saturated vapors, a corresponding condensation of the particular vapor added would result. In the same manner, an unlimited amount of a gas, such as air, could be added isothermally to a cubic foot of water vapor without affecting its condition of saturation, giving a combined pressure equal to the gas pressure plus the vapor pressure.

6 The established temperature-pressure relationship of saturated water vapor is shown by curve (1) on the charts, Figs. 1 and 2. This is the well-known temperature-pressure curve of steam.

### PARTIAL SATURATION

7 When the temperature of a definite weight of saturated vapor is increased isobarometrically, it is said to be superheated. Its

specific volume is increased, in accordance with the law of gases, in direct proportion to the increase of absolute temperature, while its density is changed in an inverse proportion, as shown in Fig. 3; that is, $\frac{D_2}{D_1} = \frac{T_1}{T_2}$, where $D_1$ and $D_2$ are the densities corresponding to the absolute temperatures $T_1$ and $T_2$, respectively, and $(T_2 - T_1)$ is the degree of superheat. If $D_2$ is the density of saturated vapor at temperature $T_2$, then the ratio $\frac{D_2}{D_1}$ is said to be the per cent of saturation, or more exactly, the per cent of isothermal saturation. When these relationships are considered with respect to water vapoı in

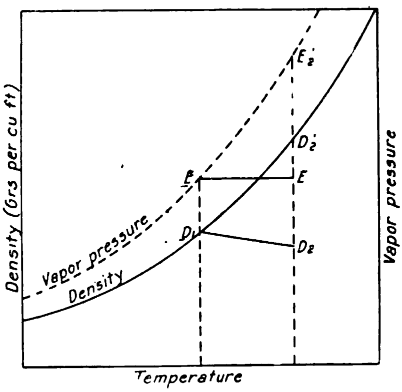


FIG. 3 TEMPERATURE-DENSITY DIAGRAM

air, this ratio is termed the per cent of relative humidity, while the densities $D_1$, $D_2$, $D'_2$, etc., customarily expressed in grains of moistuıe per cubic foot, are termed absolute humidities.

## DEW POINT

8 It should be noted that although the total weight of the water vapor remains the same, the absolute humidity $D_2$ is less than the absolute humidity $D_1$. However, if water vapor, or air containing water vapor, having a temperature $T_2$ and an absolute humidity of $D_2$, be cooled to $T_1$, it will become saturated, and if cooled further, moisture will be precipitated. Therefore $T_1$ is termed the dew point of air having a temperature $T_2$ and an absolute humidity, $D_2$, or a corresponding relative humidity, $\frac{D_2}{D'_2}$. Therefore, the dew point

may be defined as the minimum temperature to which air of a given moisture content may be cooled without precipitation of moisture.

9 Usually it is more convenient to determine the absolute and relative humidities from the temperature-pressure curve by comparing the vapor pressures. The per cent of humidity is $\frac{D_2}{D'_2}$, but it may also be shown to be equal to $\frac{e_1}{e'_2}$; i.e.

$$\text{per cent humidity} = \frac{e_1}{e'_2} = \frac{D_2}{D'_2} \quad \text{[1]}$$

where $e_1$, is the pressure of saturated vapor corresponding to the dew point $T_1$, and $e'_2$ is the vapor pressure at saturation corresponding to temperature $T_2$. It also follows that

$$D_2 = D'_2 \times \frac{e_1}{e'_2} \quad \text{[2]}$$

Proof of these relationships is given in Appendix No. 1.

## METHODS OF MEASURING ATMOSPHERIC HUMIDITY

10 Determinations of atmospheric moisture may be made by four distinct methods:

11 *Chemical Method.* A measured quantity of air is drawn through some de-hydrating solution, such as concentrated sulphuric acid, until the moisture is completely removed and the increase in the weight of the solution noted.

12 *Hygroscopic Method.* This method is chiefly useful in an approximate determination of the relative humidity directly. It is known that nearly all animal and vegetable substances containing albumen or cellulose, and also many mineral salts are very sensitive to changes in atmospheric moisture. The moisture content of such materials at equilibrium is found to bear a direct relation to the existing amount of moisture in the atmosphere.

13 The per cent of moisture which they will freely absorb, however, is not exactly the same for the same percentage of humidity for different temperatures. This relationship of moisture content of various textiles to different atmospheric humidities and temperatures has been very thoroughly investigated by Schloessing in France. Fig. 4 exhibits some of the relationships thus determined.

14 It is therefore to be seen that the moisture content of the air will be approximately indicated by measuring the increase in weight

of a skein of silk, or other textile, whose dry weight has been definitely determined. Such an instrument for the measurement of humidity has been devised by William D. Hartshorne of Lawrence, Mass.

15 The action of the hair hygrometer depends upon its linear expansion due both to humidity and temperature. The accuracy of this type of hygrometer was thoroughly investigated by Regnault. It may be calibrated to give a fairly accurate indication of humidity throughout a considerable range of temperature. However, the elasticity of the hair or any similar fiber is not permanent and any instrument operating on this principle requires frequent calibration and readjustment. Therefore it can be used only in connection with some instrument giving absolute determinations.

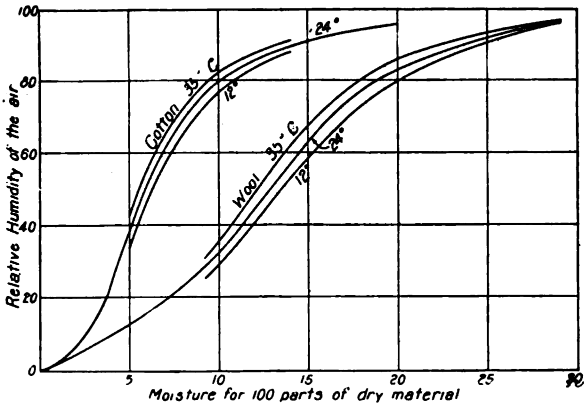


**Fig. 4 Effect of Humidity on Moisture Content of Textiles**

16 In his investigations of atmospheric humidity, Regnault found that a solution of calcium chloride exposed to the air would assume a density in proportion to the relative humidity. If the air became drier, it would evaporate moisture from the solution, increasing its density. If, on the other hand, the humidity of the air increased, moisture would be absorbed by the solution until it reached an equilibrium.

17 A test was made by the writer in May 1902, to determine the moisture-absorbing properties of calcium-chloride brine for the purpose of air conditioning. It was found that with a constant humidity of the air, the rate of absorption varied directly in proportion to its change in density, and that the density of the solution decreased to a point where absorption stopped. In connection with this test

an interesting phenomenon was observed relative to the conversion of the latent heat into sensible heat of the moisture thus absorbed. By measuring the increase in temperature, it was found possible to account very closely for the calculated latent heat of the moisture removed. The temperature of the solution was, furthermore, considerably higher than the final temperature of the air. This may be explained by the assumption that the absorption and consequent heat transformation occurred at the surface film where the air in the film and the liquid were heated to an equal temperature, and that not all of the air came into direct contact with the liquid. This is the direct inverse of phenomena occurring in evaporation with incomplete saturation. Here the temperature of the air is lowered to correspond with the increase in latent heat by evaporation, while the water always remains at a lower temperature than the partially saturated air.

18 In 1909, in connection with a test made upon a humidifying plant for conditioning tobacco, similar phenomena were noted. It was found that the ventilation of cool, dry tobacco with moist air produced a rapid rise in temperature both of the air and of the tobacco, which rose to a much higher temperature than the air.

19 *Dew-Point Method.* The dew-point method was first brought into use by Daniels and by Regnault, and adopted by the United States Weather Bureau in the determination of the values used in their psychrometric tables. The dew point is measured directly by observing the temperature at which moisture begins to form upon an artificially cooled mirror surface. Determination by this method is extremely delicate and when suitable precautions are taken, is considered very accurate. However, it is questionable whether the true dew point is ever quite as low as indicated by this method. The temperature is usually taken by a thermometer placed in a thin silver tube filled with sulphuric ether or other volatile liquid, which produces cold by evaporation. The temperature of the exterior of this tube is undoubtedly at the true dew point, but it is questionable whether the thermometer at the center of the tube registers this dew point with absolute accuracy. The exterior surface of the tube must often be cooled 25 or even 50 deg. below atmospheric temperature in order to reach the dew point.

20 In any case a considerable quantity of heat must pass through the tube to the cooling medium from the external air by convection, and to a less extent from external objects by radiation. The internal resistance to the transfer of heat of a thin plate of metal, forming the

wall of the tube, is in itself negligible; however, as any one who has studied the subject of heat transmission will recognize, the surface resistances are appreciable. On the outside, there is the resistance of the surface exposed to the water vapor at low tension, and, on the inside, the more considerable resistance of the liquid surface. There is therefore every reason to believe that the interior ether is at a slightly lower temperature than the exterior dew point. This conclusion conforms with conditions demonstrated by other observers in tests upon the temperature of the exterior of radiating or convecting surfaces. The extreme accuracy of the results obtained by the dew-point method at high temperatures and low humidities would, therefore, seem greatly in question.

21 *Evaporative or Psychrometric Method.* The evaporative or psychrometric method has not heretofore, to the writer's knowledge, been definitely accepted as an absolute means of moisture determination, but as will be demonstrated, is independent of and preferable to all other methods in scope and accuracy. It is of special interest in relation to the art of air conditioning, because the same fundamental phenomena are involved and subject to the same theory. It is of service not only in the art of air conditioning, but also a departure in the science of meteorology. It provides a method, remarkable for simplicity and accuracy, for the determination of the specific heat of air, which present methods have failed to establish, within an unquestioned accuracy of 2 per cent.

22 This method of moisture determination depends upon the cooling effect produced by the evaporation of moisture in a partially saturated atmosphere. This is usually measured by covering the bulb of an ordinary mercurial thermometer with a cloth or wick saturated with water and comparing its temperature with that of a thermometer unaffected by evaporation. The covered bulb is termed the wet-bulb thermometer, and the difference between the wet and dry-bulb readings is termed the wet-bulb depression. The temperature of the wet bulb is affected in a measure by radiation from surrounding objects. It is therefore very susceptible to air currents which serve to increase the evaporation and therefore decrease the percentage of error due to radiation. On this account, the earlier and more convenient form of hygrometer using a stationary wet bulb is very unreliable, considerable correction being necessary for radiation. The sling psychrometer advocated by the United States Weather Bureau overcomes this error to a great extent by increasing the ventilation and consequent rate of evaporation to such a degree that the

heat received by radiation becomes a small percentage of the total heat transformation.

23 The most reliable tables based on the stationary wet-bulb hygrometer are those by James Glaisher (1847)[1]. The tables of the United States Weather Bureau based upon an empirical formula deduced by Prof. Wm. Ferrel from simultaneous determinations with the sling psychrometer and the dew-point instrument are more reliable, and are now generally used. The limitations of this formula are admitted, since it is held to be correct only over the range of observation from which it was deduced, including simply temperatures below 120 deg. fahr.

24 Professor Ferrel's formula as given in the tables of the United States Weather Bureau is

$$e = e' - (0.000367\,P)\ (t - t')\left(1 + \frac{t' - 32}{1571}\right)$$

where

$e$ = partial pressure of the moisture in the air, which also = vapor pressure corresponding to the dew point

$e'$ = the vapor pressure corresponding to saturation at wet-bulb temperature $t'$

$P$ = the barometric pressure

$t$ = dry-bulb temperature in deg. fahr.

$t'$ = wet-bulb temperature in deg. fahr.

25 The temperature of the dew point is found by selecting the temperature corresponding to the pressure $e$, from the temperature-pressure diagram or table. The per cent of relative humidity is $R = \frac{e}{e_t}$, where $e_t$ is the vapor pressure corresponding to the dry-bulb temperature $t$, as previously demonstrated. The absolute humidity expressed in grains of moisture per cubic foot is then determined by multiplying the grains of moisture per cubic foot corresponding to saturation at dry-bulb temperature by the per cent of relative humidity thus determined.

26 The writer would substitute for such an empirical formula a rational one, having a thermodynamic basis, that is, a formula depending upon the transformation of sensible heat into latent heat in the adiabatic saturation of dry air.

27 Historically, it is of interest to note in this connection, that James Apjohn[2] propounded in 1836 this same theory of wet-bulb

[1] Phil. Trans. Royal Soc., 1851, p. 141.

[2] Irish Academy Trans., vol. 17, pp. 275–282, 1837.

temperature. However, he was unable to establish the correctness of his assumptions, partly because the data then extant regarding the specific heat of air and the latent heat of water vapor were inaccurate, but more particularly because he assumed the temperature indicated by the stationary wet-bulb thermometer which he used, to be the true temperature of evaporation, while as a matter of fact, it is considerably higher, owing, as we have shown, to the effect of radiation upon the stationary wet bulb.

28 The author first observed that the wet-bulb temperature given in the psychrometric tables of the United States Weather Bureau agreed substantially with the computed temperature at which air of a known temperature and moisture content would become saturated adiabatically, i.e., without the addition or subtraction of heat. These calculations were made by the writer in 1903, in determining the moisture-absorbing capacity of air in connection with the fan systems of drying. Subsequently, this relationship was still further investigated and thoroughly established in connection with the system of air conditioning introduced by the writer.

29 Tests upon progressive fan-system dry kilns in 1904 disclosed the fact that the wet-bulb temperature was substantially the same in all parts of the kiln regardless of the drop in temperature due to moisture absorption, a phenomenon which logically results from the identity of the wet-bulb temperature and the temperature of adiabatic saturation.

## PSYCHROMETRIC PRINCIPLES

30 The following principles underlie the entire theory of the evaporative method of moisture determination, as well as of air conditioning:

(*A*) *When dry air is saturated adiabatically the temperature is reduced as the absolute humidity is increased, and the decrease of sensible heat is exactly equal to the simultaneous increase in latent heat due to evaporation.*

(*B*) *As the moisture content of air is increased adiabatically the temperature is reduced simultaneously until the vapor pressure corresponds to the temperature, when no further heat metamorphosis is possible. This ultimate temperature may be termed the temperature of adiabatic saturation.*

(*C*) *When an insulated body of water is permitted to evaporate freely in the air, it assumes the temperature of adiabatic saturation of that air and is unaffected by convection; i.e., the true wet-bulb temperature of air is identical with its temperature of adiabatic saturation.*

31 From these three fundamental principles there may be deduced a fourth:

(*D*) *The true wet-bulb temperature of the air depends entirely on the total of the sensible and the latent heat in the air and is independent of their relative proportions. In other words, the wet-bulb temperature of the air is constant, providing the total heat of the air is constant.*

32 A statement of the experimental demonstration of these four principles is given in Appendix No. 2.

## APPLICATION OF THE EVAPORATION CALORIMETER TO THE DETERMINATION OF THE SPECIFIC HEAT OF AIR

33 In consequence of the psychrometric principles *A*, *B* and *C*, the moisture content of air from accurate psychrometric readings may be easily computed, provided the required temperature is known, as well as the density relations in a mixture of pure air and saturated water vapor, and also the exact latent heat of water vapor, and the specific heat of air and of water vapor at any temperature.

34 No novelty is claimed for this method since the writer found, while preparing this paper, that this very means had been proposed by James Apjohn[1]. However, it does not seem to have been taken very seriously by contemporary scientists since it was never properly developed. Moreover, the details of his method were such as to make it worthless.

35 Recent research into the properties of water vapor has fully established its properties to a great degree of exactness, with the possible exception of the specific heat, which is of minor importance in psychrometric calculations. The author, however, was surprised to find upon investigation that the usual value assigned to the specific heat of air was unquestionably incorrect, since it had been definitely proved to be variable, and not a constant as assumed by Regnault. Moreover, recent investigators conducting their experiments with modern apparatus, supposedly with extreme accuracy, differed from each other by more than 3 per cent, and from the generally accepted value of Regnault, by more than 2 per cent. Therefore, in order to use a rational formula in the construction of accurate psychrometric charts and tables, it becomes necessary to determine the specific heat of air to a much greater degree of accuracy than is known at present.

[1] Irish Academy Trans., vol. 18, pp. 1-17, 1838.

36 At the time of this writing, the author is not prepared to give any definite data with regard to such determinations, but will present a method employing the evaporation calorimeter which apparently affords great accuracy and upon which greater reliance can be placed than upon previous methods, in all of which the air or other gas must be measured with precision. This measurement, when dealing with air quantities sufficient to give accurate determinations, seems to present the chief difficulty.

37 In the present method, on the contrary, no air measurement, other than the determination of its density through temperature and barometric pressure, is required. It is, indeed, in this respect, closely allied to the throttling calorimeter method of determining the specific heat of steam. In other respects, however, it has a great advantage over that method in that it requires no subtractive calculations sensitive to error, but equates the known latent heat of water vapor, directly to the unknown specific heat of air, the weight of the water vapor having a known ratio to that of the air.

38 This method consists, first, in bringing a continuous supply of air close to saturation, where its moisture content can be determined with great accuracy by means of a wet and dry-bulb thermometer and applying the rational psychrometric formula [3] assuming an approximate value for the specific heat; second, in heating this current of air of known moisture content to any desired amount and taking the wet and dry-bulb readings as in experiment No. 2, Appendix No. 2. By applying the rational psychrometic formula derived in Pars. 58–67, we have

$$C_{pa} = \frac{r'(W' - W) - C_{ps}W}{(t - t')} \quad \ldots\ldots\ldots\ldots\ldots [3]$$

where

$C_{pa}$ = mean specific heat of air of constant pressure between temperatures $t$ and $t'$

$C_{ps}$ = mean specific heat of water vapor between temperatures $t$ and $t'$

$t$ = temperature of the dry bulb

$t'$ = temperature of the wet bulb

$r'$ = latent heat of water vapor corresponding to $t'$

$W$ = weight of water vapor actually contained in 1 lb. of dry air; i.e., it is the ratio of the weight of water vapor to the weight of air in the mixture

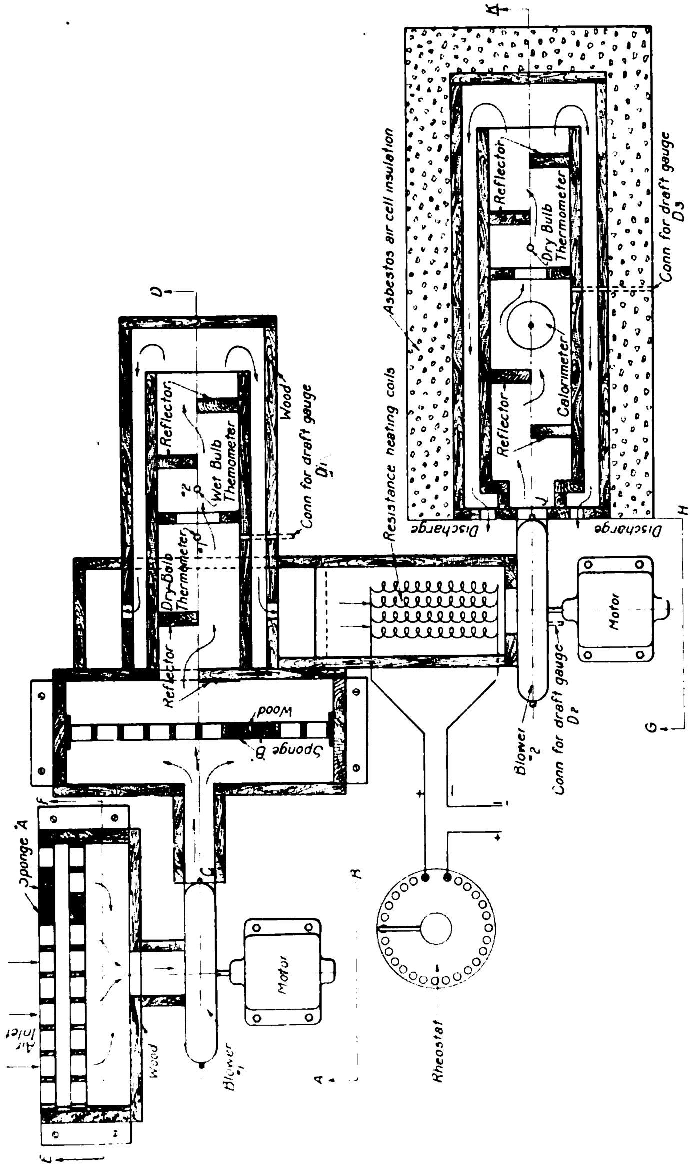


**Fig. 5 Plan of Apparatus for Determining Specific Heat**

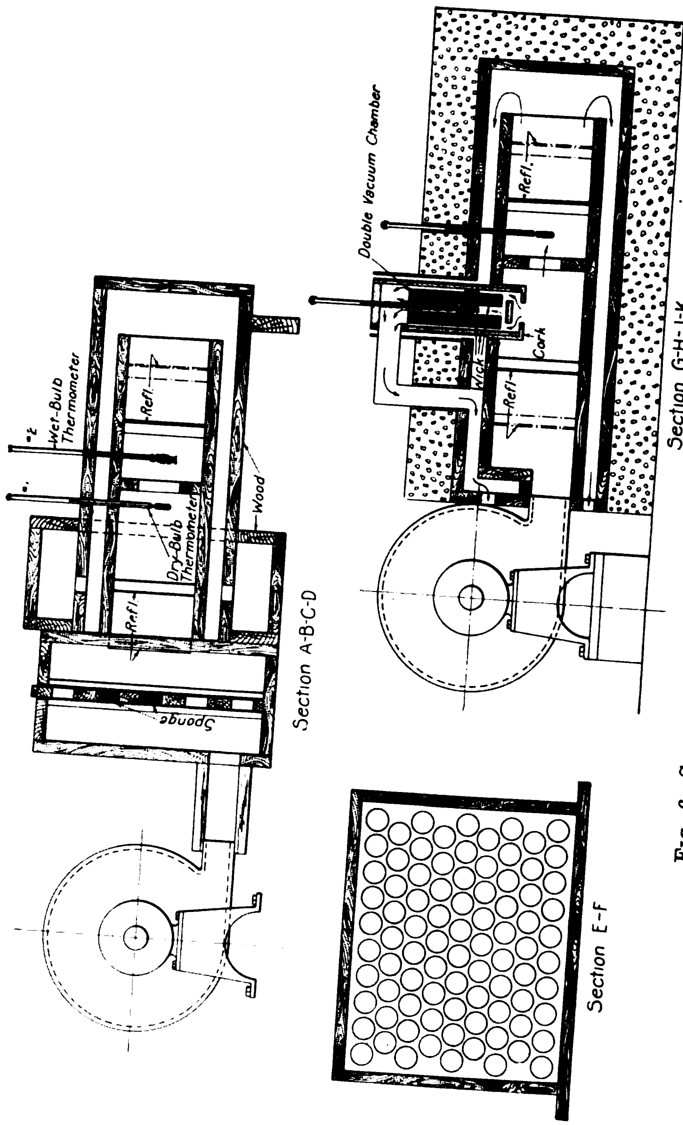


FIG. 6 SECTIONAL ELEVATIONS OF APPARATUS (FIG. 5)

$W'$ = weight of water vapor contained in 1 lb. of dry air at saturation at temperature $t'$

$$W' = \frac{Se'}{P - e'} \qquad [4]$$

where

$S$ = specific weight of water vapor
$P$ = barometric pressure
$e'$ = vapor pressure at $t'$

39 The apparatus for this determination is shown in Figs. 5 and 6. Two fans are required. Fan No. 1 draws the air through moist sponge $A$. The air in passing through the fan rises in temperature so that it is desirable to saturate it further by passing it through a moist sponge filter $B$. The wet and dry-bulb temperatures of the air are then taken with thermometers 1 and 2. These readings should be practically identical so that error in calculating the true dew point is negligible. The air is then heated by passing it through an electric heater provided with a rheostat for regulating the temperature. Thence it is blown, still under slight pressure, into fan No. 2, where it is thoroughly mixed and the pressure slightly increased. After the air passes through the second fan, the wet and dry temperatures are taken in the manner previously described, except that the greatest precaution is exercised in the construction of the air passage to avoid radiation from the thermometer bulbs. A differential gage is connected between chambers 2 and 3. Care is taken in regulating the pressures of the fans and in the damping of the discharge to keep the differential gage at zero, so that there will be the same pressure of air on both thermometers. This pressure is measured by a second draft gage $D_2$, and a third draft gage $D_3$, is connected to the second fan inlet where it is essential that the pressure be maintained above atmospheric so that any leakage occurring in the apparatus will be outward. Pitot tube and differential gages are used to determine the velocities on the thermometers.

40 The accuracy of this method is apparently limited only by the accuracy of the thermometers. Wet-bulb depressions between 20 and 50 deg. may be used to advantage, and the determinations should be accurate to at least $\frac{1}{10}$ of 1 per cent.

## DERIVATION OF A RATIONAL PSYCHROMETRIC FORMULA

41 As already pointed out, it is possible to derive a rational psychrometric formula based on the fundamental principles, *A*, *B* and *C*.

42 In considering the interchanges of heat occurring in psychrometric phenomena, it is essential to consider primarily the relative weights of dry air and of water vapor rather than the usual density-temperature relationship; that is, it is necessary to express moisture content as weight of water vapor per pound of pure air, rather than as weight of water vapor per cubic foot of space. Moreover, this relationship is much more adaptable to all of the usual calculations in air conditioning and in meteorology. The author, accordingly, has constructed all his formulae and psychrometric charts upon this basis. In the deduction of the formulae and in the construction of the accompanying charts, the following fundamental data were employed:

*a* Standard barometric pressure = 29.92 in. mercury = 14.6963 lb. per sq. in. = 2116.3 lb. per sq. ft.

*b* Absolute temperature = $t + 459.62$ deg. fahr.

*c* B.t.u. =

$$\frac{\text{heat required to raise 1 lb. of water from } 32^\circ \text{ to } 212^\circ}{180}$$

*d* Mechanical equivalent of heat = 777.52 ft-lb.

*e* Specific volume of air = weight of 1 cu. ft. of pure air at 32 deg. fahr. and 29.92 in. barometric pressure = 0.080728 lb. per cu. ft. Therefore $\frac{pv}{T} = 53.35$

*f* Instantaneous specific heat of air[1]

$$C_{pa} = 0.24112 + 0.000009\,t \text{ deg. fahr.}$$

*g* Vapor pressure, Holborn and Henning's modification of the Theisen formula $(t + 495.6) \log \frac{p}{14.70} = 5.409 (t - 212) - 3.71 \times 10^{-10} [(689-t)^4 - (477)^4]$, as calculated in tables of Marks and Davis (1909)

*h* Specific volume of steam as calculated in steam tables of Marks and Davis[2] (1909)

[1] Harvey N. Davis, Trans.Am.Soc.M.E., vol. 30, p. 750, 1908.

[2] W. F. G. Swann, Phil. Trans. Royal Soc., series A, vol. 210, pp. 199–238, 1909.

*i* Latent heat of water vapor[1]

$r = 141.124 (689 - t) 0.31249$ ($t$ = deg. fahr.)

$r = 109.16 - 0.56$ deg. fahr.

(approximately between 40 and 150 deg. fahr.)

*j* Instantaneous specific heat of water vapor (approximately)

$C_{ps} = 0.4423 + 0.00018\, t$ deg. fahr.

*k* Specific weight of water vapor at saturation for any pressure and temperature

$$S = \frac{\text{specific volume of air}}{\text{specific volume of steam}}$$

43 With respect to the reliability of these data, those on the latent heat of steam may be accepted as absolute within 0.1 per cent,

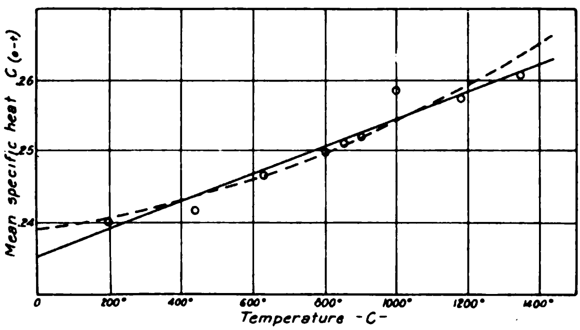


FIG. 7 SPECIFIC HEAT OF NITROGEN

since the agreement of recent investigators seems to have established the present values beyond question. Strange to say, however, the specific heat of air, as already pointed out, has not been established with accuracy within 2 per cent. Regnault gives it as a constant, $C_p = 0.2375$, and this value has generally been accepted. However, Holborn and Henning, whose valuable determinations in steam are well known, have demonstrated it to be a variable. For nitrogen they give a value $C\ (o - t) = 0.2350 + 0.000019\, t$ ($t$ in deg. cent.), a straight-line relationship, although for superheated vapors they find equations of a higher degree. The plot of their values for $C$ for nitrogen, as shown in Fig. 7, lacks considerable uniformity. So far as the points given are concerned they do not seem to warrant assuming a straight-line relationship. Their points would seem to indicate rather a curve with considerably greater values at lower temperatures

[1] C. H. Peabody, Trans. Am. Soc. M.E., vol. 31. p. 334, 1909.

than given by their line. If their values were accepted at atmospheric temperatures we would have a specific heat for air considerably lower than that given by Regnault, while psychrometric evidence seems to indicate that it should be considerably higher at such temperatures. The most reliable of recent determinations would seem to be that of W. F. G. Swann.[1] In his paper he points out a defect in the method of Regnault which would account for the latter's value being too low. The values given by Swann have therefore been adopted in this paper; although they appear still to require confirmation, since there would seem to be considerable opportunity for error in the method of air measurement used in his experiments.

44 The equation given for the specific heat of steam at low temperatures seems to agree fairly well with modern experimental data. Extreme accuracy is not pretended, nor is this essential at lower temperatures, since under 150 deg. the total heat value of the air is affected only 2 per cent at most by the specific heat of the water vapor. The values given by this equation, however, are undoubtedly more nearly correct at lower temperatures than the usual value, $C = 0.48$.

45 The psychrometric charts, Figs. 1 and 2, are constructed accurately from the foregoing data. Fig. 2 exhibits all psychrometric relationships, between the temperatures of 20 deg. and 350 deg. and saturation temperatures up to 143 deg. Fig. 1 gives the same values between temperatures 20 deg. and 110 deg. and saturation temperatures to 95 deg. These charts are here shown to a greatly reduced scale. In its original form, Fig. 1 permits the reading of both the wet and dry-bulb temperatures to an accuracy of 0.1 deg. and of the moisture weight per pound of air to 0.2 grains. All calculations have been made with accuracy to five significant figures by means of a Thatcher slide rule.

## SATURATION CURVE

46 The saturation curve, Fig. 2, expressed in grains of moisture per pound of air, was computed from the formula

$$G = \frac{5284\,(t + 459.64)\,D_s}{P - e} \qquad [5]$$

where

$G$ = grains of moisture per lb. of pure air at saturation
$t$ = temperature of saturation in deg. fahr.

[1] Phil.Trans.Royal.Soc., series A, vol. 210, pp. 199–238, 1909.

$t + 459.64$ = absolute temperature

$D_s$ = density in lb. per cu. ft. of saturated water vapor at temperature $t$

= reciprocal of specific volume of steam

$P$ = 29.92 = assumed standard of barometric pressure in in. of mercury

$e$ = vapor pressure of saturated water vapor

5284 = constant of the equation

The derivation of equation [5] is given in Appendix No. 3.

TABLE 1 SPECIFIC WEIGHT OF STEAM

$$S = \frac{53.35\ (t + 459.6)\ D_S}{144 \times 0.4908\ E}$$

| $t$ | $e$ | $D_S$ | $S$ | $S$ Corrected | $D_S$ Corrected | Grains Moisture per cu. ft. |
|---|---|---|---|---|---|---|
| 40 | 0.2477 | 0.000410 | 0.6245 | 0.6228 | 0.0004089 | 2.8623 |
| 50 | 0.3625 | 0.000587 | 0.6230 | 0.6231 | 0.0005871 | 4.1097 |
| 60 | 0.5220 | 0.000828 | 0.6221 | 0.6233 | 0.0006296 | 4.4072 |
| 70 | 0.7390 | 0.001148 | 0.6212 | 0.6236 | 0.0011524 | 8.0668 |
| 80 | 1.0290 | 0.001570 | 0.6217 | 0.6239 | 0.0015755 | 11.0285 |
| 90 | 1.4170 | 0.002130 | 0.6237 | 0.6242 | 0.0021320 | 14.9240 |
| 100 | 1.9260 | 0.002851 | 0.62525 | 0.6246 | 0.0028482 | 19.9374 |
| 110 | 2.5890 | 0.003766 | 0.6255 | 0.6250 | 0.0037630 | 26.3410 |
| 120 | 3.4380 | 0.004924 | 0.62665 | 0.6254 | 0.0049140 | 34.3980 |
| 130 | 4.5200 | 0.006370 | 0.6273 | 0.6260 | 0.0063570 | 44.4990 |
| 140 | 5.8800 | 0.008140 | 0.6266 | 0.6266 | 0.0081400 | 56.9800 |
| 150 | 7.5700 | 0.010320 | 0.6280 | 0.6273 | 0.0103100 | 72.1700 |
| 160 | 9.6500 | 0.012960 | 0.6282 | 0.6280 | 0.012956 | 90.6920 |
| 170 | 12.200 | 0.016140 | 0.6288 | 0.6288 | 0.016140 | 112 9800 |
| 180 | 15.290 | 0.019940 | 0.6296 | 0.6296 | 0.019940 | 139.5800 |
| 190 | 19.020 | 0.024440 | 0.6301 | 0.6307 | 0.024465 | 171.2550 |
| 200 | 23.47 | 0.029760 | 0.6313 | 0.6316 | 0 029780 | 208.4600 |

47 The specific weight of saturated water vapor is not constant, but varies with the temperature of saturation and may be calculated from equation [1]. The theoretical value, computed from its molecular weight, assuming it to be a perfect gas, is 0.6221. This is the assumption made in the computation of the psychrometric tables published by the United States Weather Bureau, which are inaccurate, therefore, in proportion to the variation of $S$ from this theoretical value. The actual values for the specific weight of water vapor at various saturation temperatures, computed from equation [35] are given in Table 1.

48 The specific weight of water vapor may also be given independent of the density as

$$S = 0.6221 + 0.001815 \sqrt{e} + 0.0000051 \sqrt{e^3}$$

Hence

$$G = \frac{7000 \ (0.6221e + 0.00182 \sqrt{e^3} + 0.0000051 \sqrt{e^5})}{P - e}$$

At atmospheric temperature the term $0.0000051 \sqrt{e^5}$ is negligible. Hence

$$G = \frac{7000 \ (0.6221e + 0.00182 \sqrt{e^3})}{P - e}$$

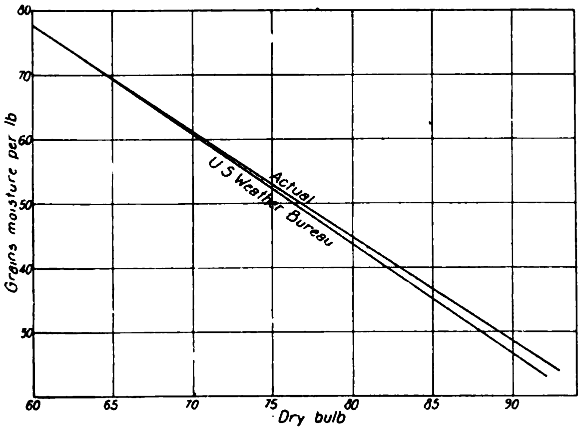


Fig. 8 Specific Weight of Steam

### CONSTRUCTIONS OF ADIABATIC SATURATION LINES

49 As shown in Par. 30 any adiabatic change involving moisture content and temperature of air may be expressed by equating the change in total specific heat to the corresponding change in latent heat. It may also be expressed by equating the total heat contained in the air in the state resulting from adiabatic change. By either of these two methods, given in Appendix No. 4, the relations of formula [6] are established.

$$r'(W' - W) = C_{pa}(t - t') + C_{ps}W(t - t') \dots\dots\dots [6]$$

in which

$(t-t')$ = the true wet-bulb depression

$(W'-W)$ = the moisture absorbed per lb. of pure air when it is adiabatically saturated from an initial dry-bulb temperature $t_0$ and an initial moisture content $W$

$C_{pa}$ = mean specific heat of air at constant pressure between temperature $t$ and $t'$

$C_{ps}$ = specific heat of steam at constant pressure between $t$ and $t'$

$r'$ = latent heat of evaporation at wet-bulb temperature $t'$

Knowing any two of the three important values of $t$, $t'$ or $W$, we may solve for the third or for any other required relation.

50 *Determination of Weight of Moisture in 1 Lb. of Pure Air, having a Dry-Bulb Temperature t and Wet-Bulb Temperature t'.* To determine the equation of the adiabatic line corresponding to a given saturation, or true wet-bulb temperature $t'$, and dry-bulb temperature $t$, we have from equation [6]

$$[r' + C_{ps}(t - t')]\, W = r'W' - C_{pa}(t - t') \qquad [7]$$

$$W = \frac{r'W' - C_{pa}(t - t')}{r' + C_{ps}(t - t')} \qquad [8]$$

51 The diagonal adiabatic lines in the charts, Figs. 1 and 2, representing saturation or wet-bulb temperatures, are calculated from this formula. It should be observed that they would be perfectly straight if it were not for the element $C_{ps}(t - t')$, which produces a slight curvature, becoming more pronounced at higher saturation temperatures. The dew point $t_1$ corresponds to $W$ on the saturation curve. The slope of these lines, neglecting $C_{ps}(t - t')$, is $\frac{dW}{dt} = -\frac{C_{pa}}{r'}$. This will always give the intercept $t$ for $W = 0$.

52 *Wet-Bulb Depression and Cooling Effect.* The wet-bulb depression or cooling effect obtained by having $t$ and $W$ known is

$$t - t' = \frac{r'(W' - W)}{C_{pa} + C_{ps}W} \qquad [9]$$

and

$$t = t' + \frac{r'(W' - W)}{C_{pa} + C_{ps}W} \qquad [10]$$

53 Having $t$ and $W$ known, $t$ cannot be calculated except by relating $W$ to $t$ by an empirical equation. By referring to the psychrometric charts, Figs. 1 and 2, constructed chiefly for that purpose, $t$ is conveniently determined. The cooling effect $(t - t')$, to be obtained by saturating air of known temperature and moisture content, is likewise obtained from the chart.

54 *Moisture-Absorbing Capacity of Air.* For determining the moisture-absorbing capacity, or moisture deficit of air, having a known temperature and moisture content, we have per pound of pure air

$$(W' - W) = \frac{(C_{pa} + C_{ps} W)\ (t - t')}{r'} \qquad [11]$$

55 *Per Cent Adiabatic Saturation.* The per cent of adiabatic saturation is

$$\frac{W}{W'} = \frac{r' W' - C_{pa}\,(t - t')}{r' W' - C_{ps}\,(t - t')\ W'} \qquad [12]$$

or if we neglect $C_{ps}\,(t - t')\ W'$

$$\frac{W}{W'} = 1 - C_{pa}\,\frac{(t - t')}{r' W'} \qquad [13]$$

56 *Specific Heat of Air.* The equation for the experimental determination of the specific heat of air by the evaporative method is

$$C_{pa} = \frac{r'\,(W' - W) - C_{ps}\,(t - t')}{(t - t')} \qquad [14]$$

57 For engineering purposes however, it is preferable to determine any unknown value directly from the psychrometric charts, which afford to a great degree of accuracy a simple graphic solution of any problem of psychrometry.

## DERIVATION OF THE RATIONAL PSYCHROMETRIC FORMULA FOR VAPOR PRESSURE

58 The present empirical psychrometric formula in use by the United States Weather Bureau was first deduced by Professor Ferrel,[1] while the constants of the formula were deduced from a series of experiments by Professor Marvin and Prof. H. A. Hazen. The error in Broch's and Regnault's values for vapor pressures which they adopted alone would require its revision. Moreover, the opportunity for error in their methods has already been pointed out. However, considering the difficulties of their experimental method and the correction necessary for radiation in the wet-bulb reading, the results obtained are remarkable for consistency and accuracy. There are errors in the form of the equation, however, as well as in

[1] Annual Report, Ch. Signal Officer, 1886, Appendix 24, pp. 233 259.

the constants employed, which make its inaccuracy more pronounced at lower humidities and at the higher temperature. At very high temperatures used in mechanical drying it is entirely inoperative.

59 The need of an accurate rational psychrometric formula for vapor pressures using modern data is therefore apparent. The required values could be obtained indirectly from the formula already given, but computation is facilitated by another derivation giving directly the vapor pressure *e*.

60 In equation [8]

$$W = \frac{r' W' - C_{pa} (t - t')}{r' + C_{ps} (t - t')}$$

let *t* be the dew point corresponding to *W*, and *e* the vapor pressure corresponding to *W* in in. of mercury. Referring to equation [5]

$$W = \frac{Se}{P - e}$$

by substitution

$$\frac{S_1 e}{P - e} = \frac{r' \left(\frac{S'e'}{P - e'}\right) - C_{pa} (t - t')}{r' + C_{ps} (t - t')} \qquad [15]$$

Solving for *e*

$$e = P \left\{ \frac{\left[\frac{S'e'r' - (P - e') C_{pa} (t - t')}{(P - e') [r' + C_{ps} (t - t')]}\right]}{\left\{\frac{S_1 (P - e') [r' + C_{ps} (t - t')] + [S'e'r' - (P - e') C_{pa} (t - t')]}{(P - e') [r' + C_{ps} (t - t')]}\right\}} \right\} \qquad [16]$$

Assuming $S'e = S_1 e_1$, this simplifies to

$$e = P \left[\frac{S'e'r' - (P - e') C_{pa} (t - t')}{S_1 P r' + (S_1 C_{ps} - C_{pa}) (P - e') (t - t')}\right] \qquad [17]$$

At 100 deg.

$$S_1 C_{ps} - C_{pa} = [(0.623 \times 0.46) - 0.242] = 0.033 \qquad [18]$$

Therefore the value $-e (S_1 C_{ps} - C_{pa}) (t - t')$ is ordinarily negligible. Hence we have

$$e = \frac{S'e'r' - C_{pa} (P - e') (t - t')}{S r' + (S_1 C_{ps} - C_{pa}) (t - t')} \qquad [19]$$

61 By comparison it will be found that the difference between $S'r'$ and $Sr' + (S_1 C_{ps} - C_{pa}) (t - t')$ is negligible. Hence it may be assumed

$$e = e' - \frac{C_{pa}\,(P - e')\,(t - t')}{S'R'} \quad\text{..............[20]}$$

For $r'$ may be substituted the approximate value $r' = 1091.6 - 0.56\,t'$ and for $S'$ the value $S' = 0.6215 + 0.000034\ t'$ (approximately). Hence

$$e = e' - \frac{C_{pa}\,(P - e')\,(t - t')}{(0.6215 + 0.000034\,t')\,(1091.6 - 0.56\,t')} \quad\text{......[21]}$$

$$e = e' - \frac{C_{pa}\,(P - e')\,(t - t')}{678.4 - 0.3011\,t'} \quad\text{..............[22]}$$

TABLE 2 COMPARISON OF NEWLY DETERMINED PSYCHROMETRIC VALUES WITH OLD UNITED STATES WEATHER BUREAU VALUES

| Water Vapor Contained in 1 Lb. of Pure Air for Wet Bulb of 60 Deg. Fahr. and Dry Bulb of $t$ from U. S. Weather Bureau Formulæ | | | | | | Water Vapor Actually Contained in 1 Lb. of Pure Air for Wet Bulb of 60 Deg. Fahr. | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| $t$ | $t - t'$ | $e$ | $29.92 - e$ | Grain per Lb. Air | Per Cent Error | $t$ | $t - t'$ | $C_{ps}$ | $C_{pa}$ | Grain per Lb. Air |
| 70 | 10 | 0.4053 | 29.515 | 59.8 | 0.0205 | 70 | 10 | 0.4540 | 0.24170 | 61.06 |
| 75 | 15 | 0.3495 | 29.570 | 51.5 | 0.0280 | 75 | 15 | 0.4544 | 0.24172 | 52.98 |
| 80 | 20 | 0.2936 | 29.626 | 43.1 | 0.0388 | 80 | 20 | 0.4549 | 0.24175 | 44.84 |
| 85 | 25 | 0.2380 | 29.682 | 34.9 | 0.0546 | 85 | 25 | 0.4553 | 0.24177 | 36.915 |
| 90 | 30 | 0.1820 | 29.738 | 26.6 | 0 0808 | 90 | 30 | 0.4558 | 0.24179 | 28 934 |
| 95 | 35 | 0.1260 | 29 794 | 18.4 | 0.1236 | 95 | 35 | 0.4562 | 0.24181 | 20 995 |
| 100 | 40 | 0.0700 | 29.850 | 10.2 | 0 2200 | 100 | 40 | 0.4567 | 0 24184 | 13.082 |
| 105 | 45 | 0.0145 | 29.905 | 2.11 | 0 5960 | 105 | 45 | 0.4571 | 0.24187 | 5.220 |

$e = e' - 0.000367\,P\,(t - t')\left(1 + \frac{t' - 32}{1571}\right)$

$G = \frac{e \times 0.6221 \times 7000}{29.92 - e}$

$t$ = dry-bulb temperature, deg. fahr.

$C_{pa}$ = specific heat of air

$C_{ps}$ = specific heat of vapor

$G'$ = 77.32 grains per lb.

$t'$ = 60 deg. fahr.

$r'$ = 1057.8

$C_{ps} = 0.4423 + 0.00018\,t_m$

$C_{pa} = 0.24112 + 0.000009\,t_m$

$G = \frac{G'r' - 7000\,C_{pa}\,(t - t')}{r' + C_{ps}\,(t - t')}$

and if Swann's value of $0.24112 + 0.000009\,t$ is accepted for the value of $C_{pa}$ as in the charts,

$$e = e' - \frac{(P - e')\,(t - t')}{2803 - 1.329\,t'} \quad\text{..............[23]}$$

This equation has been carefully tested by comparing with values of the psychrometric coefficient as determined by means of the charts as shown in Table 2 and Fig. 9. This shows that it is permissible to use $\frac{1}{2800 - 1.3\, t'}$ as the coefficient instead of $\frac{1}{2803 - 1.329\, t'}$, giving

$$e = e' - \frac{(P - e)\,(t - t')}{2800 - 1.3\,t'} \quad \ldots\ldots\ldots\ldots\ldots [24]$$

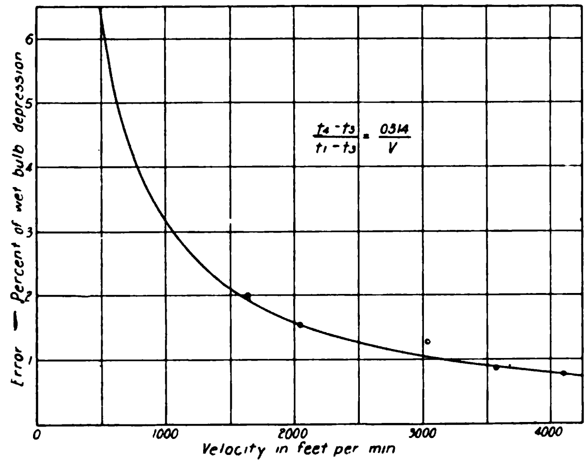


FIG. 9 RELATION OF GRAINS OF MOISTURE FROM GOVERNMENT TABLES TO GRAINS ACTUALLY CONTAINED

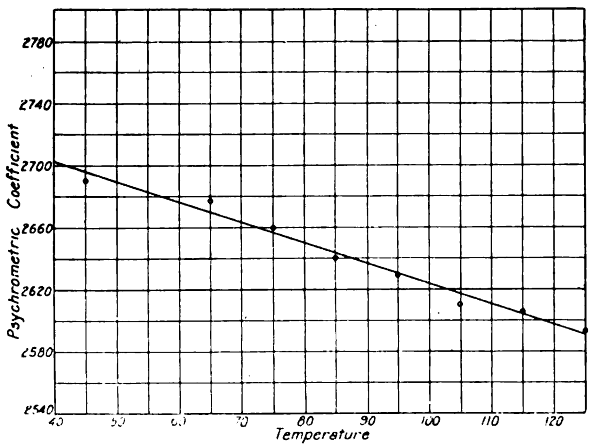


FIG. 10 RADIATION ERROR IN WET BULB OF SLING PSYCHROMETER

This formula will give values of $e$ for all wet and dry-bulb temperatures and all barometric pressures with an error of less than 0.5 per cent, assuming the chosen value of $C_{pa}$ to be correct.

62 This equation should be used where the true wet-bulb temperature is obtained as in the aspiration psychrometer. With the sling psychrometer a correction must be made for the error in depression due to radiation and stem correction. By referring to Fig. 10 showing the per cent of radiation error, it is seen that this is inversely proportional to the velocity. It is also, of course, greatly affected by the conditions of exposure, i.e., whether it is surrounded on all four sides by bodies at the temperature of the dry bulb, or only partly by bodies of that or a different temperature. The effect of radiation outside of an enclosure may be assumed to be approximately one-half of that within an enclosure.

64 A sling psychrometer 15 in. in length is ordinarily revolved between 150 and 225 r.p.m. giving a velocity between 1200 and 1800 ft. per min. This will give, according to Fig. 10, a radiation error of 2.6 to 1.75 per cent within an enclosure, and 1.3 to 0.9 per cent without an enclosure. Hence an average radiation error of 1.6 per cent of the wet-bulb depression may be arbitrarily assumed. The wet-bulb depression given by the sling psychrometer may be corrected by this amount to give the true depression, which may be used in the foregoing psychrometric formula, or the formula itself may be modified to allow for this error.

65 If this formula is corrected for 1.6 per cent radiation error

$$e = e' - \frac{(P - e')\,(t - t')}{2755 - 1.28\,t'} \quad \ldots\ldots\ldots\ldots\ldots\ldots [25]$$

for the sling psychrometer.

66 Using the true wet-bulb depression in formula [24], letting $e_2$ be the vapor pressure corresponding to saturation at the dry-bulb temperature $t$

$$R = \frac{e}{e_2} = \frac{e'}{e^2} = \frac{(P - e')\,(t - t')}{(2800 - 1.3\,t)\,e_2} \quad \ldots\ldots\ldots\ldots [26]$$

for the per cent of relative humidity.

67 Let $W$ be the grains of moisture per cu. ft. at any vapor pressure $e$, and $W_2$, grains per cu. ft. at $e_2$; then

$$W = (RW_2) = \frac{W_2}{e_2}\left[e' - \frac{(P - e')\,(t - t')}{2800 - 1.3\,t'}\right] \quad \ldots\ldots\ldots [27]$$

also

$$W = \left(\frac{460 + t'}{460 + t}\right) W_1 \quad \ldots\ldots\ldots\ldots\ldots\ldots [28]$$

where $W_1$ is the grains of moisture per cu. ft., corresponding to the dew point at vapor pressure $e$.

EFFECT OF CHANGE IN BAROMETRIC PRESSURE

68 Suppose that air in which the vapor pressure is $e_0$ is compressed from a barometric pressure $P_0$ to a barometric pressure $P$, then the partial pressure of both the air and the vapor are increased proportionally and $e = \frac{e_0 P}{P_0}$. The temperature corresponding to saturation at $e$ is the temperature of the dew point at pressure $P$.

69 The per cent of isothermal saturation becomes

$$R = \left(\frac{e}{e_2}\right) = \frac{e_0}{e_2} \frac{P}{P_0} = \frac{R_0 P}{P_0} \quad \ldots\ldots\ldots\ldots\ldots [29]$$

where $e_2$ is the saturated vapor pressure corresponding to the dry-bulb temperature $t$.

TOTAL HEAT CURVE

70 This curve shows the sensible heat in the air above a base temperature of 0 deg. fahr., plus the latent heat contained in the water vapor at saturation, but not including the heat of the liquid. Since the wet-bulb temperature, or adiabatic lines contain all points having the same total heat (neglecting heat of liquid), the curve serves to determine the total heat in the air under any and all conditions represented by the chart. This is of great convenience in calculating refrigeration required to cool and de-humidify air. For example, suppose it is required to find the refrigeration necessary to cool 1 lb. of air containing 98 grains of moisture and having a dry-bulb temperature of 95 deg., to a final temperature of 40 deg. saturated. We find from the chart that the wet-bulb temperature is 75 deg. The total heat corresponding to a saturation temperature of 75 deg. is 37.8 B.t.u., while the total heat at 40 deg. is 15.3 B.t.u. The difference, 22.5 B.t.u. is the refrigeration required per pound of air.

The author wishes to acknowledge his indebtedness to his assistants, Mr. Theodore A. Weager and Mr. Frank L. Busey, for the actual work of computation and the construction of the diagrams.

## APPENDIX No. 1

### PROOF OF FORMULA [1]

$$\text{Per cent humidity} = \frac{e_1}{e'_2} = \frac{D_2}{D'_2}$$

71 In this formula $e_1$ is the pressure of saturated vapor corresponding to the dew point $T_1$, and $e'_2$ is the vapor pressure at saturation corresponding to temperature $T_2$. It also follows that

$$D_2 = D'_2 \times \frac{e_1}{e'_2}$$

At constant pressure

$$\frac{D_2}{D_1} = \frac{T_1}{T_2}, \text{ or } D_2 = \frac{D_1 T_1}{T_2} \quad \ldots\ldots\ldots\ldots [30]$$

Also if it is assumed $\frac{pv}{T}$ is constant, i.e., $\frac{e}{DT}$ is constant for saturated water vapor (not exactly correct),

$$\frac{e_1}{D_1 T_1} = \frac{e'_2}{D'_2 T_2}$$

Therefore

$$\frac{e_1}{e'_2} = \frac{D_1 T_1}{D'_2 T_2} \quad \ldots\ldots\ldots\ldots [31]$$

But substituting $D_2$ for its value in [30]

$$\frac{e_1}{e'_2} = \frac{D_2}{D'_2} = \text{per cent of isothermal saturation.}$$

# APPENDIX No. 2

### EXPERIMENTAL DEMONSTRATION OF THE FOUR PSYCHROMETRIC PRINCIPLES GIVEN IN PARS. 30 AND 31

**72** **While the four psychrometric principles might be all logically surmised, experimental demonstration is desirable. A calorimetric method was devised**

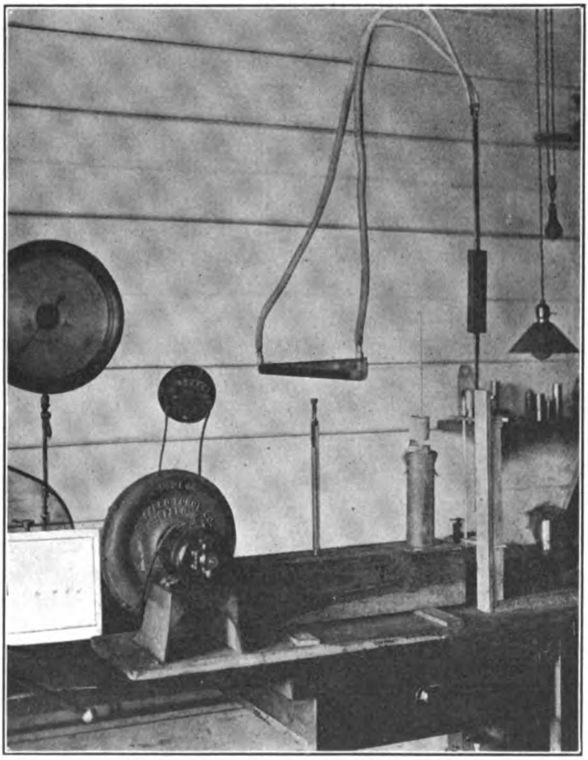

FIG. 11 GENERAL VIEW OF APPARATUS

by the author for this purpose and also to determine the probable error of the indications of the wet bulb in the sling psychrometer due to radiation.

73 The apparatus used is shown in Figs. 11, 12 and 13. Air was supplied by fan *A* at slight pressure to the wooden air duct *B*, from which it escaped through the orifice *C*, and through the tube *D*, in which the wet-bulb calo-

rimeter, Figs. 11 and 12, was used in different experiments. A differential draft gage and pitot tube indicated the velocity of the air through the orifice and over the wet-bulb thermometer No. 4.

74 This velocity could be varied any desired amount between 1000 and 4000 ft. per min. by adjustment of the motor rheostat. It was found that the static pressure in the box agreed substantially with the velocity head at the thermometer bulb so that no further measurements of the former were recorded. Thermometer No. 1 indicated the dry-bulb temperature of the air in the box, thermometer No. 2, the dry-bulb temperature of the air outside, and thermometer No. 3, the calorimeter temperature. Thermometers Nos. 3 and 4 were calorimeter thermometers especially constructed for this test by the Taylor

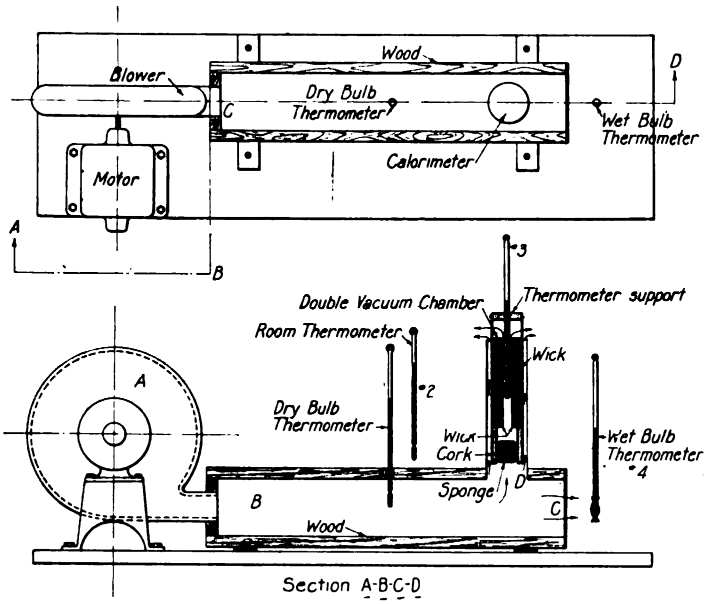


FIG. 12 PLAN AND ELEVATION OF APPARATUS

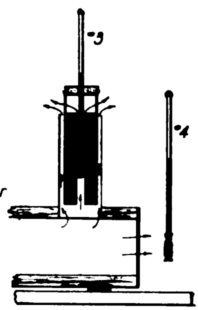

FIG. 13 DETAIL OF CALORIMETER

Instrument Company. They were in the fahrenheit scale, graduated to tenths of a degree, and calibrated to $\frac{1}{40}$ deg. They were also carefully compared.

75 *Experiment No. 1.* This test was made in order to determine the effect of an air blast of known intensity upon the readings of thermometers No. 3 and No. 4. The need of the determination was evident as the velocities were not necessarily the same upon the two bulbs nor in the same relative direction. Moreover, it was evident that a portion of the heat of the air was converted into mechanical energy of the air current; also that a portion of this, at least, was re-converted into heat by impact on the bulb. This temperature error, if any, would be proportional to the velocity head; therefore a maximum condition of 1-in. velocity head and static pressure were taken. Both thermometers and the calorimeter were perfectly dry. The apparatus was run under constant

conditions for 1 hour previous to the test. Consecutive readings were taken of marked uniformity, and the average results are given in Table 3.

76 The actual calculated drop in temperature due to 1-in. air blast under the above conditions is

$$D = (82.7 + 459.6)\left[1 - \left(\frac{397}{398}\right)^{0.29}\right] = 0.38 \text{ deg.} + \ldots\ldots\ldots[32]$$

77 It will be noted that thermometer No. 3 read 0.047 lower than No. 4 at 1 in pressure. However, at a wet-bulb temperature of 70 deg., 1 deg. in the temperature of the dry-bulb produces only 0.3 deg. increase in wet-bulb temperature; i.e., $\frac{dt'}{dt} = 0.30$. Therefore at 1 in. pressure the error would be 0.014 and at ¼ in. pressure 0.0035. Hence, in any case, the correction would be negligible.

TABLE 3 EFFECT OF AIR BLAST OF KNOWN INTENSITY ON READINGS OF THERMOMETERS NO. 3 AND NO. 4

| Thermometers | | | | Temperature Differences | | |
|---|---|---|---|---|---|---|
| No. 2 | No. 1 | No. 4 | No. 3 | 1 and 3 | 1 and 4 | 3 and 4 |
| ...... | 82.737 | ...... | 82.653 | 0.084 | ...... | ...... |
| ...... | ...... | 82.566 | 82.613 | ...... | ...... | 0.047 |
| ...... | ...... | ...... | ...... | ...... | 0.131 | ...... |

Barometer pressure = 29.3 in. mercury = 397 in. water.

The temperature increase $E$ produced by an air blast equivalent to $p$ in. of water may be expressed by the equation

$$E = \left(\frac{0.38 - 0.13}{1}\right) p = 0.25\, p \ldots\ldots\ldots\ldots\ldots\ldots[33]$$

or $\frac{0.25}{0.38} = 66$ per cent of the theoretical temperature.

78 *Experiment No. 2.* This was for the purpose of determining approximately the per cent of error due to radiation and stem correction in the depression of the wet bulb of the sling psychrometer, and was accomplished by comparing wet-bulb thermometer No. 4, with wet-bulb thermometer No. 3, which was protected from practically all radiation by surrounding it with insulated wet surfaces at precisely the same temperature, and by protecting the stem with a wet cloth. This arrangement is shown in Fig. 11, and may be termed a wet-bulb or evaporation calorimeter. The protection for the wet bulb consisted in an annular vacuum tube, having the exterior surface covered with a wet cloth, and the interior with a tube of wet blotting paper. This was placed in an open tube leading from the air duct so that there is the same circulation of air over the wet surfaces as over the wet-bulb thermometer placed within. Thermometer No. 4 was rotated while being subjected to the blast, so that the condition in the sling psychrometer would be exactly reproduced.

79 The log of these tests shows that the error in the depression of the wet blub in the sling psychrometer for various velocities is as shown in Table 4 and Fig. 10. This error has been taken as directly proportional to the depression. More accurately it is proportional to the difference of the fourth powers of the respective absolute temperatures, except for the stem correction. However, where the depression is the usual small percentage of the absolute temperature, the error in assuming direct proportionality is insignificant.

80 The sling psychrometer, however, is subject to another error, heretofore seemingly overlooked. As shown in experiment No. 1, there is a rise in temperature due to the impact of the air upon the bulb, which, in the case of the dry bulb is 66 per cent of the theoretical, or 0.25 $p$, and in the case of the wet

TABLE 4 AVERAGE RESULTS OF TEST FOR RADIATION ERROR IN WET BULB OF SLING PSYCHROMETER

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 1 | Velocity pressure, in. water..... | 0.08 | 0.16 | 0.25 | 0.55 | 0.75 | 1.00 |
| 2 | Velocity, ft. per min............. | 1160 | 1640 | 2050 | 3040 | 3550 | 4100 |
| 3 | Room temperature No. 2....... | 86.0 | 82.0 | 85.1 | 85.2 | 87.2 | 87.25 |
| 4 | Dry-bulb temperature No. 1.... | 87.125 | 83.93 | 83.88 | 83.975 | 88.175 | 88.59 |
| 5 | Calorimeter temperature No. 3.. | 68.935 | 69.725 | 71.158 | 71.740 | 68.494 | 68.830 |
| 6 | Wet-bulb temperature No. 4..... | 69 21 | 70.01 | 71.353 | 71.892 | 68.654 | 68.965 |
| 7 | Calorimeter depression (difference between items 4 and 5).. | 18.19 | 14.205 | 12.722 | 12.235 | 19.681 | 19.760 |
| 8 | Difference between wet-bulb and calorimeter temperature....... | 0.295 | 0.285 | 0.195 | 0.152 | 0.160 | 0.135 |
| 9 | Ratio of wet bulb minus calorimeter temperature to calorimeter depression (item 8÷7). | 0.016 | 0.020 | 0.015 | 0.012 | 0.008 | 0.007 |
| 10 | Item 9 corrected for difference in impact......................... | 0.01606 | 0.02018 | 0.01527 | 0.01239 | 0.00853 | 0.00771 |

Temperature difference due to impact = 0.3 × 0.047 × velocity pressure.

$\frac{dt'}{dt}$ = 0.3 at $t'$ = 69 to 70 deg. fahr.

0.047 = temperature difference (thermometer No. 3–thermometer No. 4) with dry-bulb thermometers due to difference in impact at 1 in. velocity pressure.

bulb, $0.25 p \frac{dt'}{dt}$. This, however, would have no effect upon the calculated absolute humidity, but only on the temperature and consequent relative humidity.

81 The type of psychrometer which lends itself to the most accurate determinations is the Aszmann aspiration psychrometer[1] shown in Fig. 14. Here the air is aspirated through two tubes containing the wet and dry-bulb thermometers. The wet-bulb temperature is brought to a minimum by the use of an atomizer. This serves also to moisten the inner surface of the enveloping tube, thus cooling it and preventing radiation. In this type of psychrometer it should be noted that the impact of the air upon the thermometer bulbs largely neutralizes the reduction in pressure, producing the velocity as demonstrated in experiment No. 1.

[1] For full description see Zeitschrift für Instrumentenkunde, January 1892.

82 *Experiment No. 3.* The purpose of this experiment was to demonstrate principles *C* and *D* in Pars. 30 and 31. A modified form of the evaporation calorimeter as shown in Figs. 5 and 6 was used. The air was first passed through two layers of moistened sponge, bringing it very close to true adia-

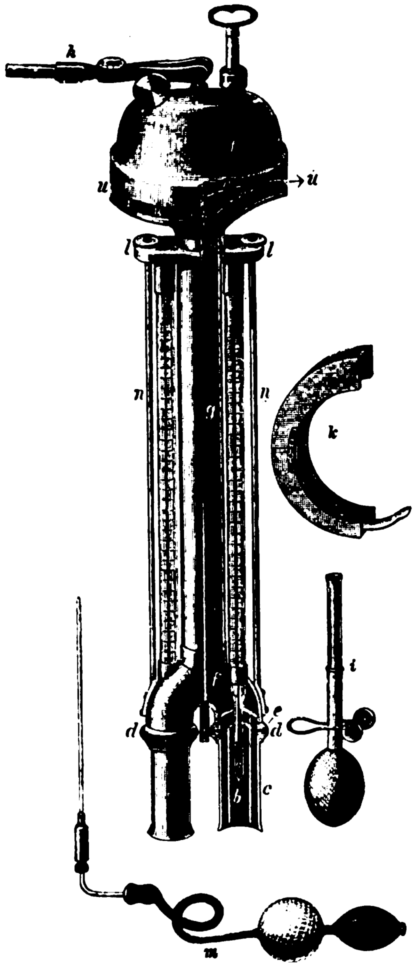


FIG. 14 ASPIRATION PSYCHROMETER

batic saturation. Its temperature was then taken alternately with a wet-bulb and a dry-bulb thermometer, and simultaneous readings were taken with thermometer No. 4, the error of which had been established. It was found very difficult to obtain consistent readings to the degree of accuracy desired, on account of the extreme lag of temperature in the calorimeter thus constructed. On this account it was found necessary to maintain the temperature constant at No. 4 by continuous hand regulation at the fan inlet and continuous observations of thermometer No. 4. It was found possible in this way to prevent a variation of more than 0.05 deg. Results showed the temperature in the calorimeter with a wet bulb to be a little lower than a No. 3 when a dry bulb was used, owing to slightly imperfect saturation. This test, therefore, did not agree exactly with the results of experiment No. 2. It appeared to be possible, however, for the water on the wet bulb in experiment No. 2 to be cooled to a lower temperature than that of adiabatic saturation, and it is necessary, therefore, to attribute this slight discrepancy to some source of error in the temperature of the air in experiment No. 3. Three explanations

TABLE 5 COMPARISON OF WET-BULB TEMPERATURE WITH SATURATION TEMPERATURE WHEN PASSING AIR THROUGH WET SPONGE IN CALORIMETER, PRESSURE 0.25 IN.

| No. 1 Dry-Bulb Temperature | No. 2 Wet-Bulb Temperature | No. 3 Calorimeter Temperature | Difference |
|---|---|---|---|
| 81.75 | 61.90 | 61.80 | 0.10 |
| 81.75 | 61.95 | 61.85 | 0.10 |
| 81.75 | 62.00 | 61.85 | 0.15 |
| 81.75 | 62.05 | 61.90 | 0.15 |
| 81.75 | 62.00 | 61.90 | 0.10 |
| 81.75 | 62.00 | 61.90 | 0.10 |
| 81.75 | 62.65 | 62.65 | 0.00 |
| 81.75 | 62.60 | 62.65 | 0.05 |
| 81.75 | 62.65 | 62.65 | 0.00 |
| 81.75 | 62 65 | 62.625 | 0 025 |
| 81.75 | 62.65 | 62.65 | 0.00 |
| 81.75 | 62.60 | 62.625 | 0.025 |
| 81.75 | 62.65 | 62.65 | 0.00 |
| 81.75 | 62.60 | 62.625 | 0.025 |
| 81.75 | 62.65 | 62.65 | 0.00 |
| 81.75 | 62.60 | 62.65 | 0.05 |
| 81.75 | 62.65 | 62.625 | 0.025 |
| 81.75 | 62.70 | 63.65 | 0.05 |

are possible: (*a*) the air being thoroughly saturated before entering the tube of the calorimeter, its temperature would easily be increased with any slight adiation due to imperfect insulation, especially since air delivery was greatly educed by the resistance of the sponge; (*b*) at the time the readings were taken the outside was always beginning to get dry, due to the very long time required to bring the temperature of the calorimeter to a minimum, during which the cloth on the calorimeter would begin to dry and require moistening, resulting in a momentarily increase of temperature; (*c*) the possibility of some parts of the sponge becoming dry and conducting a slight amount of heat to the wet portions.

83 The agreement of these tests, however, is quite sufficient to warrant fully the acceptance of the fundamental principles previously stated. It is also made evident that the reading of the wet-bulb thermometer properly protected from radiation as in experiment No. 2 is a most practicable and accurate method of determining the temperature of adiabatic saturation.

# APPENDIX No. 3

## PROOF OF FORMULA [5]

$$G = \frac{5284\ (t + 459.64)\ D_s}{P - e}$$

84 In this equation

$G$ = grains of moisture per lb. of pure air at saturation
$t$ = temperature of saturation in deg. fahr.
$t$ + 459.64 = absolute temperature
$D_s$ = density in lb. per cu. ft. of saturated water vapor at temperature $t$
= reciprocal of specific volume of steam
$P$ = 29.92 = assumed standard of barometric pressure in in. of mercury.
$e$ = vapor pressure of saturated water vapor
5284 = constant of the equation

85 According to the law of gaseous mixtures the total pressure is equal to the sum of the gaseous pressures of the component parts, and the weights of the two components are in proportion to the products of their respective pressures times their specific weights

$$\frac{W_1}{W_2} = \frac{p_1 S_1}{p_2 S_2} \text{ and } P = p_1 + p_2 \ldots\ldots\ldots\ldots\ldots\ldots\ldots [34]$$

For a mixture of 1 lb. of air and water vapor saturated at a given temperature, therefore

$$\frac{W_s}{1} = \frac{S_w\ p_s}{1\ (P - p_s)}, \text{ or } W_s = \frac{S_w\ p_s}{P - p_s}\ \frac{W_s}{1} = \frac{S_w\ p_s}{1\ (P - p_s)}, \text{ or } W_s \frac{S_w\ p_s}{P - p_s}$$

where

Weight of air = 1 lb.
Specific weight of air = 1
$(P - p_s)$ = total barometric pressure in lb. per sq. ft.
$W_s$ = weight of saturated water vapor in 1 lb. pure air
$p_s$ = pressure of saturated water at given temperature $t_1$ in lb. per sq. ft.
$S_1$ = specific weight of water vapor at temperature $t$, compared with air at same temperature and pressure; $p_s$ or $e$.
$W$ = weight of moisture vapor in mixture containing 1 lb. pure air.

Also

$$S = \frac{V_a}{V_s} = V_a D_s \text{..........................[35]}$$

where

$V_s$ = specific volume of saturated steam (volume of 1 lb.) at a given temperature, $t$

Pressure $e V_a$ = specific volume of air at the same pressure and temperature

$D_s$ = density of saturated steam in lb. per cu. ft. at temperature $t$

But we have for air

$$\frac{p^v}{T} = 53.35$$

$$V_a = 53.35 \left( \frac{t + 459.64}{P_s} \right) \text{.....................[36]}$$

Therefore

$$S_1 = \frac{53.35\, C_s\, (t + 459.64)}{p_s} D_s \text{....................[37]}$$

Hence, substituting in [34]

$$W = \frac{53.35\, (t + 459.64)}{(P - p)} D \text{......................[38]}$$

$$G = 7000\, W$$

$$(P - e) \text{ in. mercury} = (144 \times 0.4908)\ (P - p) \text{ lb. per sq. ft.}$$

Hence

$$G = \frac{5284\, (t + 459.64)\, D_s}{(P - e)} \text{......................[39]}$$

# APPENDIX No. 4

## DERIVATION OF FORMULA [6], GIVING THE EQUATION OF THE ADIABATIC SATURATION LINE

$$r' (W' - W) = C_{pa} (t - t') + C_{ps} W (t - t')$$

86 Assuming 1 lb. of pure air having the temperature $t$ containing $W$ lb. of moisture with the corresponding dew point $t_1$ and vapor pressure $e_1$ having a resultant adiabatic saturation temperature of $t'$, assume also a moisture increment $dW$ under adiabatic conditions resulting in a temperature increment of $-dt$. This moisture increment $dW$ is evidently evaporated at a vapor pressure $e_1$ corresponding to temperature $t_1$ and superheated to temperature $t$. The temperature of the liquid is evidently constant at temperature $t'$, from principle $C$. The total heat of the vapor in the increment is $H_1 dW + C_{ps} (t\text{-}t_1) dW$, where $H_1$ is the total heat of steam corresponding to temperature $t_1$ and vapor pressure $e_1$, and $C_{ps} (t\text{-}t_1)\, dW$ is the heat required to superheat from saturation temperature $t_1$ to dry-bulb temperature $t$. The heat of the liquid evaporated, however, is $q'dW$ corresponding to temperature of saturation $t'$.

87 The total heat interchange required to evaporate $dW$ under these conditions is therefore

$$\Sigma = (H_1 - q' + C_{ps}) \ (t - t)_1]\ dW \ldots\ldots\ldots\ldots [40]$$

The change in sensible heat of 1 lb. of air and $W$ lb. of water vapor due to the temperature increment $-dt$ is

$$\Sigma = - (C_{pa} + W C_{ps})\ dt \ldots\ldots\ldots\ldots [41]$$

Since the change is adiabatic these values may be related by the equation

$$H_1 - q' + [C_{ps} (t - t_1)]\ dW - (C_{pa} + WC_{ps})\ dt = 0 \ldots\ldots [42]$$

$$\int_W^{W'} \left\{H_1 - q' \ [C_{ps} (t - t_1)]\right\} dW = \int^{t'} (C_{pa} + WC_{ps})\ dt \ldots [43]$$

in which $H_1$ and $t_1$ are variables corresponding to the variable $W$ while $t$ is a variable related to $W$ by the different equation. A constant corresponding to $t'$ is $q'$ while $C_{ps}$ may be taken approximately as a mean between its values at $t_1$ and at $t'$ and $C_{ps}$ as a mean between its values at $t$ and at $t'$. The temperature of saturation is $t'$, and $W'$ is the corresponding moisture content at saturation.

88 It is not necessary, however, to solve this equation in this form as this relationship may be simplified.

$$\left\{H_1 - q' + [C_{ps} (t - t_1)]\right\} dW = \left\{H_1 - q' + [C_{ps} (t - t_1)) + (C_{ps} (t - t')]\right\} dW . [44]$$

It may be shown thermodynamically, assuming steam to be a perfect gas, that

$$H_1 - q' + [C_{ps}(t - t_1)] = H' - q' = r' \quad [45]$$

89 This may also be demonstrated approximately for the range of temperatures under discussion by computation from the values given in the steam tables of Marks and Davis, as in Table 6:

TABLE 6 COMPARISON OF ACTUAL VALUES OF $r'$ WITH VALUES OF $r'$ COMPUTED FROM THE TOTAL HEAT AT DIFFERENT TEMPERATURES $t_1$

$t' = 80$ *deg.*, $r' = 1046.7$

| $t'$ | $t_1$ | $C_{ps}$ | $H_1$ | $q'$ | $r'$ (Computed) |
|---|---|---|---|---|---|
| 80 | 70 | 0.44365 | 1090.3 | 48.03 | 1046.70 |
| 80 | 60 | 0.44356 | 1085.9 | 48.03 | 1046.74 |
| 80 | 50 | 0.44347 | 1081.4 | 48.03 | 1046.73 |
| 80 | 40 | 0.44338 | 1076.9 | 48.03 | 1046.6 |

$t' = 100$ *deg.*, $r' = 1035.6$

| $t'$ | $t_1$ | $C_{ps}$ | $H_1$ | $q'$ | $r'$ (Computed) |
|---|---|---|---|---|---|
| 100 | 90 | 0.44401 | 1099.2 | 67.97 | 1035.67 |
| 100 | 80 | 0.44392 | 1094.8 | 67.97 | 1035.7 |
| 100 | 70 | 0.44383 | 1090.3 | 67.97 | 1035.64 |
| 100 | 60 | 0.44374 | 1085.9 | 67.97 | 1035.67 |
| 100 | 50 | 0.44365 | 1081.4 | 67.97 | 1035.81 |
| 100 | 40 | 0.44356 | 1076.9 | 67.97 | 1035.54 |

$t' = 120$ *deg.*, $r' = 1024.4$

| $t'$ | $t_1$ | $C_{ps}$ | $H_1$ | $q'$ | $r'$ (Computed) |
|---|---|---|---|---|---|
| 120 | 110 | 0.44419 | 1108.0 | 87.91 | 1024.4 |
| 120 | 100 | 0.44410 | 1103.6 | 87.91 | 1024.57 |
| 120 | 90 | 0.44401 | 1099.2 | 87.91 | 1024.62 |
| 120 | 80 | 0.44392 | 1094.4 | 87.91 | 1024.64 |
| 120 | 70 | 0.44383 | 1090.3 | 87.91 | 1024.58 |
| 120 | 60 | 0.44374 | 1085.9 | 87.91 | 1024.50 |
| 120 | 50 | 0.44365 | 1081.4 | 87.91 | 1024.54 |
| 120 | 40 | 0.44356 | 1076.9 | 87.91 | 1024.47 |

$$r' = H_1 - q' + [C_{ps}(t' - t_1)]$$

or $$H' = H_1 + [C_{ps}(t' - t_1)]$$

Hence substituting in equation [43]

$$r' \int_W^{W'} dW + C_{ps} \int_W^{W'} (t - t')\, dW = C_{pa} \int_{t'}^{t} dt + C_{ps} \int_{t'}^{t} W dt \quad [46]$$

$$r'(W' - W) + C_{ps} \int_W^{W'} \left[ \int_{t'}^{t} dt \right] dW = C_{pa}(t - t') + C_{ps} W \int_{t'}^{t} dt$$

$$+ C_{ps} \int_{t'}^{t} \left[ \int_W^{W'} dW \right] dt \quad [47]$$

$$r'(W' - W) = C_{pa}(t - t') + C_{ps} W (t - t') \quad [48]$$

90 The same result may be obtained by equating the total heat in the air in any state with its total heat when in the state of adiabatic saturation. The total heat in a mixture of 1 lb. of pure air and saturated water vapor at a temperature $t'$ calculated from a base temperature of 0 deg. fahr. and deducing the heat of the liquid, $q'$, which as we have shown is unaffected by the adiabatic change, is

$$\Sigma = C_{pa}\, t' + r' W' \qquad [49]$$

91 The total heat under any other adiabatic condition, where temperature is $t$ and moisture $W$, is

$$\Sigma = C_{pa}\, t + [\,(H_1 - q_1) + C_{ps}\,(t' - t_1)\,]\, W \qquad [50]$$

which is substantially equivalent to

$$\Sigma = C_{pa}\, t + r' W + C_{ps}\,(t - t')\, W \qquad [51]$$

Therefore since the change is adiabatic we may equate [47] and [49].

$$C_{pa}\, t + r' W + C_{ps}\,(t - t')\, W = C_{pa}\, t' + r' W' \qquad [52]$$

$$C_{pa}\,(t - t') + C_{ps}\,(t - t')\, W = r'\,(W' - W) \qquad [53]$$

where

$(t\text{-}t')$ = the true wet-bulb depression

$(W' - W)$ = the moisture absorbed per lb. of pure air when it is adiabatically saturated from an initial dry-bulb temperature $t_o$ and an initial moisture content $W$

$C_{pa}$ = mean specific heat of air at constant pressure between temperature $t$ and $t'$

$C_{ps}$ = specific heat of steam at constant pressure between $t$ and $t'$

$r'$ = latent heat of evaporation at wet-bulb temperature $t'$

This is identical with equation [20] obtained by the differential method.

# TEST OF AN 85-H.P. OIL ENGINE

By Forrest M. Towl

## ABSTRACT OF PAPER

The paper describes a test of a DeLaVergne oil engine, FH type, operating an oil pump, and one of the same engine under the same conditions but with the load applied by a prony brake instead of a pump. The object of the test was to find the friction of the pump and gearing and the efficiency of the plant. Data of test and results of computations are given. The pump and transmission efficiency were 92.1 per cent, the total station efficiency, 25.52 per cent, and the duty per 1,000,000 B.t.u., 198,664,000.

# TEST OF AN 85-H.P. OIL ENGINE

By Forrest M. Towl, New York

Member of the Society

A test of a De La Vergne oil engine, FH type, was made at the pumping station of the Standard Oil Company, Fawn Grove, Pa., on April 20 and 21, 1911. The engine was one of the regular 85-h.p. machines, built by the De La Vergne Machine Company, New York, cylinder 17 in. by 27½ in. and running, as installed at Fawn Grove, at about 180 r.p.m.

2 This type of engine operates on the well-known Beau de Rochas cycle. The successive operations take place in much the same manner as in the ordinary 4-cycle gas engine, except that the fuel is injected into the cylinder at the completion of the compression stroke instead of being drawn in gradually as in the gas engine. Figs. 1 and 2, an exterior view and a longitudinal section, show the relationship of the various parts and the internal construction. Fig. 3 shows the engine and pump as installed, with clutch connection.

3 The charge of air is drawn into the cylinder through the inlet valve *A* (Fig. 2), and during the compression stroke which follows is forced into the small combustion chamber at the rear end of the cylinder, where it is compressed to about 300 lb. per sq. in.

4 A valuable feature of this engine is the high thermal efficiency without excessive cylinder pressure. The highest pressure after ignition is approximately 500 lb. per sq. in.

5 Fuel is preferably stored in an underground tank, from which it is raised by a small rotary pump driven by the engine to a miniature standpipe. An oil pump withdraws it from the standpipe and delivers it at high pressure to the spraying device, whence it is propelled into the cylinder at the proper moment in a highly atomized state.

The American Society of Mechanical Engineers 29 West 39th Street, New York. All papers are subject to revision.

6 The spraying nozzle is designed especially with a view to making derangement impossible. The oil and compressed air are admitted on opposite sides of a sleeve which encloses the needle-valve pin. On the surface of the sleeve is cut a series of diagonal grooves and channels through which the oil and air are forced to pass. In this way an extremely minute subdivision of the particles of oil and a most intimate mixture with the air are obtained. The needle valve by which the charge is admitted into the cylinder is about ½ in. in diameter, and with its appurtenances, is so arranged that the whole may be instantly withdrawn for inspection at any time.

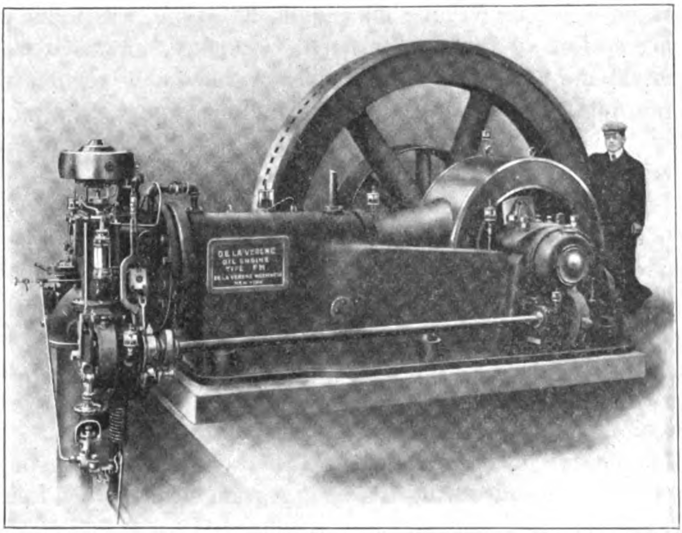

Fig. 1 Exterior View of 85-h.p. De La Vergne Oil Engine, Type FH

7 The air for spraying the oil is supplied by a two-stage air compressor, shown at *C*, Fig. 2, driven by an eccentric on the engine shaft. The air compressed by the first stage is stored in a tank at about 150 lb. pressure, and is utilized for starting the engine. The second stage of the compressor is quite small and handles only sufficient air to effect the spraying of the oil from stroke to stroke. The amount of air drawn in by the second stage is controlled by the engine governor to suit the various charges of fuel.

8 Ignition of the charge is effected by means of the vaporizer or hot cap shown at *D*, a device consisting of a massive gun-iron thimble,

heavily ribbed on the inside to increase its radiating surface. It is located on the side of the cylinder head and opens directly into the combustion chamber, across which and into the vaporizer the charge of fuel is injected. By this device the fuel is ignited as soon as the spraying valve is opened, and it is therefore possible exactly to time the point of ignition. As the fuel is not introduced into the cylinder until the moment of ignition, a relatively high compression may be had without the possibility of back-firing. The vaporizer must be heated by a blast lamp for a few minutes before the engine is started; but this may be removed as soon as the engine is in operation.

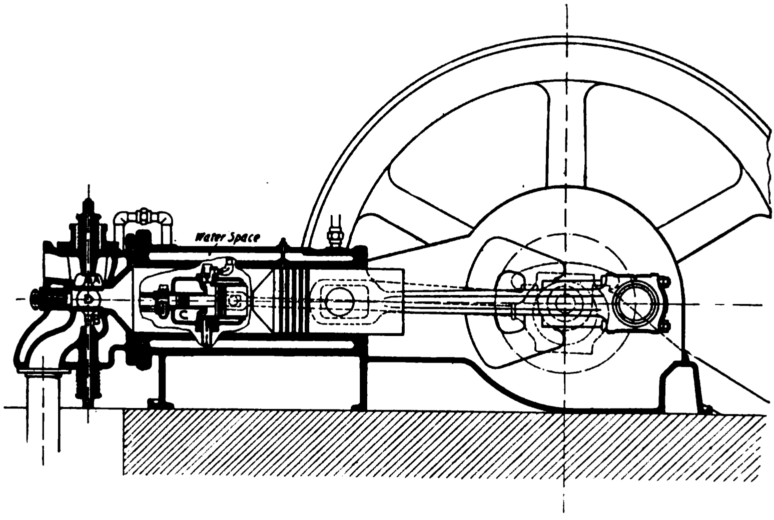


FIG. 2 LONGITUDINAL SECTION OF OIL ENGINE

9 Before shipment the engine was tested and developed a brake horsepower with 0.474 lb. of Solar fuel oil per hour when running at 65.11 b.h.p., and 0.462 lb. when running at 85.74 b.h.p.

10 In order to obtain as accurate data as possible, not only of the engine but of the combined pumping plant, it was decided to make a second brake test at Fawn Grove with the engine doing practically the same work as when pumping, and to ascertain as accurately as possible the ratio between the b.h.p. and the pump h.p.

11 In preparation for the test, a Government sealed platform scale, weighing to single ounces, was procured for weighing the oil. The water for cooling purposes was taken by gravity from a tank and

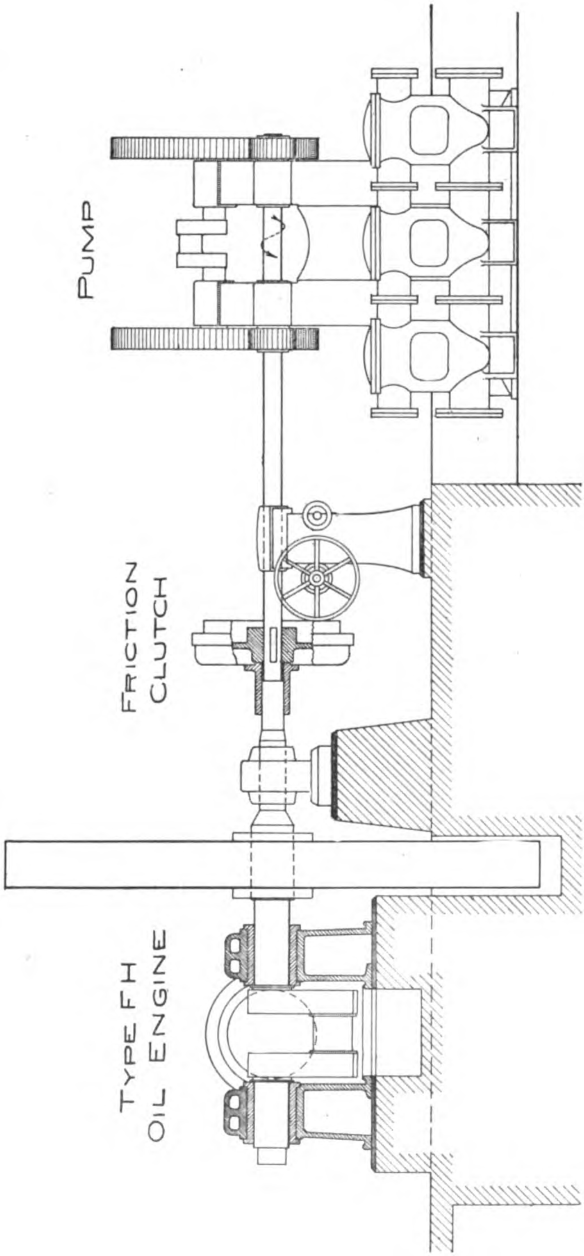


FIG. 3 ENGINE AND PUMP INSTALLED WITH CLUTCH CONNECTION

allowed to waste, the amount used being computed from measurements taken. The inlet temperature was taken at the tank, and the temperature of the water after passing the jackets by placing a thermometer in the line near the engine.

12 The amount pumped was ascertained by gaging the tank at Fawn Grove, and checked by gaging the tank into which the oil was pumped. The pressure was recorded by a Bristol recording gage and also read on a special Ashcroft gage, the latter, on the completion of the test, being taken to New York and compared with the standard gage of the company, which is graduated from a mercury column, situated in the Standard Oil Building, high enough to give direct readings up to 875 lb. per sq. in. The temperatures were taken with standardized thermometers, and the cards with a Crosby indicator, which was returned to the makers at the close of the test and found to be correct.

13 The exhaust gases were tested on the ground by using an Orsat apparatus. Samples of the oil were tested for calorific power. The average as obtained by one observer was 19,059 and this figure was used in working up the tests. Two tests were made by another observer and recorded 18,920 and 19,300 B.t.u. Prof. H. C. Sherman's formula, B.t.u. = 18,650 + 40 (Baumé deg. –10)[1] makes this 19,570. This formula is roughly applicable to all the American crude oils.

14 No analysis of the oil was made, but for the purposes of chemical calculations, it was assumed to be as follows:

| | Per cent by weight |
|---|---|
| Carbon | 86 |
| Hydrogen | 12 |
| Other material | 2 |
| | 100 |

The accuracy of the method used in analysing the gases is not such as to warrant going to the trouble of making an analysis of the oil. By comparison with available analyses the above is believed to be substantially correct.

15 In order to attach the Prony brake to the engine, it was necessary to remove the drag-link coupling between the engine and the friction clutch, thus running an extra shaft-bearing during the brake test. The brake had an arm 5 ft. 4 in. long and an unbalanced weight of 48 lb.

[1]Am.Chem.Soc., vol. 30, October 1908.

16 Three tests were made, the first, *A*, a full-load brake test; the second, *B*, a pumping test using the engine under the actual operating conditions; and the third, *C*, without disturbing any of the engine adjustments, but simply substituting the brake load for the pump load, so that the oil consumption and speed were, as nearly as possible, the same. By comparing *B* and *C* it was thought that the friction of the pump could be more accurately ascertained than in any other way.

17 The duration of each test was 3 hours, and each hour checked so closely that it was considered unnecessary to continue the runs for a longer period.

18 The air for spraying the oil was pumped by an attached compressor. There was no auxiliary machinery used, the cooling water being delivered by gravity.

19 The number of revolutions per hour was obtained by using an Ashcroft counter. During test *B* the counter was on the pump and the revolutions were computed in the ratio of the gearing; during tests *A* and *C* the counter was connected direct to the engine. The resistance of the pump load, test *B*, was so constant and the regulation of the engine so good, that the number of counts recorded for each hour was the same. The fuel consumed for the first hour was 31 lb. 2 oz., the second, 31 lb. 3 oz., and the third, 31 lb. During the brake test *C* the number of revolutions recorded was respectively 10918, 10916 and 10919. The fuel consumption for the above hours was 31 lb. 6 oz., 31 lb. 8 oz., and 31 lb. 4 oz.

20 The following chemical computation was made in connection with test *C*, and is based on the analysis previously given, assuming that all of the oil was burned.

| | Lb. per Hr. | |
|---|---|---|
| Oxygen for hydrogen combustion | 30.12 | |
| Oxygen for carbon | 71.95 | |
| Total oxygen | 102.07 | |
| Air used for combustion | | 443.8 |
| Excess air (165.2 per cent) | | 733.2 |
| Hydrogen burned | | 3.765 |
| Carbon burned | | 26.983 |
| | | 1207.748 |

21 For comparison with other pump tests the duty per 1,000,000 B.t.u. is given. This duty is, however, based on the heat units in the oil and not on the heat units delivered to the engine in the steam, as is the customary duty of a steam pumping engine.

22 It may be interesting to compare this duty with that obtained by Professor Denton in his test of the Laketon pumping engine,[1] as oil fuel was used during that test. The fuel used at Laketon contained, by Professor Sherman's formula, 19,770 B.t.u. The evaporation, test 5, was 16.64 lb. from and at 212 deg. This makes the boiler efficiency 81.3 per cent. The engine performance was 124,-375, 834 ft-lb. per 1,000,000 B.t.u., or 15.985 per cent, and the total

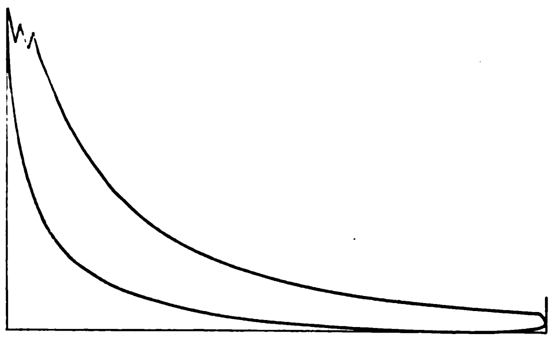

Fig. 4 Typical Indicator Diagram, Test *A*
180 r.p.m.; 89 m.e.p.; 126 i.h.p.

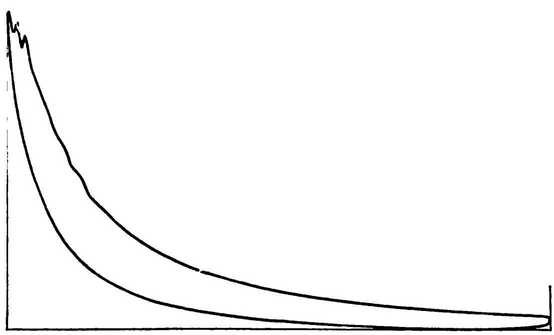

Fig. 5 Typical Indicator Diagram, Tests *B* and *C*
182 r.p.m.; 68 m.e.p.; 98 i.h.p.

efficiency of the plant was 13 per cent, as against 27.75 per cent for the engine and 25.52 per cent for the plant obtained from the present tests. Professor Carpenter's test of the North Point, E. P. Allis & Company pumping engine, if figured at the same boiler efficiency, would give a plant efficiency of 14.38 per cent. The Standard Oil

[1] Trans.Am.Soc.M.E., vol. 14, pp. 1349 and 1373.

Company of Louisiana have 12 of this same type of engine. Tests of two, made at Flora, La., by James Anderson, Jr., show that the engines developed a pump horsepower with 0.545 and 0.5205 lb. of crude oil per hour respectively.

23 After the engine at Fawn Grove was tested, several adjustments were made and resulted in the development of a pump horsepower with 0.48 lb. of oil per hour.

24 Fig. 4 shows a typical indicator diagram for test *A*; Fig. 5, a diagram for tests *B* and *C*. The details of the test are as follows:

HORSEPOWERS

| | | | |
|---|---|---|---|
| Test number | *A* | *B* | *C* |
| Date | 4/20/11 | 4/20/11 | 4/21/11 |
| Start | 9.00 a.m. | 2.00 p.m. | 9.00 a.m. |
| End | 12.00 m. | 5.00 p.m. | 12.00 m. |
| Duration, hr | 3 | 3 | 3 |
| Average r.p.m | 181.528 | 182.5 | 181.96 |
| Average m.e.p. of cards, lb. per sq.in. | 86.14 | 65.6 | 65.85 |
| Average i.h.p.* | 123.14 | 94.2 | 93.36 |
| Prony brake load, lb | 465.00 | | 350.00 |
| Scale load, lb | 560.00 | | 445.00 |
| Average b.h.p | 85.86 | 64.57 (computed) | 64.68 |
| Pressure pumped against lb. per sq. in. | | 570.00 | |
| Gage bbl. pumped 42 gal. per bbl | | 769.14 | |
| Average gage bbl. per hr | | 256.38 | |
| Pump h.p. by piston displacement | | 60.143 | |
| Pump h.p. by actual gage bbl. pumped | | 59.48 | |

EXHAUST

| | | | |
|---|---|---|---|
| Test number | *A* | *B* | *C* |
| Temperature of gases, deg. fahr | 678 | 483 | 485 |
| Average Analyses | | | |
| $CO_2$, per cent | 7.77 | 5.37 | 5.44 |
| CO, per cent | 0 | 0 | 0 |
| O, per cent | 10.17 | 13.5 | 13.24 |
| N, per cent | 82.06 | 81.13 | 81.32 |
| Specific heat | 0.2393 | 0.2388 | 0.2387 |
| Amount of gases | | | |
| By calculation of displacement, 70 deg. fahr. lb. per hr | 1455.00 | 1500.00 | 1491.00 |
| If temperature were same as jacket water | 1181.00 | | 1220.00 |
| From chemical test (Par. 20) | | | 1208.00 |

* I.h.p. probably high due to the momentum of indicator parts. This accounts for comparatively low mechanical efficiency shown in a table which follows.

### JACKET WATER

(Capacity of tank 39.429 gal. per in. depth)

| Test number | *A* | *C* |
|---|---|---|
| Inches used from tank | 18 | $12\frac{7}{16}$ |
| Total gal. used | 709.7 | 490.4 |
| Average lb. per hr | 1971.0 | 1362.0 |
| Average lb. per. b.h.p-hr | 22.97 | 21.05 |
| Average inlet temperature, deg. fahr | 68.7 | 71.3 |
| Average outlet temperature, deg. fahr. | 193.3 | 187.8 |

### HEAT BALANCES

| Test number | *A* | *B* | *C* |
|---|---|---|---|
| Input, B.t.u-hr | 815,153 | 592,813 | 597,976 |
| Engine useful work | | | |
| B.t.u-hr | 218,514 | 164,331 | 164,610 |
| Per cent | 26.8 | 27.75 | 27.52 |
| Loss in cooling water | | | |
| B.t.u-hr | 246,375 | | 158,673 |
| Per cent | 30.2 | | 26.5 |
| Loss in exhaust | | | |
| B.t.u-hr | | | 119,520 |
| Per cent | | | 20.03 |
| Loss in friction and radiation by difference | | | |
| B.t.u-hr | | | 155,173 |
| Per cent | | | 25.95 |
| B.t.u. per hr. in cylinder work | 313,391 | 239,739 | 240,046 |
| B.t.u. per hr. in useful pump-work output of station | | 151,376 | |
| B.t.u. per hr., input per b.h.p | 9,491 | 9,186 (calculated) | 9,244 |
| B.t.u. per hr. input per pump h.p | | 9,987 | |
| Duty, ft-lb. per 1,000,000 B.t.u (based on oil pumped per actual gage) | | 198,664,000 | |

### EFFICIENCIES

| Test number | *A* | *B* | *C* |
|---|---|---|---|
| Engine efficiency | | | |
| Thermal, per cent | 38.4 | 40.45 | 40.2 |
| Mechanical, per cent* | 69.71 | 68.55 (assumed same as test *C*) | 68.55 |
| Total, per cent | 26.8 | 27.75 | 27.52 |
| Pump | | | |
| Volumetric, per cent | | 98.9 | |
| Pump and transmission, per cent | | 92.1 | |

### FUEL CONSUMPTION

| Test number | A | B | C |
|---|---|---|---|
| Lb. of fuel per hr. | 42.77 | 31.1041 | 31.375 |
| Lb. of fuel i.h.p. per hr. | 0.347 | 0.331 | 0.333 |
| Lb. of fuel b.h.p. per hr. | 0.498 | 0.482 | 0.485 |
| Lb. of fuel pump h.p. by displacement. | | 0.5171 | |
| Lb. of fuel pump h.p. per hr. by gage bbl. | | 0.524 | |

### ENGINE DATA

| | | | |
|---|---|---|---|
| Governor lift, in. | $\frac{3}{64}$ | $\frac{5}{32}$ | $\frac{5}{32}$ |
| Air pressure in tanks, lb., per sq. in. | 94 | 96 | 97 |
| Regulation full load to no load, r.p.m. | | 182–186 | |
| Compression, lb. per sq.in. | | 347 | |

### LUBRICATION

| Test number | A | B | C |
|---|---|---|---|
| Cylinder oil | | | |
| Lb. per hr. | | 0.6875 | 0.9375 |
| Lb. per 100 b.h.p. per hr. | | 1.0625 | 1.445 |
| Engine oil | | | |
| Lb. per hr. | | 1.78 | 1.16 |
| Lb. per hr. 100 b.h.p. per hr. | | 2.76 | 1.795 |

### FUEL OIL CHARACTERISTICS

Illinois Crude Oil

| | | | |
|---|---|---|---|
| Baumé | 33 deg.fahr. | specific gravity | 0.863 |
| Flash point | 35 deg.fahr. | burning point | 65 deg. fahr. |
| Heating value | 19,059 B.t.u. per lb. per test | | |
| | 19,570 per Professor Sherman's formula | | |

# STRAIN MEASUREMENTS OF SOME STEAM BOILERS UNDER HYDROSTATIC PRESSURES

By James E. Howard

## ABSTRACT OF PAPER

Hydrostatic tests were made upon two horizontal tubular boilers which had been in service for a period of 27 years. Gaged lengths were established on different parts of the boilers by means of holes 10 in. apart and about 0.05 in. in diameter, reamed to a conical shape. The deformations of the boilers at different pressures were determined by a 10-in. micrometer strain gage with conical points to fit the reamed holes laid out on the boilers. The paper gives by means of diagrams and illustrations the strains occurring at the locations where measurements were taken; and for the sake of comparison, stresses were computed using a modulus of elasticity of 30,000,000 lb.

# STRAIN MEASUREMENTS OF SOME STEAM BOILERS UNDER HYDROSTATIC PRESSURES

By James E. Howard,[1] Washington, D. C.

Non-Member

The object of these tests is to ascertain the condition of the metal of the shell and other parts of two horizontal tubular steam boilers which had been in use for a term of service of unusual length; and in addition thereto to acquire information on constructive details by means of measured strains.

2 The boilers were contributed for investigative purposes by the treasurer of the Kendall Manufacturing Company, Providence, R. I., the late Nicholas Sheldon, Esq. They were of early manufacture and from their remarkable history and present condition were of special value for these tests. They were made by the Whittier Machine Company, Boston, Mass., using "Benzon" brand of steel, and were put into service March 1881. They were in continuous service for a period of 27 years, during which time, as Mr. Sheldon wrote, "no repairs were required; in fact, not one cent has been spent upon them."

3 They consisted of five course boilers, two sheets to a course, having the following general dimensions:

| | |
|---|---|
| Diameter | 72 in. |
| Length, over dry sheet | 16 ft. |
| Thickness of shell | $\frac{3}{8}$ in. |
| Thickness of heads | $\frac{1}{2}$ in. |
| Number of tubes | 140 |
| Diameter of tubes | 3 in. |
| Length of tubes | 15 ft. |
| Diameter of dome | 2 ft. 6 in. |

Longitudinal seams, double-riveted lap joints, $\frac{3}{4}$-in. rivets, 2-in. pitch, punched holes, rows $2\frac{1}{8}$ in. apart, rivets staggered.

Girth seam, $\frac{3}{4}$-in. rivets, $2\frac{1}{8}$-in. pitch.

Heads stayed, each, with 14 braces.

Cast-iron manhole frames and safety-valve nozzle.

Supported by lugs, three on a side.

The feedwater came from the Pawtucket River.

[1] Engineer-Physicist, Bureau of Standards, Washington, D. C.

The American Society of Mechanical Engineers, 29 West 39th Street, New York. All papers are subject to revision.

4 The hydrostatic tests were made at the W. H. Hick's Boiler Works, Providence. Mr. Francis B. Allen, Vice-President of the Hartford Steam Boiler Inspection & Insurance Company, assisted and advised with the writer in conducting them. The boilers will be designated by the numbers 4084 and 4092 under which they were carried on the books of the Hartford company.

5 The tests began with strain measurements upon different parts of the boilers as they were subjected to successive increments of hydrostatic pressures. The results of this portion of the inquiry are now available and herewith presented. Much remains to be done in the other direction of testing, pertaining to the physical properties of the materials.

6 Measurements of the deformations of engineering structures, whether steam boilers, bridges or buildings, may be expected to develop information of a kind not attainable in the tests of the component parts of those structures. A comparatively new field of inquiry is presented in the tests of structures over the tests of the materials thereof. The effects of combined stresses may readily be studied in this manner.

7 No more simple type of boiler could be chosen than the plain, horizontal, tubular boiler of these tests, yet it will be seen from the results that complexity of strains and stresses are found in most parts of the shell. In comparatively few places are tangential strains displayed corresponding in magnitude to those which would be expected in a thin cylindrical shell subjected to a given interior pressure.

8 Ascertaining the deformations by the method of measured strains, locally determined, consists of establishing gaged lengths on different parts of the boiler and then measuring them initially and at intervals as the hydrostatic pressures are successively applied and released.

9 Gaged lengths of 10 in. each were used in the examination of these boilers. Their extremities were defined by small drilled and reamed holes. The holes are about 0.05 in. in diameter by, say, 0.10 in. deep, and reamed to a conical shape. The angle of the reamer is 65 deg., and the distance across the hole at the surface of the shell sheet about 0.08 in.

10 Such holes carefully made, in metal surfaces, are capable of centering with considerable precision the contact points of the micrometer strain gage. The strain gage is used as a transfer instrument to compare the gaged lengths on the work with a corresponding length on a standard reference bar.

11 Fig. 1 shows the 10-in. strain gage used on these tests. It consists of two principal parts, an outer tube and an inner stem, which are telescopic, working on ball bearings. Each part carries a conical contact point for centering the instrument on the reference bar and on the work. A screw micrometer measures the length of the instrument when in position.

12 The conical contact points of the strain gage have an angle of 55 deg. This difference of 10 deg. between the reamed hole in the boiler shell and the points of the gage secures contact at a short distance below the surface of the shell. Ordinarily the reference holes are safe against accidental injury, due to their position.

13 As to the degree of precision attained with the strain gage, in the hands of skilled manipulators and under favorable conditions, such as were experienced with these boilers, it is believed the readings are generally reliable to one ten-thousandth of an inch. This strain corresponds to a stress of 300 lb. per sq. in. on a 10-in. gaged length,

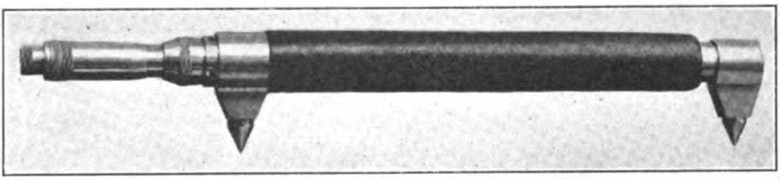

Fig. 1 10-In. Strain Gage

using a modulus of elasticity of 30,000,000 lb. Fig. 2 shows boiler No. 4084. Both boilers were of the same dimensions except at the dry sheets. When on their settings, boiler No. 4084 was on the right, boiler No. 4092 on the left side. This view shows the locations of some of the gaged lengths which were established on this boiler, taken in both tangential and longitudinal directions.

14 A more comprehensive series of lengths was established on boiler No. 4092, and the general discussion of the results of the strain measurements will be given in connection with the test of that boiler.

15 In the test of No. 4084 greater strains were displayed in the vicinity of the dome and the manhole frame than at other parts of the shell. This resulted, as would clearly be expected, in the early failure of the boiler at those places.

16 Actual rupture of the dome was not accomplished, but leakage along its single-riveted longitudinal seam became so great at 266 lb. pressure that it was necessary to remove the dome and patch the shell in order to reach higher pressures with the pump available.

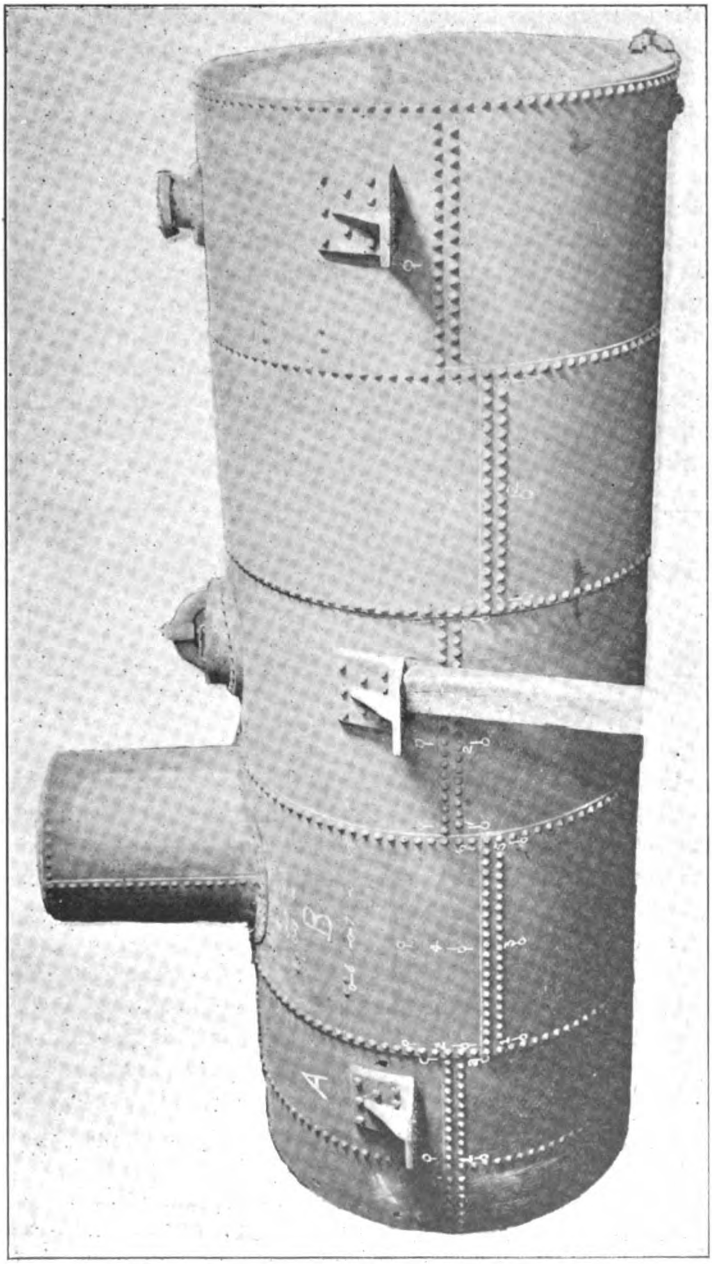

FIG. 2 STEAM BOILER NO. 4084 BEFORE TESTING

17 At 270 lb. pressure the cast-iron manhole frame fractured across the middle of its length. Another patch was then put on the shell covering the manhole.

18 The test was again resumed when at 295 lb. pressure the rupture of three braces of the front head occurred. The test was then discontinued and the boiler dismantled.

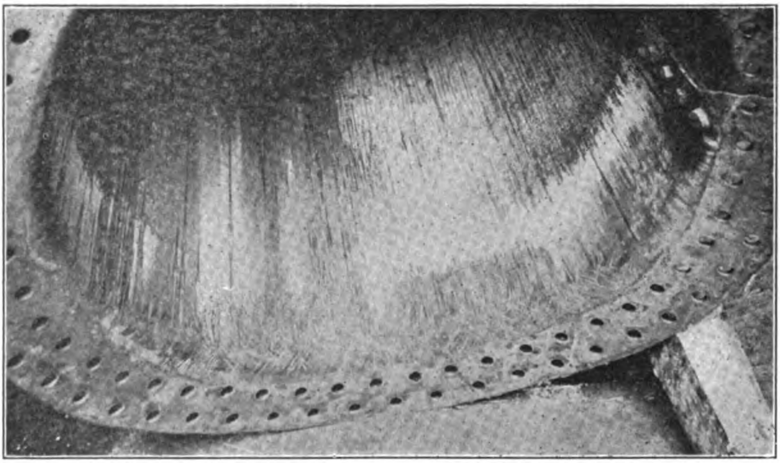

FIG. 3 INTERIOR OF DOME SHOWING LINES ALONG WHICH SCALE WAS DISTURBED AFTER PRESSURE OF 266 LB. ON SHELL

19 The strain measurements made in the test of No. 4084 were of the same general order as those subsequently made in the test of the second boiler and the results were, for the most part, quite similar.

20 A feature, however, in the test of the first was absent or obscure in that of the second. There was a progressive difference in the extensibility taken across the longitudinal seams of the several courses in passing from the front to the rear end of the boiler.

TABLE 1 TANGENTIAL EXTENSIONS OF THE SEAMS, BOILER NO. 4084

| Pressures | Course | | | |
|---|---|---|---|---|
| | *B* | *C* | *D* | *E* |
| 210 | 0.0166 | 0.0121 | 0.0099 | 0.0084 |
| 240 | 0.0241 | 0.0171 | 0.0138 | 0.0121 |
| 270 | 0.0341 | 0.0241 | 0.0212 | 0.0187 |

21 The tangential extensions of the seams, at the middle of their lengths, were as shown in Table 1.

22 While these seams were not directly exposed to the heated gases over the grate, nevertheless it seems probable that a wider range of thermal conditions prevailed in the vicinity of the seams at the front end over those at the rear end of the boiler. If such was the case it would aid in explaining the greater slip of the forward seams.

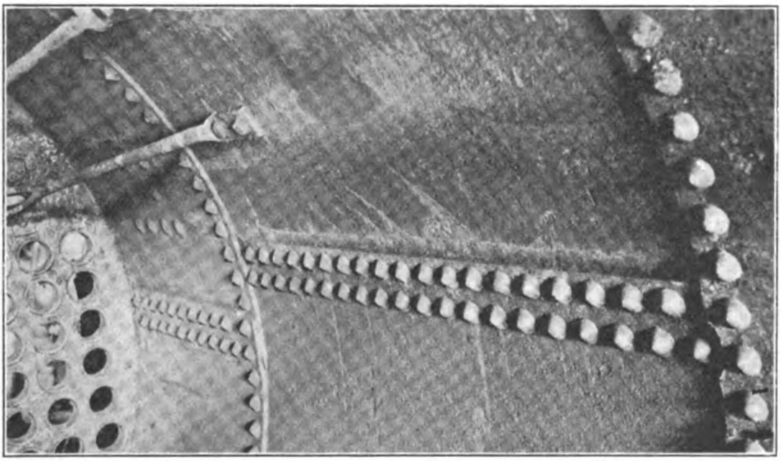

FIG. 4 INTERIOR VIEW OF BOILER NO. 4084 AFTER 295 LB. PRESSURE SHOWING SCALE DISTURBED IN VICINITY OF THE LONGITUDINAL SEAMS

23 Hydrostatic pressures on the exterior surfaces of the tubes necessarily extend them in length. The amount of the extension appears to depend upon their position with reference to their proximity to the shell. Tubes adjacent to the shell extended less than those at the middle of the rows, a restraining influence from the shell appearing to affect the outer ones.

24 The results in Table 2 were obtained by measuring the tubes over their full length.

25 Practically no leakage occurred about the tubes throughout the test of this boiler. A slight leakage took place at two tubes at 120 lb. pressure, but soon ceased and was not renewed during the remainder of the test. The girth seams remained tight up to 210 lb. pressure, and then showed only small leaks which were not materially increased under the higher pressures.

26 Leakage at the longitudinal seams began at 120 lb. pressure and increased as higher pressures were applied. The leakage became general at these seams with 180 lb. pressure on the boiler, but at

this time the slip of the joints had become a pronounced feature of the case, which necessarily disturbed the calking.

TABLE 2 EXTENSION OF TUBES, BOILER NO. 4084

| Pressures | Third Row | | Seventh Row | |
|---|---|---|---|---|
| | Next Shell | Middle of Row | Next Shell | Middle of Row |
| 210 | 0.0110 | 0.0162 | 0.0077 | 0.0167 |
| 240 | 0.0128 | 0.0184 | 0.0086 | 0.0189 |
| 270 | 0.0142 | 0.0210 | 0.0099 | 0.0210 |

27 Upon removal of the dome, evidence of overstraining was found at its base next the flanged portion. The scale had been disturbed on the inside on the line and in the vicinity of the upper element of the boiler, as shown in Fig. 3. Near the flange the scale was disturbed in oblique, shearing directions, which changed to longitudinal and then tangential directions a little farther up the dome.

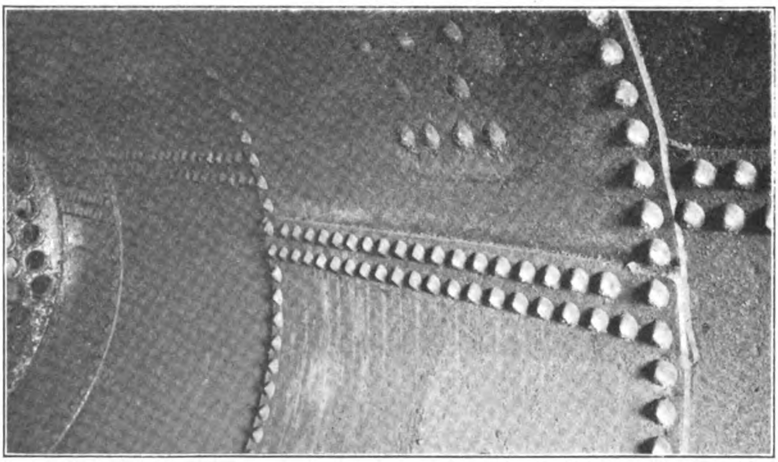

Fig. 5 Interior View of Boiler No. 4084 after 295 Lb. Pressure Showing Scale Disturbed in Vicinity of the Longitudinal Seam and under Supporting Lug

28 Figs. 4 and 5 are interior views of the boiler illustrating the manner in which the scale was disturbed during the test in the vicinity of the longitudinal seams and under one of the lugs.

29 Struts were used under the middle lugs and supported a part of the weight of the boiler during the test. They probably intensi-

fied the stresses in the shell in that vicinity. The interior surface of the shell and also the heads were found in good condition. Fig. 6 shows the appearance of the inside of the rear head.

30 A series of six photographs, Figs. 7 to 12 inclusive, shows the appearance of the exterior surfaces of the tubes. The system of lettering and numbering the horizontal and the vertical rows is indicated in Fig. 6. The layout of the feed pipes appears on Fig. 13.

31 Tubes in the horizontal row marked *D*, the fourth in the boiler from the top, Fig. 7, had a deposit on the rear third of their length, and also a slight deposit on the front ends. On some of the lower rows the deposit was thicker, as Figs. 8–12 indicate. In general the deposit was greatest in the lower rows of tubes and on those farthest from the shell, being confined chiefly to the rear quarter or half of their lengths. The lower rows of tubes, at the front end of the boiler, had a deposit on them. The surfaces of the upper row and the side rows were clean without deposit.

32 Material collected from the bottom of the boiler at the front and rear ends had the following chemical composition:

| Deposit from front end of boiler: | Per Cent |
|---|---|
| Loss at 105 deg. cent. | 8.70 |
| Loss on ignition | 26.00 |
| $SO_3$ | 4.10 |
| Silica | 21.60 |
| $Fe_2O_3+Al_2O_3$ | 25.40 |
| Lime | 5.30 |
| Magnesia | 13.10 |
| Copper oxide (about) | 0.25 |
| $CO_2$ | slight amount |
| Chlorides | trace |

| Deposit from rear end of boiler: | Per Cent |
|---|---|
| Loss at 105 deg. cent. | 9.65 |
| Loss on ignition | 23.85 |
| $SO_3$ | trace |
| Silica | 27.60 |
| $Fe_2O_3+Al_2O_3$ | 24.80 |
| Lime | 9.60 |
| Magnesia | 12.70 |
| Copper oxide (about) | 0.25 |
| Chlorides | trace |
| Carbonates | small amount |

33 Prior to testing boiler No. 4092, it was stripped of its dome and manhole frame and the shell patched at those places. The heads were strengthened by means of six 1½-in. braces extending from head

to head. The cast-iron safety-valve nozzle was allowed to remain in place, but was eventually replaced by a soft patch, after 300 lb. pressure had been applied and released. The distortion of the shell under the flange of the nozzle caused leaks impracticable to calk.

34 Fig. 14 shows the boiler when about ready for the hydrostatic test. It was supported on two wooden shoes sawed to fit the curvature of the shell, in lieu of the blocking shown in the illustration.

35 The gaged lengths which were established on the right side

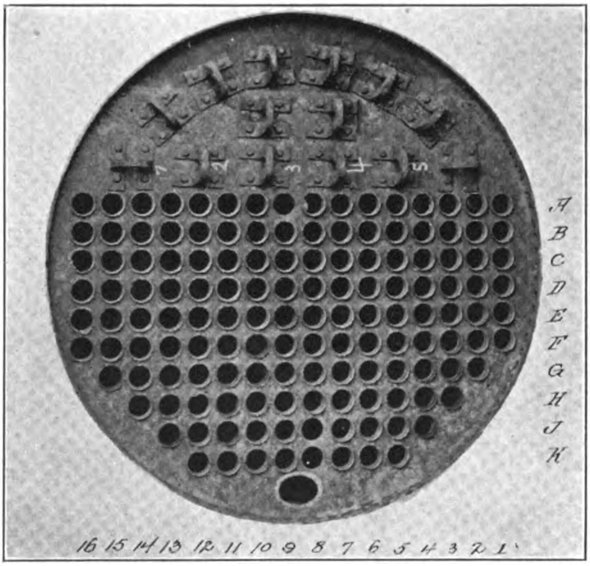


Fig. 6 Inside of Rear Head, Boiler No. 4084, after 295 Lb. Pressure. Letters and Figures refer to Marks Showing Location of Tubes in Subsequent Photographs

of the boiler are shown in this figure and practically stand for those on the left side, while additional ones were laid off on the top. Figs. 15, 16 and 17 show, however, the different gaged length on each side and the top. Additional gaged lengths were laid off and measured which are not shown on these diagrams, the results of which confirmed those which will be referred to. There were 165 gaged lengths used in the principal series of observations, on which some 3300 readings were taken.

36 The general results of the strain measurements have been plotted on a series of ten diagrams, Figs. 18 to 27, inclusive. For the

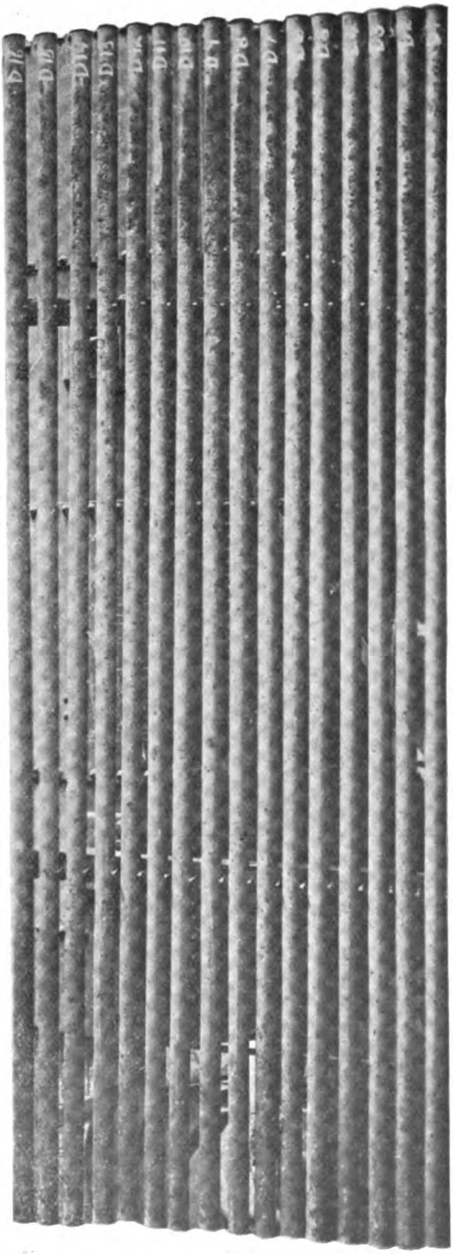

Fig. 7 Appearance of Tubes, Boiler No. 4084, after Dismantling. Horizontal Row *D*, Fourth from Top

Fig. 8 Appearance of Tubes, Boiler No. 4084, after Dismantling. Vertical Row, First on Right Side of Boiler

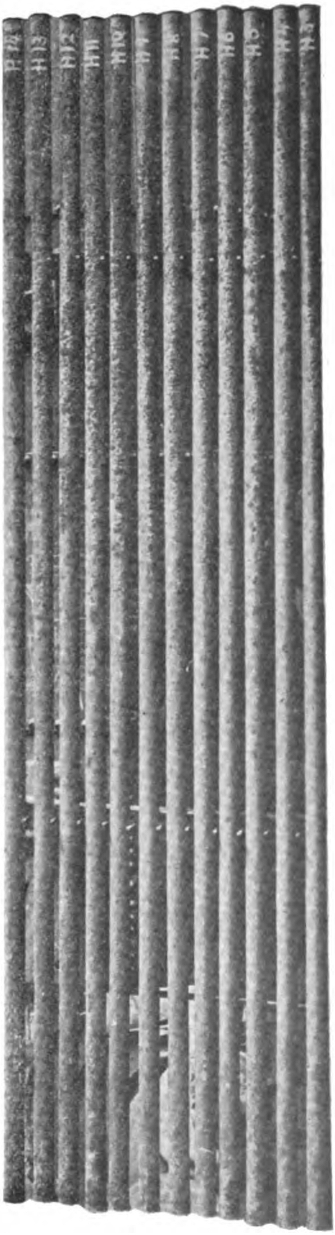

FIG. 9 APPEARANCE OF TUBES, BOILER NO. 4084, AFTER DISMANTLING. HORIZONTAL ROW *H*, EIGHTH FROM TOP

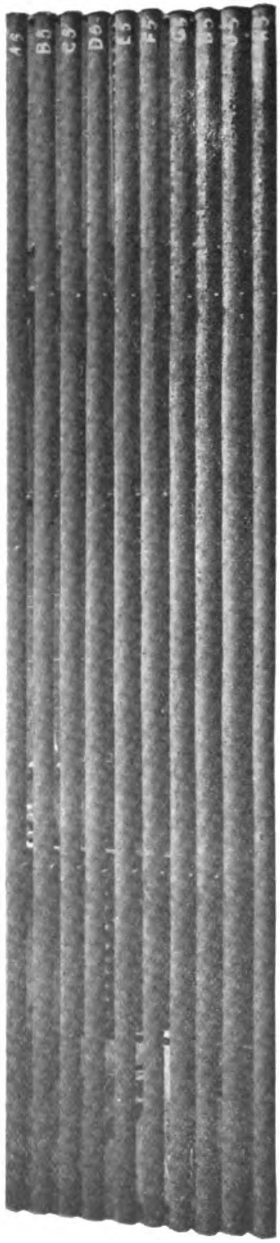

FIG. 10 APPEARANCE OF TUBES, BOILER NO. 4084 AFTER DISMANTLING. VERTICAL ROW, FIFTH FROM RIGHT SIDE OF BOILER

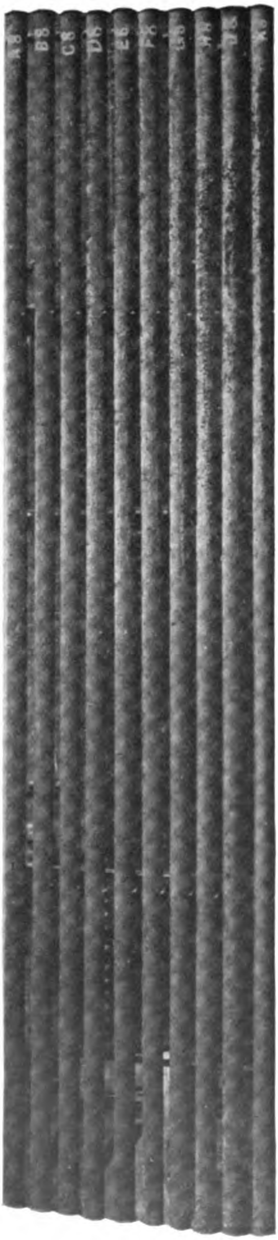

Fig. 11 Appearance of Tubes, Boiler No. 4084, after Dismantling. Vertical Row, Eighth from Right Side of Boiler

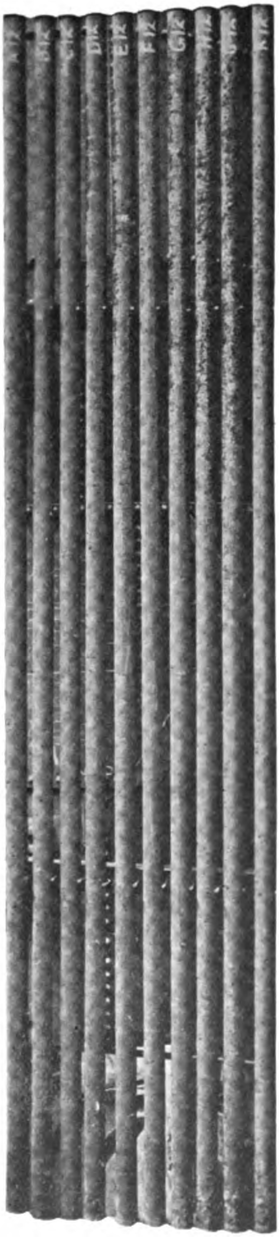

Fig. 12 Appearance of Tubes, Boiler No. 4048, after Dismantling. Vertical Row, Twelfth from Right Side of Boiler

purpose of furnishing a convenient basis of comparison, in judging the behavior of the boiler at different parts and under different pressures, heavy lines have been drawn on each diagram which indicate strains corresponding to those which would be displayed by the

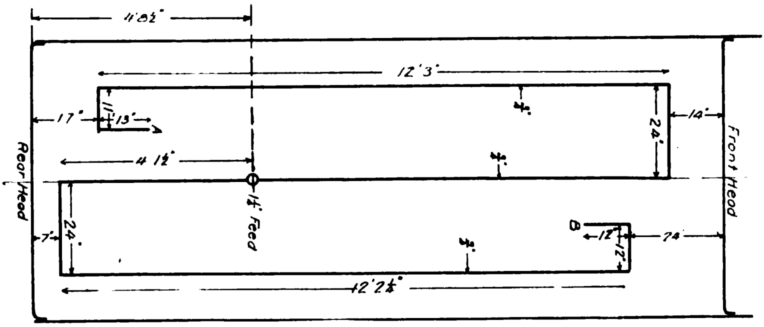


Fig. 13 Layout of Feed-Pipes
Pipe *A* Discharged directly over Tubes of Row No. 5 at Rear End
Pipe *B* Discharged directly over Tubes of Row No. 12 at Front End

TABLE 3 COMPUTED STRESSES ON THE SHELL SHEETS, BOILER NO. 4092

| Boiler Pressure, Lb. per Sq. In. | Stress on ⅜-In. Shell, Lb. per Sq. In. | Strain on Gaged Length of 10 In. |
|---|---|---|
| 30 | 2880 | 0.0010 |
| 60 | 5760 | 0.0019 |
| 90 | 8640 | 0.0029 |
| 120 | 11520 | 0.0038 |
| 150 | 14400 | 0.0048 |
| 180 | 17280 | 0.0058 |
| 210 | 20160 | 0.0067 |
| 240 | 23040 | 0.0077 |
| 270 | 25920 | 0.0086 |
| 300 | 28800 | 0.0096 |

sheets under direct tensile stresses, using a modulus of elasticity of 30,000,000 lb. per sq. in. Plotted curves, which are steeper than the modulus of elasticity reference line, indicate places on the boiler having greater rigidity than normal to the plain sheets; while flatter curves indicate greater extensibility than pertains to the plain metal.

37 Tangential rigidity above the normal was displayed in the vicinity of the girth seams, while the gaged lengths taken across the longitudinal seams at the middle of the length of the courses showed a much lower degree of rigidity than common to the plain sheet. Zones of greater extension than normal were also found in the vicinity of the manhole and dome.

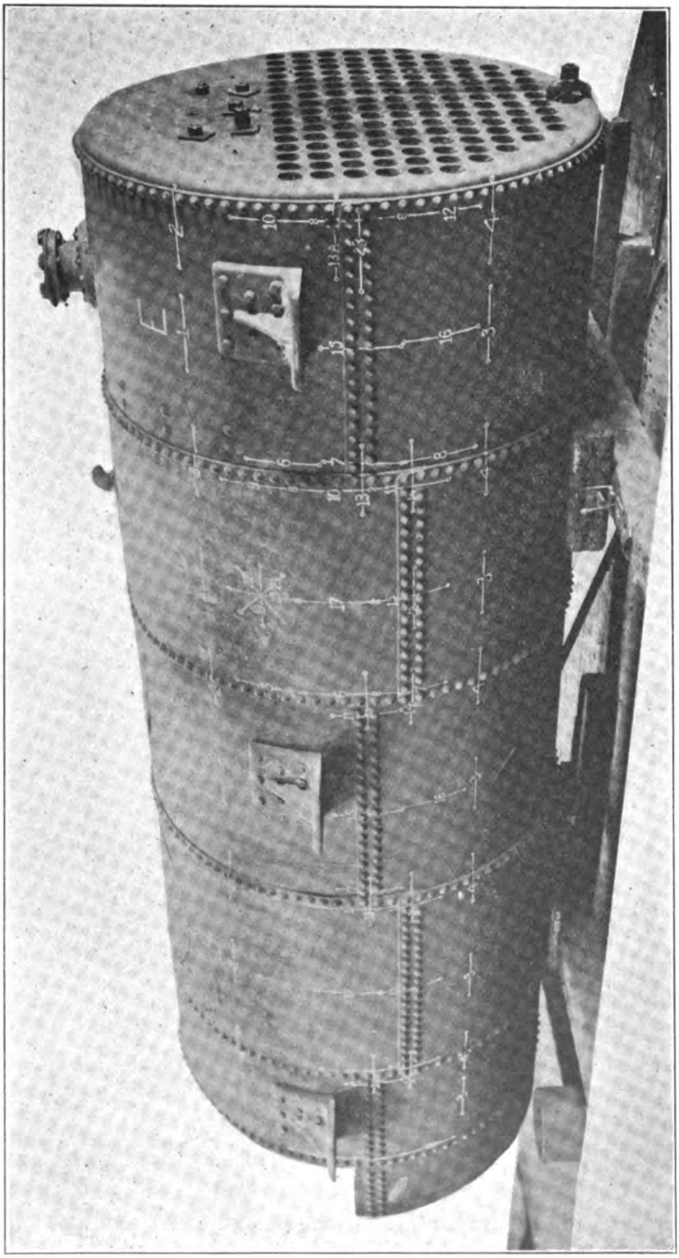

FIG. 14 STEAM BOILER, NO. 4092, DOME AND MANHOLE FRAME REMOVED PREPARATORY TO TESTING. HEADS STRENGTHENED WITH 6 THROUGH BRACES

38 Flattening of the curves representing the solid sheets necessarily accompanied those pressures, which caused a tensile stress on the shell in excess of its elastic limit.

39 Table 3 shows the computed stresses on the shell sheets, considering only tangential stresses as acting, and the strains which should

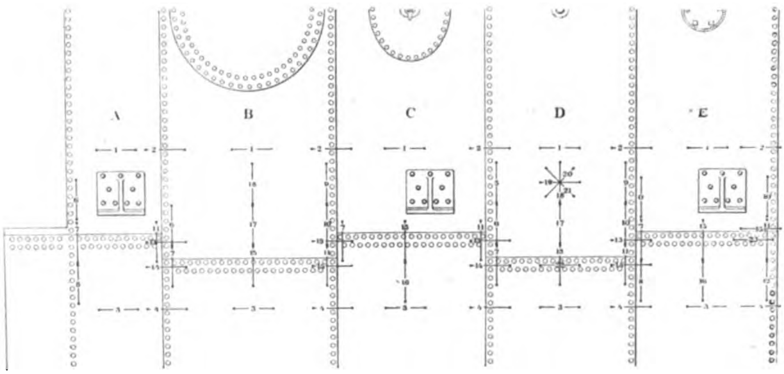


FIG. 15 DIAGRAM SHOWING LOCATION OF GAGED LENGTHS, 10 IN. EACH, LAID OFF ON RIGHT SIDE ON BOILER No. 4092

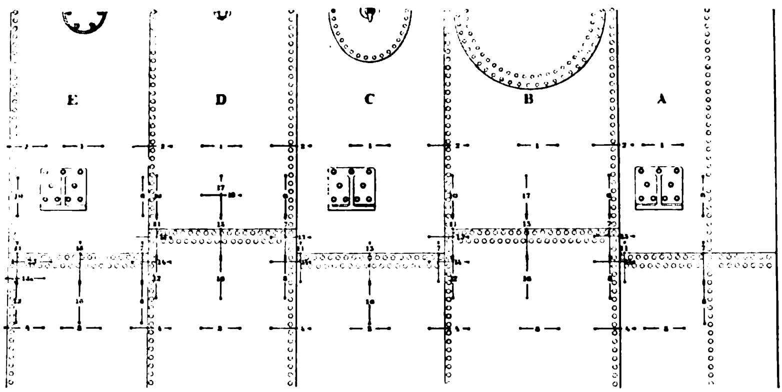


FIG. 16 DIAGRAM SHOWING LOCATION OF GAGED LENGTHS, 10 IN. EACH, LAID OFF ON LEFT SIDE OF BOILER No. 4092

be developed on a gaged length of 10 in., using a modulus of elasticity of 30,000,000 lb., the interior diameter of the boiler being 72 in.

40 Referring now to the plotted results, Fig. 18 shows the tangential extensions of sheets *C* and *D* on the right and left sides of the

boiler respectively, taken at the middle of the lengths of the courses. Gaged length *D*-18, on the right side of the boiler, was located above the longitudinal seam, while *C*-16, on the right side, was located below the longitudinal seam.

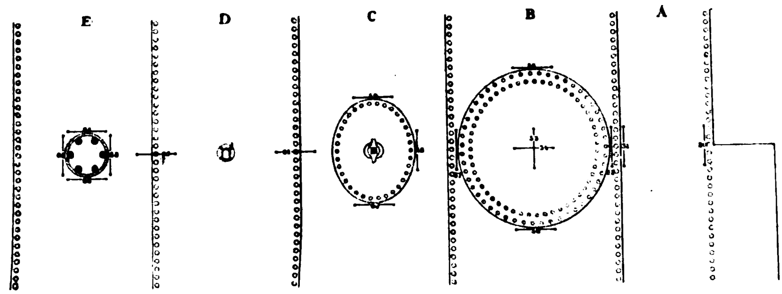


FIG. 17 DIAGRAM SHOWING LOCATION OF GAGED LENGTHS, 10 IN. EACH, LAID OFF ON TOP OF BOILER NO. 4092

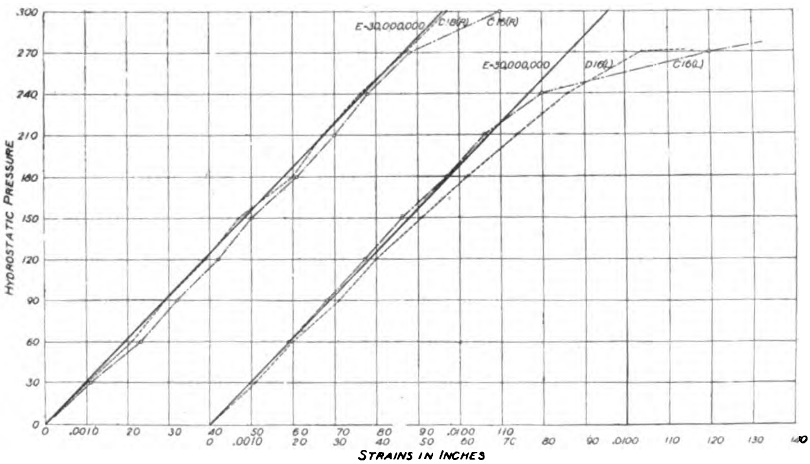


FIG. 18 CURVES OF TANGENTIAL EXTENSION, SOLID SHEETS, AT MIDDLE OF LENGTH OF COURSES *C* AND *D*, RIGHT AND LEFT SIDES OF BOILER

41 The tangential extensions of each of these gaged lengths closely follow the modulus of elasticity comparison curve. The departure of *D*-18 from this line does not exceed 0.0002 in. at any pressure, and coincides with it at several pressures. The extensions displayed by the gaged lengths on the opposite side of the boiler agreed fairly well with the modulus of elasticity reference line also, but not so closely as the results found on the right side, while rapid extension took

place one increment of pressure earlier than on the right side. So close a correspondence between the measured and the computed

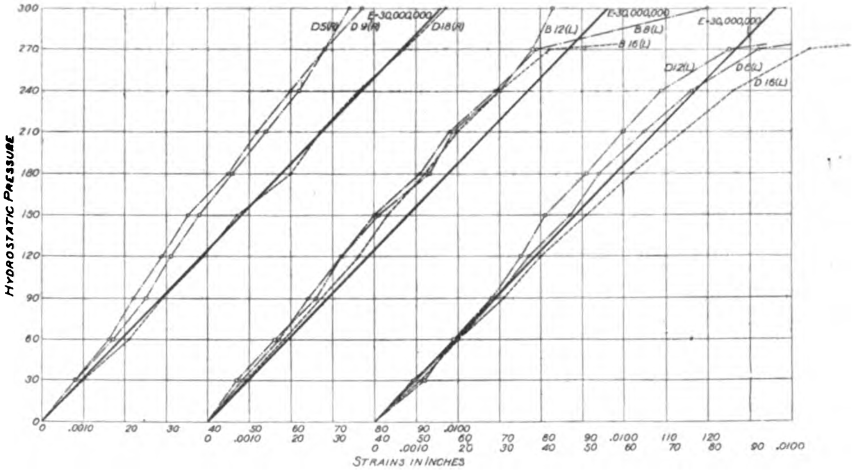


**FIG. 19 CURVES OF TANGENTIAL EXTENSION, SOLID SHEETS, NEAR GIRTH SEAMS AND AT MIDDLE OF LENGTHS OF COURSES**

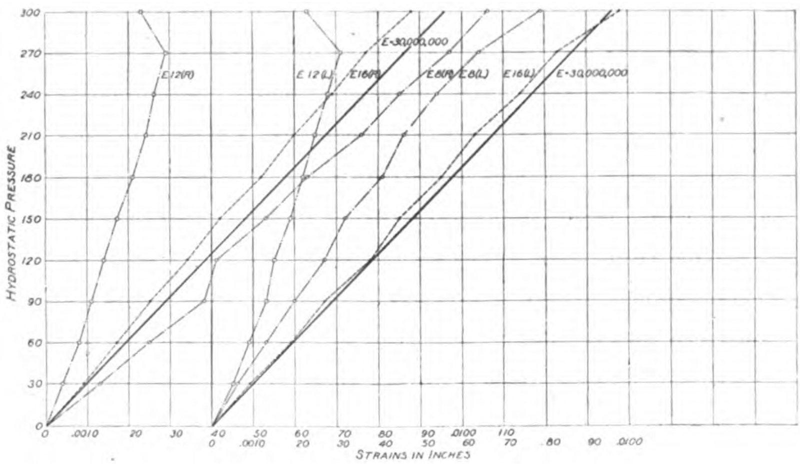


**FIG. 20 CURVES OF TANGENTIAL EXTENSION, SOLID SHEETS, END COURSE *E*, NEAR REAR HEAD, GIRTH SEAM, AND MIDDLE OF LENGTH OF COURSE**

strains as shown on this diagram did not, however, characterize many places on the shell. Commonly there were modifying influences which disturbed the normal display of elastic extensions of the metal.

42 Fig. 19 shows that the tangential strains near the girth seams, *D*-5 and *D*-9, were less than at the middle of the course. In general

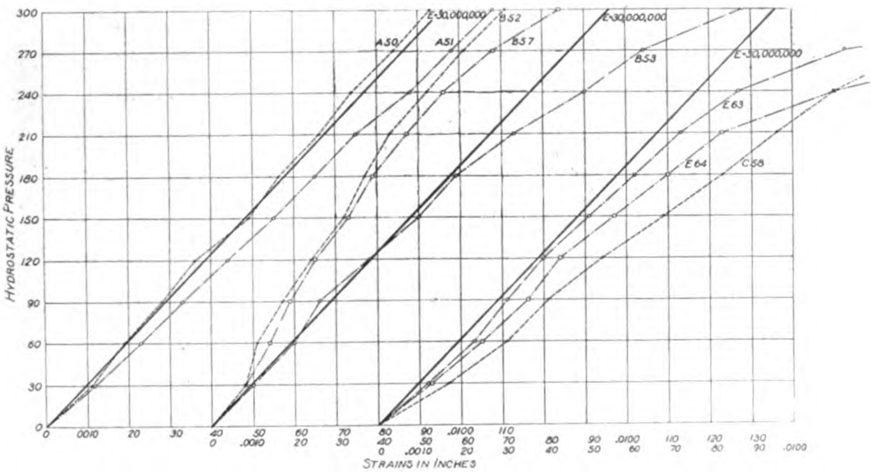


Fig. 21 Curves of Tangential Extension, top of Boiler, near Front Head, Girth Seams, Dome and Manhole Patches, and Safety-Valve Nozzle

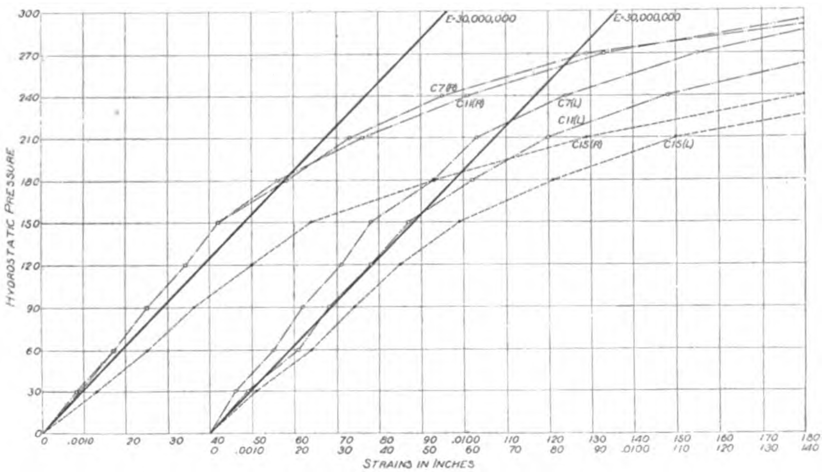


Fig. 22 Curves of Tangential Extension, across Longitudinal Seams, at Middle of Length of Course *C*, and at Edges, Right and Left Sides of Boiler

this behavior was shown in the other courses, but an exception was found on the left side of the boiler in course *B* where substantially the same rigidity was displayed at the middle as at the edges of the course.

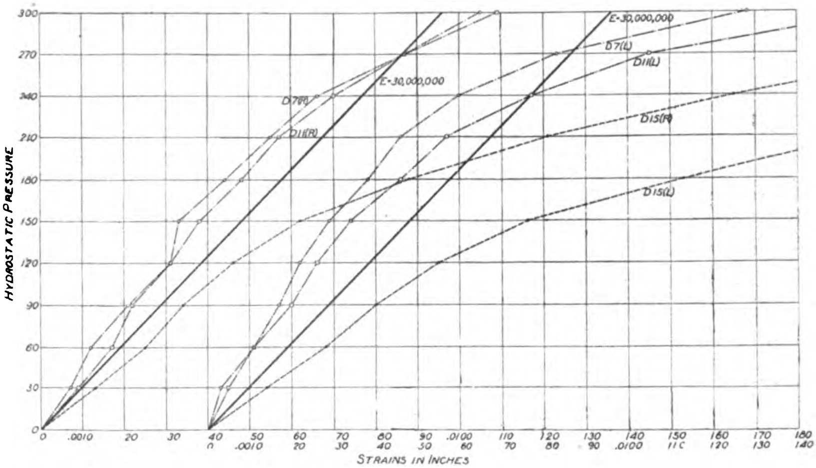


FIG. 23 CURVES OF TANGENTIAL EXTENSION, ACROSS LONGITUDINAL SEAMS, AT MIDDLE OF LENGTH OF COURSE *D*, AND AT EDGES, RIGHT AND LEFT SIDES OF BOILER

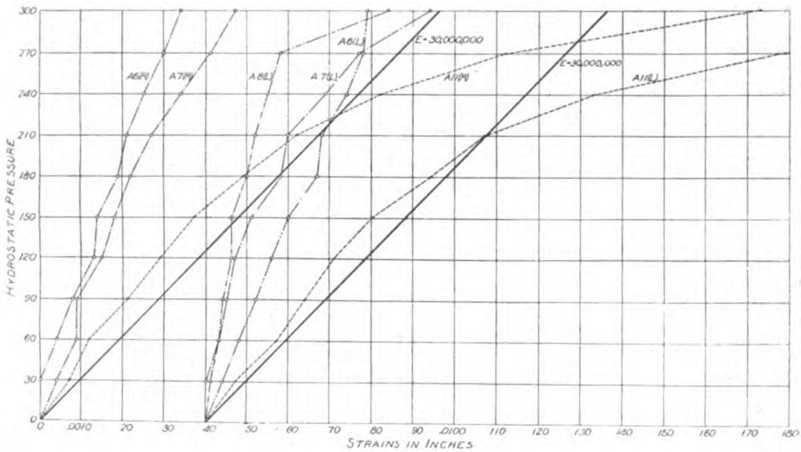


FIG. 24 CURVES OF TANGENTIAL EXTENSION, ACROSS LONGITUDINAL SEAMS AND SOLID SHEETS, END COURSE *A*; EXTENSIONS NEAR FRONT AND GIRTH SEAM

43 In the third group of curves on this diagram, however, the extension of *D*-16 taken at the middle of the course is seen to be greater than at *D*-8 and *D*-12, curves representing the edges.

44 There is a marked difference in the tangential extension of the two edges of the end courses of the boiler, due to the influence of the

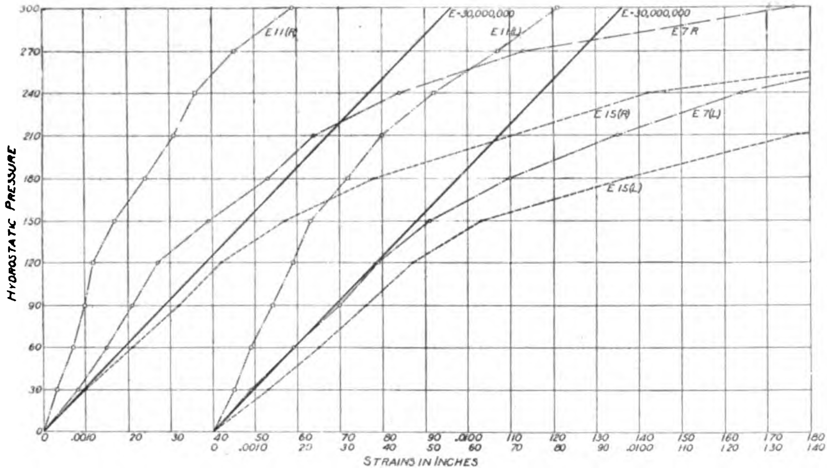


**Fig. 25 Curves of Tangential Extension, across Longitudinal Seams, End Course *E*, Extensions near Rear Head and Girth Seam and Middle of Length of Course**

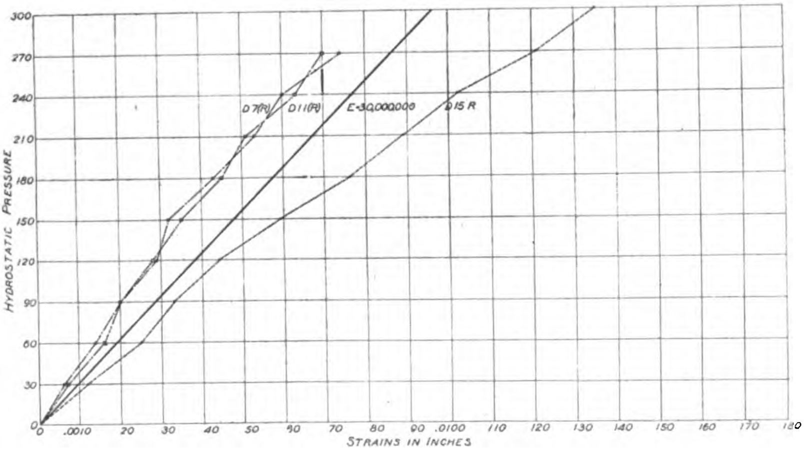


**Fig. 26 Curve of Tangential Resilience, across Longitudinal Seam, Course *D*, Right Side of Boiler, at Middle of Course and near Girth Seams**

heads in supporting the shells. Fig. 20 shows the greater rigidity of gaged lengths *E*-12 which are taken nearly over the rear head, than at the other places, which were measured on this course.

45 In regard to the top of the boiler there were many disturbing factors present, as indicated by Fig. 21. The first course is a short one with the front head to stiffen one edge. Then came the dome in the original construction on course *B*, which was patched, and the patch double-riveted, using the rivet holes that were made for securing the flange of the dome to the shell. Course *C* had the manhole patch, a single riveted one, using the holes made for securing the manhole frame to the shell. In course *D* was found the feedwater connection which probably did not have much influence on the behavior of this course while under pressure. Course *E* had the cast-iron safety-valve nozzle riveted to it, which did seem to have an influence on the tangential extension of the steel, permitting greater extension than normal.

46 The extension of course *A* at the edge over the front head was less than at the opposite edge. Gaged lengths *B*-52 and *B*-57 showed the influence of the overlapping metal of the patch, as well as that of the girth seams. The extension at these two places was less than normal.

47 At the side of the manhole patch, *C*-58, there was found diminished rigidity in the shell. The weakness of this single-riveted patch was apparent in the measurements from the earliest pressures which were applied to the boiler. Conditions about the safety-valve nozzle did not seem fully to compensate for this opening in the shell, as shown by the extensions on gaged lengths *E*-63 and *E*-64.

48 Referring next to the behavior of the shell at the seams, Fig. 22 shows two groups of curves of three lines each which represent the tangential extensions on gaged lengths established on course *C* taken across the longitudinal seam at the middle and at the edges of the course.

49 Curves *C*-7 and *C*-11, representing the extension at the edges of the course on the right side of the boiler, coincide in places and show but slight divergence where they depart most from the same line; that is, they indicate that uniform behavior was displayed at the opposite edges of this course. Each deflect rapidly under pressure above 150 lb. per sq. in., corresponding to a tensile stress of 14,400 lb. per sq. in. on the solid sheet.

50 At the middle of the length of the course, curve *C*-15 showed an increase in the rate of extension at the above-mentioned pressure, and for each succeeding pressure a greater extension than that witnessed at the edges. Necessarily, variations in the tangential extensions at different parts of the length of a seam would cause

variations in the stresses of the solid metal of the shell in those localities.

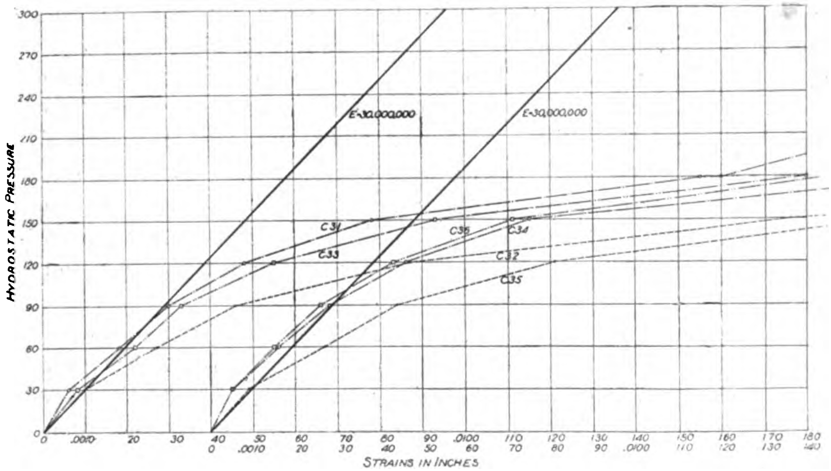


Fig. 27 Curves of Tangential Extension, Hand-Riveted Section, Course *C*, Top of Boiler

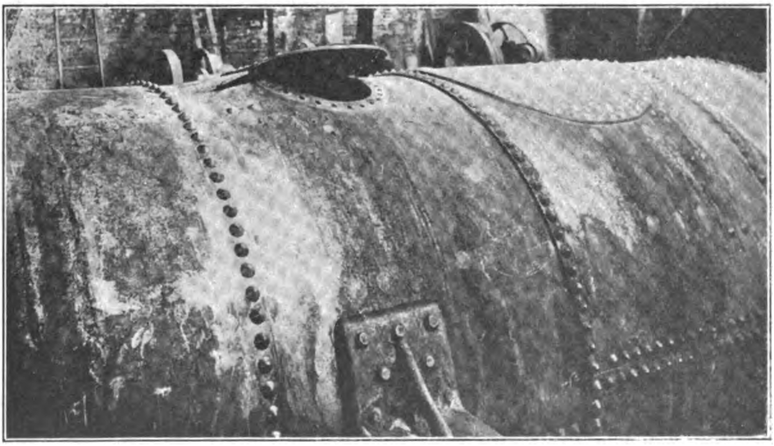

Fig. 28 Manhole Patch after Rupture. Maximum Pressure on Shell 335 Lb. per Sq. In.

51 In the case of a three-course boiler with one sheet to a course, as found in current construction, it would seem that a double-riveted

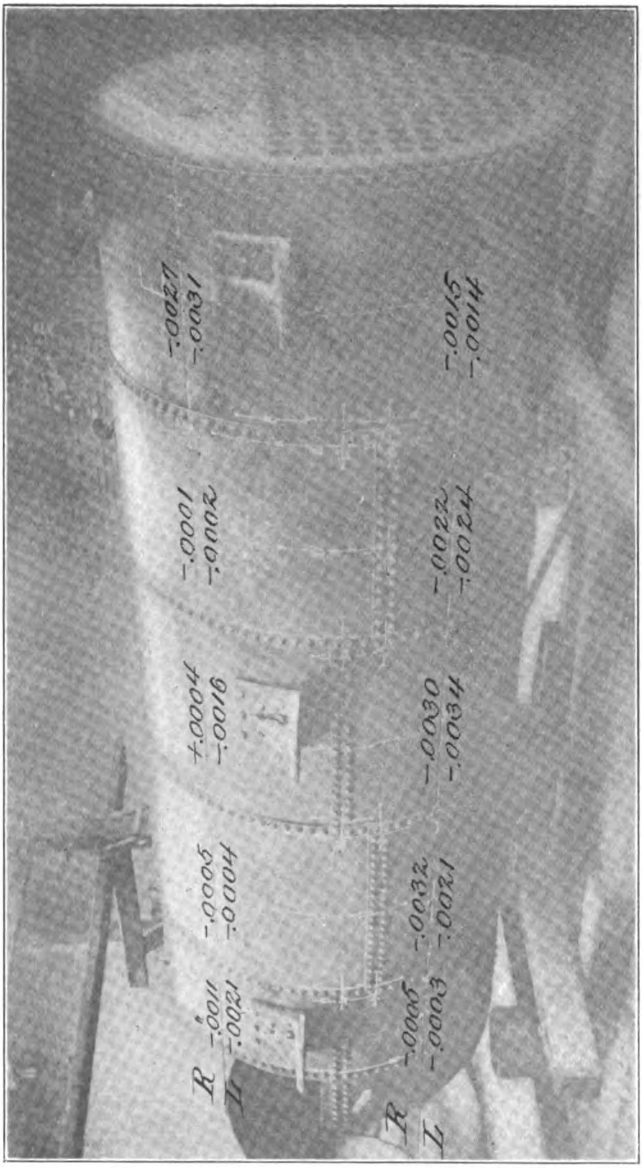


Fig. 29 Longitudinal Strains on Solid Sheets at Middle of Length of Courses, at 270 Lb. Pressure per Sq. In., Right and Left Sides of the Boiler. Minus Signs Indicate Longitudinal Contraction; Plus Signs Longitudinal Extension

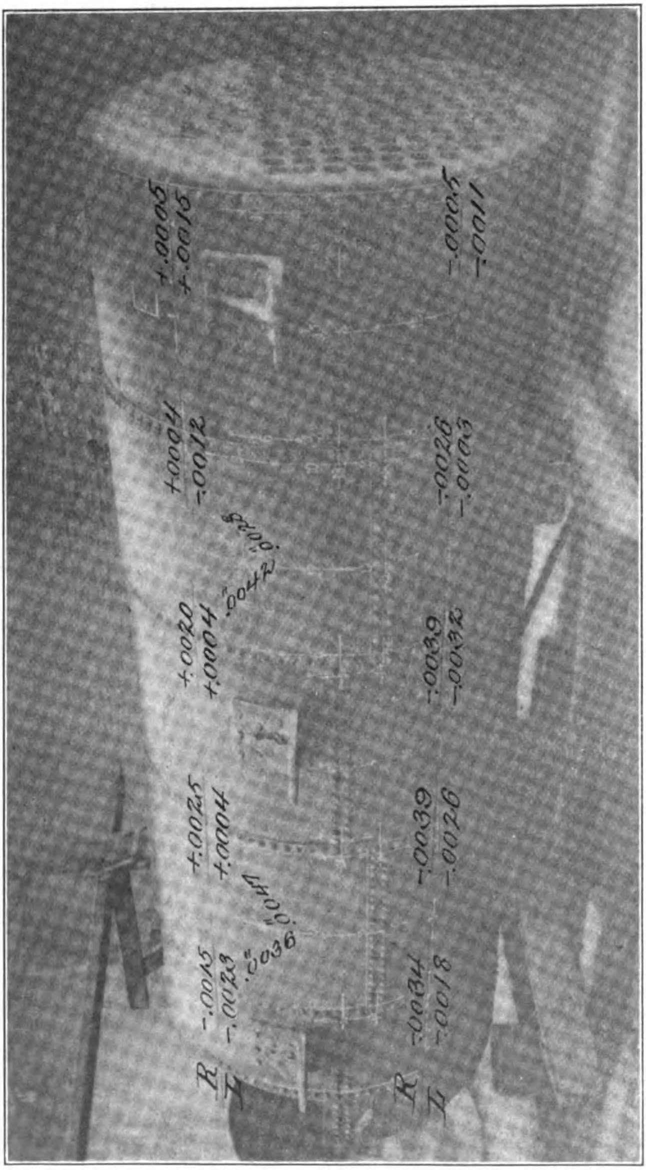


Fig. 30 Longitudinal Strains, across Girth Seams, at 270 Lb. Pressure per Sq. In., Right and Left Sides of the Boiler. Also Strains on Diagonal Gaged Lengths of Courses *B* and *D*. Minus Signs Indicate Longitudinal Contraction; Plus Signs Longitudinal Extension

lap joint might occasion an excessive stress in the solid sheet abreast the end of the seam, under certain pressures.

52 In the present test the longitudinal seams, being only three rivet pitches apart, furnish a line from front to rear of the boiler across which the extensions are greater than those which are displayed by the solid sheets.

53 Fig. 23 shows results corresponding to those of Fig. 22 but pertaining to *D*, the next course of the boiler. The results are about the same on each, the maximum tangential extensions being displayed at the middle of the length of the seams.

54 Fig. 24 shows the extension of end course *A*, across the longitudinal seams on either side of the boiler and also the extension of

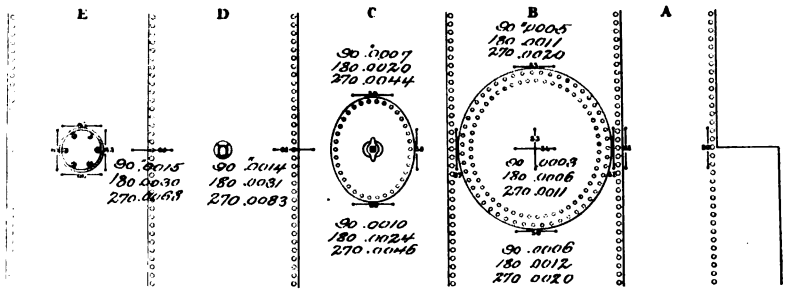


FIG. 31 LONGITUDINAL STRAINS, ON TOP OF BOILER IN VICINITY OF DOME AND MANHOLE PATCHES, ON DOME PATCH, AND ACROSS GIRTH SEAMS, AT 90, 180 AND 270 LB. PRESSURE

the solid sheet near the girth rivets of the front head. The divergent curves of this diagram indicate how differently in degree the metal is strained at the several gaged lengths of this narrow course. There seems, however, no lack of consistency in the behavior of the metal. The strains were relatively such as would be expected under the conditions present in this part of the boiler.

55 The strains in course *E*, at the rear end of the boiler are shown in Fig. 25, where the behavior of the shell was found to be similar to that at the front end. Notwithstanding the fact that the results appear consistent and the relations between the different parts of the boiler harmonious, attention is attracted by the variableness of the strains as they are found developed, according to the position of the measured lengths. The degree of variability witnessed in this type of boiler, which is certainly one of plain form, is such as to excite speculative interest in more complicated types.

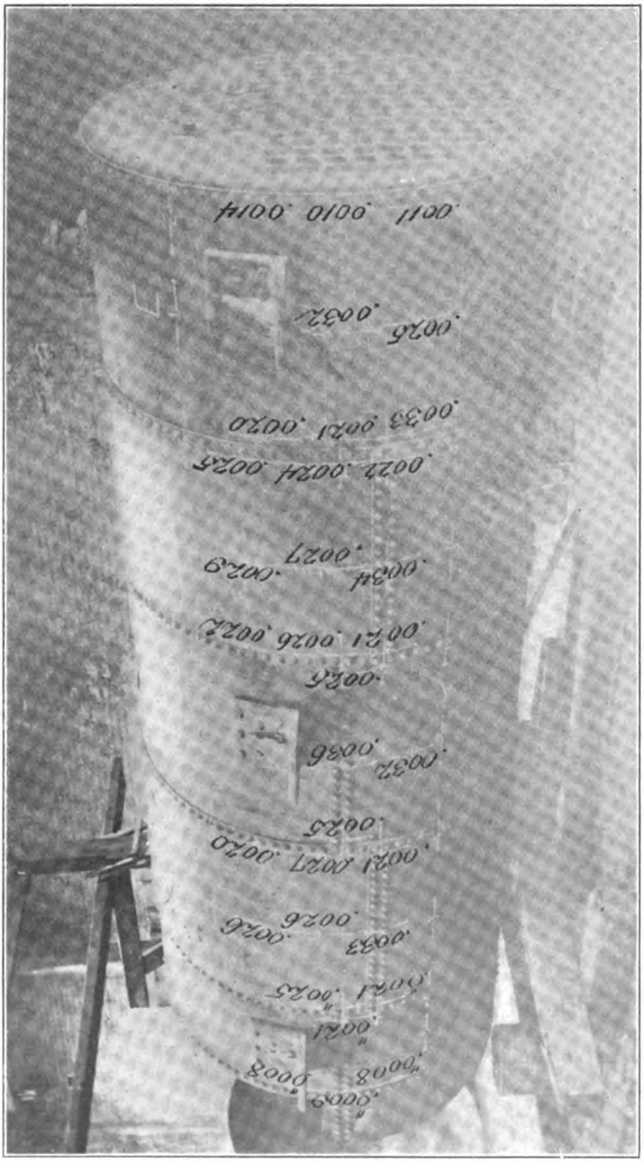

FIG. 32 TANGENTIAL EXTENSION AT 90 LB. PRESSURE. RIGHT SIDE OF BOILER. NORMAL, COMPUTED, EXTENSION AT THIS PRESSURE, 0.0029 IN.

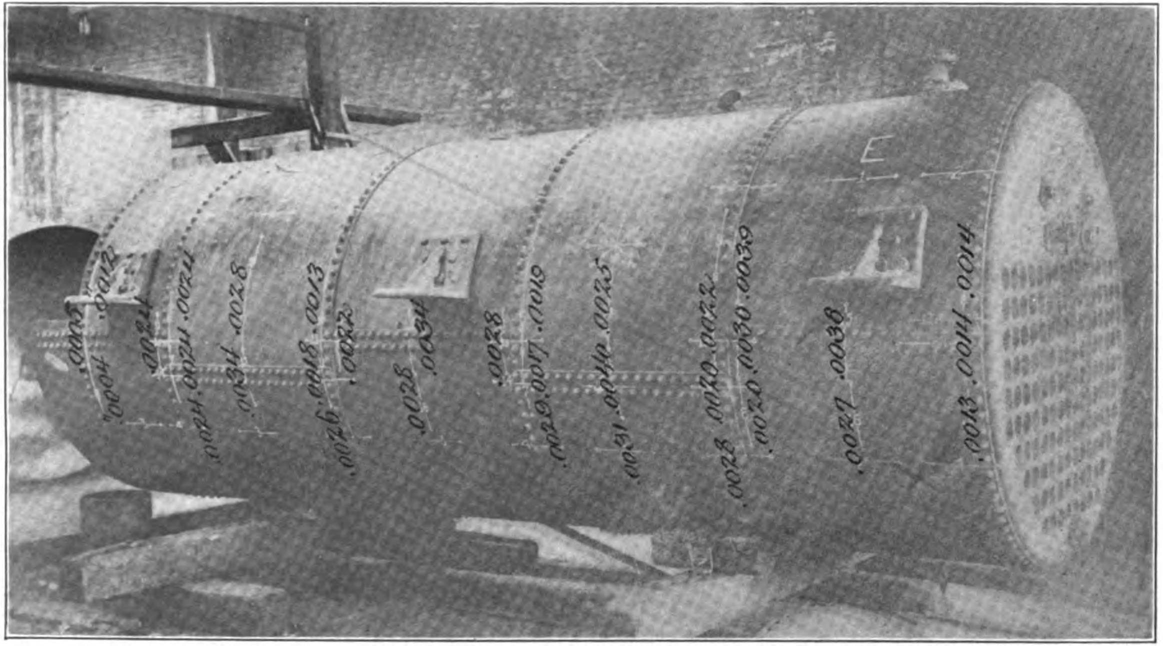


FIG. 33 TANGENTIAL EXTENSION AT 90 LB. PRESSURE. THE FIGURES GIVEN REPRESENT STRAINS DEVELOPED ON THE LEFT SIDE OF THE BOILER. NORMAL, COMPUTED, EXTENSION AT THIS PRESSURE 0.0029 IN.

FIG. 34 TANGENTIAL EXTENSION AT 180 LB. PRESSURE. RIGHT SIDE OF BOILER. NORMAL, COMPUTED, EXTENSION AT THIS PRESSURE 0.0058 IN.

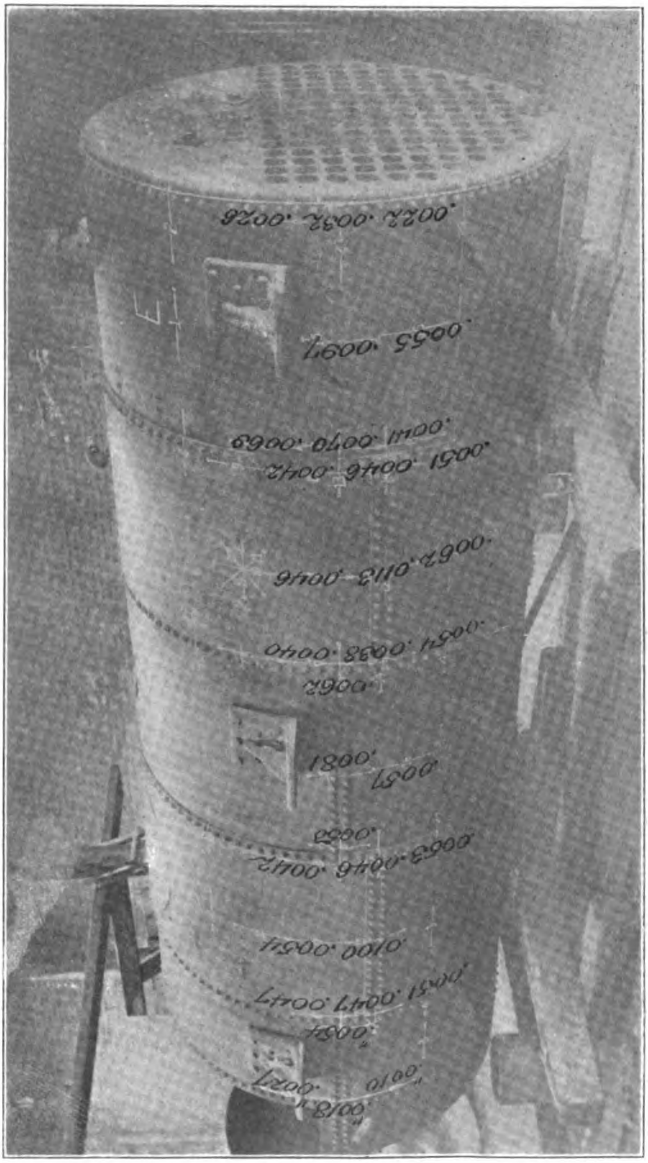

FIG. 35 TANGENTIAL EXTENSION, AT 180 LB. PRESSURE. THE FIGURES GIVEN REPRESENT STRAINS DEVELOPED ON THE LEFT SIDE OF THE BOILER. NORMAL, COMPUTED, EXTENSION AT THIS PRESSURE 0.0058 IN.

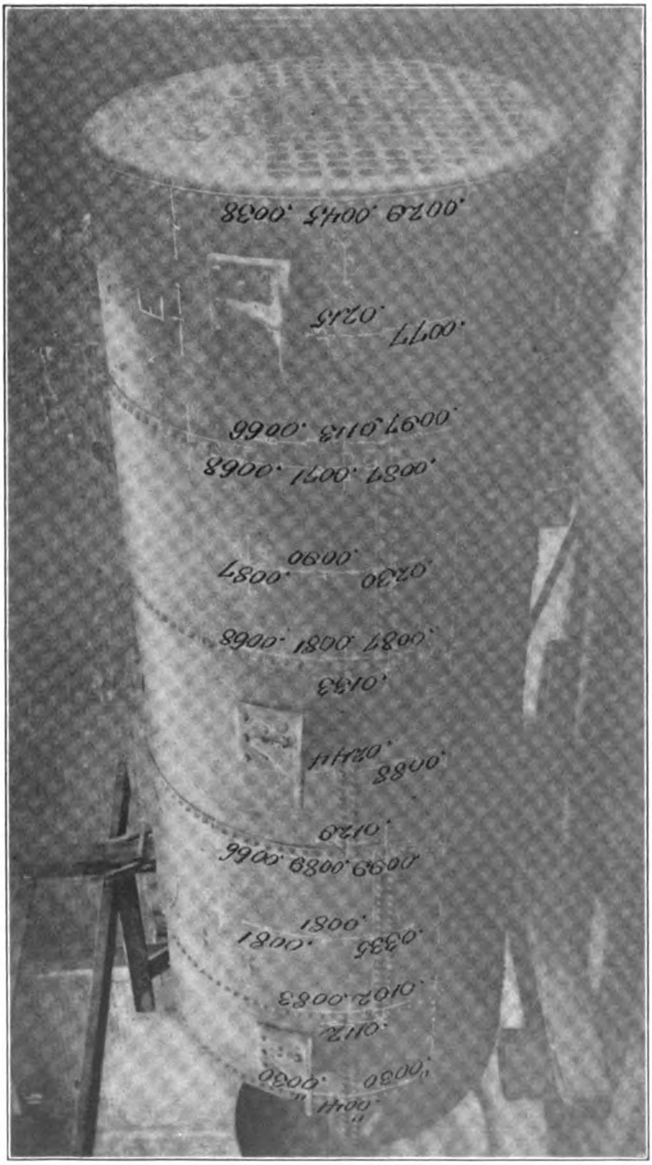


Fig. 36 Tangential Extension at 270 Lb. Pressure. Right Side of Boiler. Normal, Computed, Extension at this Pressure 0.0086 In.

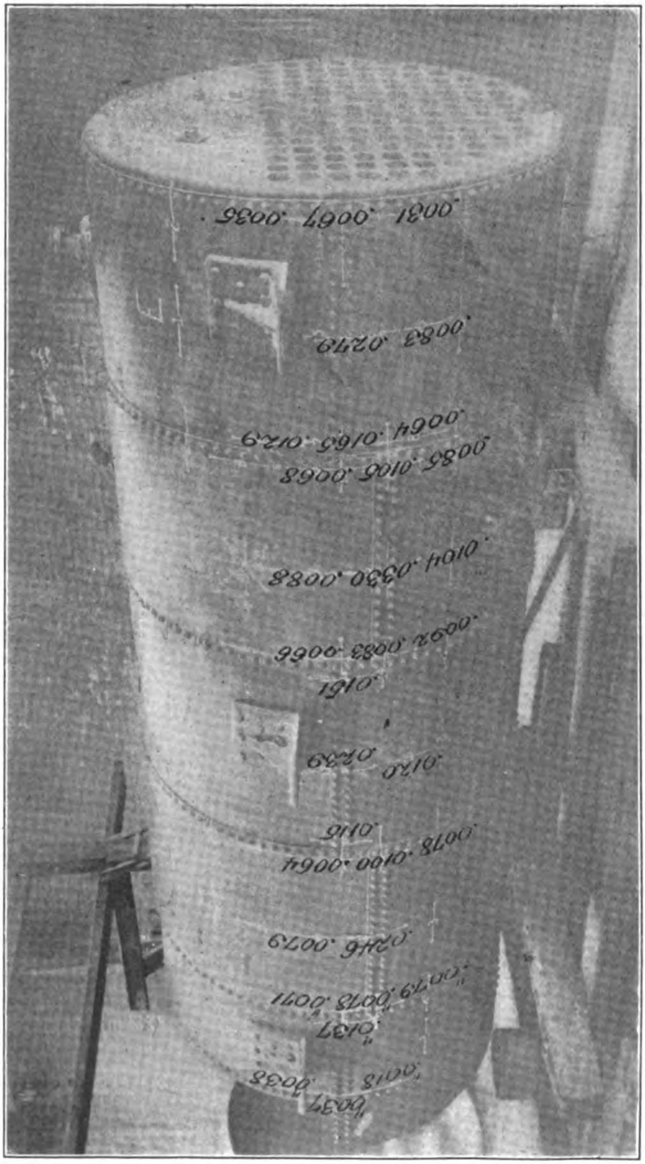

FIG. 37 TANGENTIAL EXTENSION AT 270 LB. PRESSURE. THE FIGURES GIVEN REPRESENT STRAINS DEVELOPED ON THE LEFT SIDE OF THE BOILER. NORMAL, COMPUTED, EXTENSION AT THIS PRESSURE 0.0086 IN.

56 The results of the diagrams, Figs. 18–27, refer to the total extensions of the gaged lengths, that is, they include the elastic extensions and the permanent sets when sets have occurred. The curves in Fig. 26 were plotted for the purpose of showing the elastic

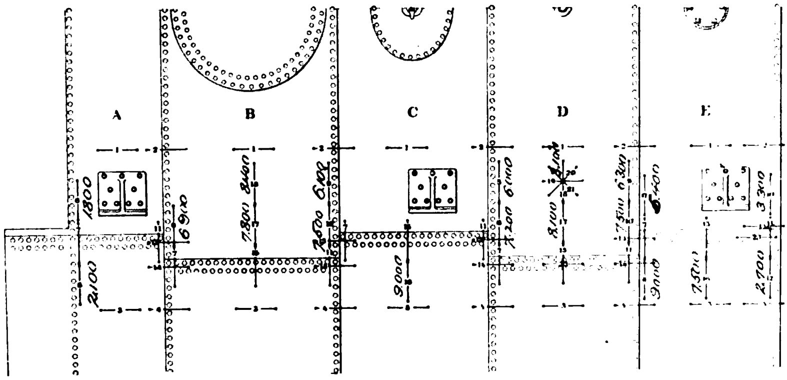


FIG. 38 TANGENTIAL STRESSES, LB. PER SQ. IN., AT 90 LB. BOILER PRESSURE. RESULTS BASED ON RESILIENCES. RIGHT SIDE OF BOILER. NORMAL, COMPUTED, STRESS, 8640 LB. PER SQ. IN.

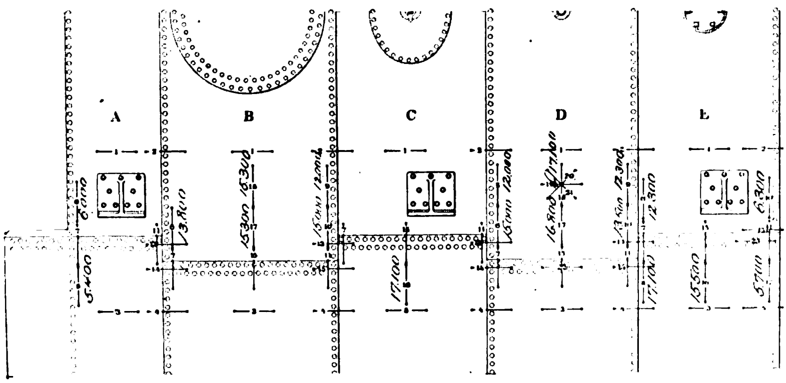


FIG. 39 TANGENTIAL STRESSES, LB. PER SQ. IN., AT 180 LB. BOILER PRESSURE. RESULTS BASED ON RESILIENCES. RIGHT SIDE OF BOILER. NORMAL COMPUTED, STRESS, 17,280 LB. PER SQ. IN.

extensions only, or what is equivalent to the same, the resilience of the shell taken across the longitudinal seam of course *D*, right side. The greater resilience of gaged length *D*-15, which was located across the longitudinal seam at the middle of its length, over the amount called for by the modulus of elasticity curve will be noted. This might be taken to indicate an intensity of stress above the normal in the shell in that vicinity, or it may mean that bending and shearing stresses at the seam in addition to tensile stresses on the sheets modified the results.

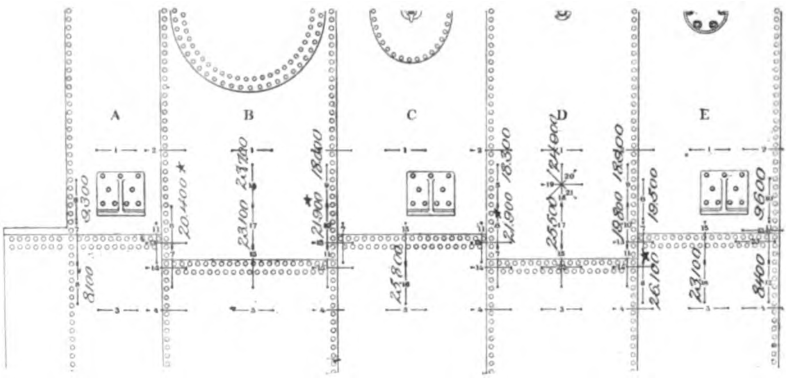


FIG. 40 TANGENTIAL STRESSES, LB. PER SQ. IN. AT 270 LB. BOILER PRESSURE. RESULTS BASED ON RESILIENCES. RIGHT SIDE OF BOILER. NORMAL, COMPUTED, STRESS, 25,920 LB. PER SQ. IN. GAGED LENGTHS ON WHICH DECIDED PERMANENT SETS OCCURRED, INDICATED BY A STAR

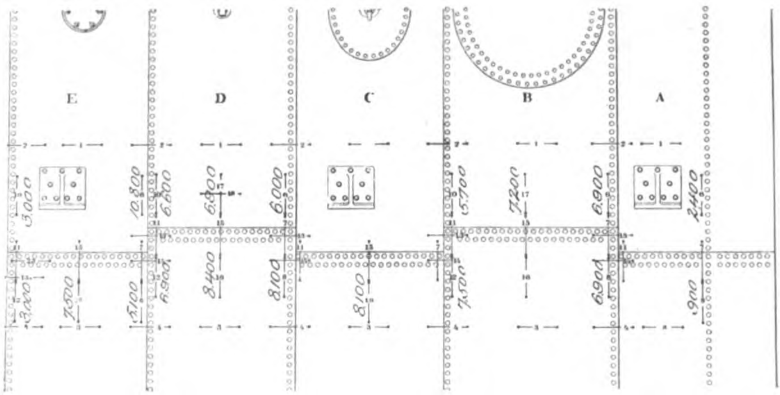


FIG. 41 TANGENTIAL STRESSES, LB. PER SQ. IN., AT 90 LB. BOILER PRESSURE. RESULTS BASED ON RESILIENCES. LEFT SIDE OF BOILER. NORMAL, COMPUTED, STRESS, 8640 LB. PER SQ. IN.

57 The interior pressure on the boiler was increased from 300 lb., the highest indicated on the diagrams, to 335 lb., under which latter pressure rupture of the manhole patch occurred. Three of the rivets were sheared by the tangential stress of the shell, followed, apparently,

by the fracture of other rivets by tension on the stems, which pulled off the heads and finally tore the shell longitudinally along its upper element, starting this fracture at a rivet hole of the manhole opening. Fig. 28 shows the appearance of this fracture.

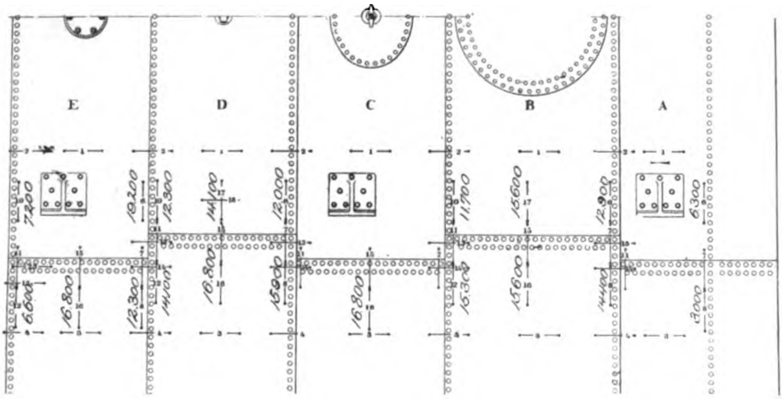


FIG. 42 TANGENTIAL STRESSES, LB. PER SQ. IN., AT 180 LB. BOILER PRESSURE. RESULTS BASED ON RESILIENCES. LEFT SIDE OF BOILER. NORMAL, COMPUTED, STRESS, 17,280 LB. PER SQ. IN.

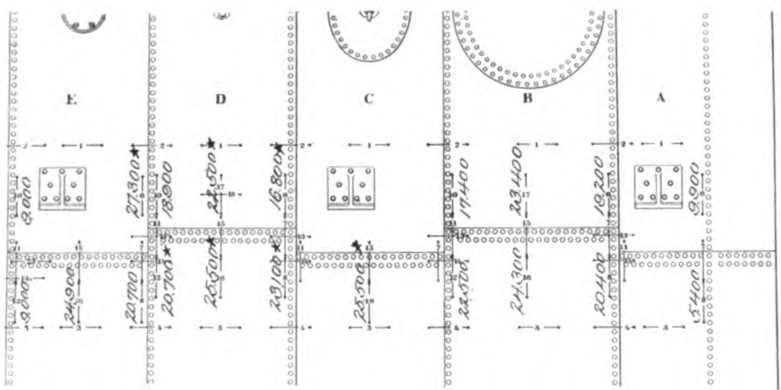


FIG. 43 TANGENTIAL STRESSES, LB. PER SQ. IN., AT 270 LB. BOILER PRESSURE. RESULTS BASED ON RESILIENCES. LEFT SIDE OF BOILER. NORMAL, COMPUTED, STRESS, 25,920 LB. PER SQ. IN. GAGED LENGTHS ON WHICH DECIDED PERMANENT SETS OCCURRED, INDICATED BY A STAR

58 The shell was repaired by cutting out a portion of course *C*, across the top of the boiler and putting in a section the full length of the course and about 3 ft. wide, measured on the arc. This new

section was double-riveted to the shell at its longitudinal seams. The rivets were $\frac{11}{16}$ in. in diameter and had a pitch of 2.87 in. The rows were 1.53 in. apart, with rivets staggered, which, were, of course, hand-driven. The points of the rivets were hammered down to conical shape, low in height and with thin edges. In this respect they were less substantial than the points of the original machine-driven rivets of the seams.

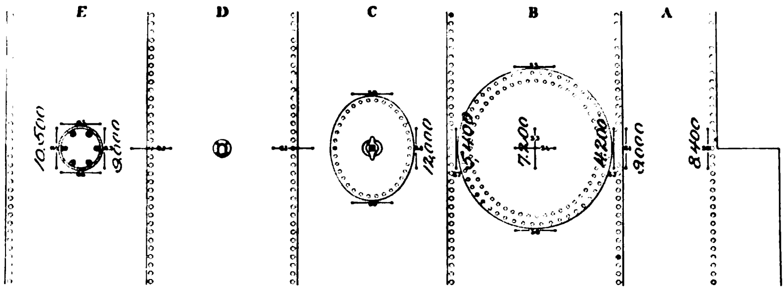


FIG. 44 TANGENTIAL STRESSES, LB. PER SQ. IN., AT 90 LB. BOILER PRESSURE. RESULTS BASED ON RESILIENCES. TOP OF BOILER. NORMAL, COMPUTED, STRESS, 8640 LB. PER SQ. IN.

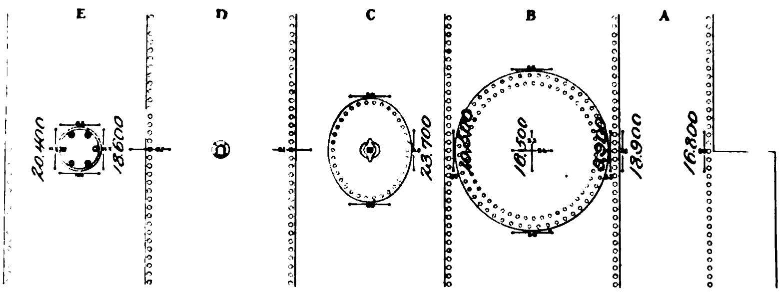


FIG. 45 TANGENTIAL STRESSES, LB. PER SQ. IN., AT 180 LB. BOILER PRESSURE. RESULTS BASED ON RESILIENCES. TOP OF BOILER. NORMAL, COMPUTED, STRESS, 17,280 LB. PER SQ. IN.

59 The hand-driven rivets would not be expected to hold the calking as well as the machine-driven rivets by reason of the difference in their points, and the test showed that such weakness was the case.

60 Diagram, Fig. 27, shows the behavior of the seams of this new section of course *C*. The flatness of the curves indicate how early these new seams began to display rapid extension, and with so decided a movement the calking was soon disturbed and copious leaks started.

At the time of presenting these notes no higher pressure has been reached than the rupturing of one of 335 lb. previously mentioned.

61 The strain measurements thus far described were those which were observed on tangential gaged lengths. In addition to this as indicated in the diagrams, Figs. 15, 16 and 17, there were longitudinal gaged lengths laid off on the shell and measured.

62 In a plain cylindrical shell the tangential extension of the metal would necessarily be attended with a definite amount of longitudinal contraction, eliminating the effect of pressures on the head. The conditions, however, which are present in steam boiler construction will generally prevent realizing the longitudinal strains which would be looked for in a plain sheet.

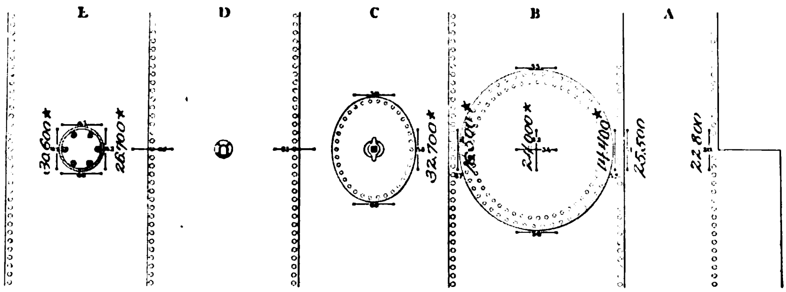


FIG. 46 TANGENTIAL STRESSES, LB. PER SQ. IN., AT 270 LB. BOILER PRESSURE. RESULTS BASED ON RESILIENCES. TOP OF BOILER. NORMAL, COMPUTED, STRESS, 25,920 LB. PER SQ. IN. GAGED LENGTHS ON WHICH DECIDED PERMANENT SETS OCCURRED, INDICATED BY A STAR

63 In the present test there were parts of the boiler nearly free from longitudinal strains, while there were other places in which the strains were reversed, and longitudinal extension shown instead of longitudinal contraction.

64 In order to determine whether the action immediately at the girth seams was represented by the 10-in. gaged lengths which spanned them symmetrically, other gaged lengths were established on the shell not indicated on the diagrams herewith presented. These were in pairs, one being wholly on the solid sheet, the other just stepping on to the adjacent course. The observations on these gaged lengths lead to the same results, however, as found on those which symmetrically spanned the seam.

65 The results of these observations showed that along the lower quarter of the boiler the longitudinal strains were contractions;

while along the upper quarter they were in part contractions, and in part extensions. The strains observed at 270 lb. pressure are entered on two lightly printed photographs, Figs. 29 and 30. In Fig. 29 are shown the strains which were measured on gaged lengths 1 and 3, taken on the solid sheets at the middle of the lengths of the courses. In Fig. 30 are shown the strains which were measured on gaged lengths 2 and 4, taken across the girth seams. Minus signs before the figures indicate contractions while plus signs indicate extensions.

66 It will be observed that the lower part of the shell contracted longitudinally, notwithstanding the fact that the tubes were extended by reason of the exterior pressures to which they were subjected.

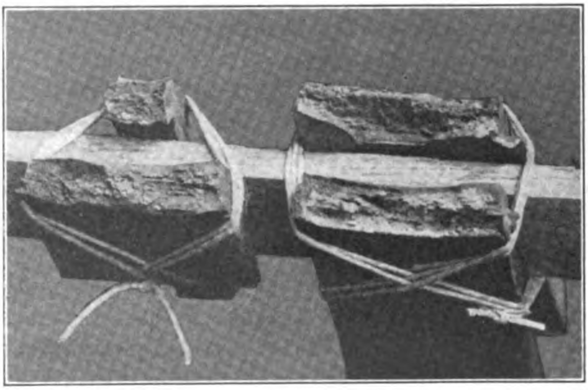

Fig. 47 Lamellar Appearance of Metal, Sheet *C*, Fractured by Bending while at a Blue Heat

67 This behavior calls for bending at the flanges of the heads to compensate for the difference in direction of these movements. The six through braces would relieve the shell of a portion of the longitudinal tension coming from the heads in the upper half of the boiler.

68 Longitudinal gaged lengths on the upper part of the shell showed diminished contractions over those observed on the lower portion, or displayed strains of extension. On the very top of the boiler the strains were extensions of a pronounced order.

69 It was found on diagonal gaged lengths, laid off on courses *B* and *D*, upper quarter of the boiler, that greater extensions were displayed on the converging diagonals over those of diverging directions. The converging diagonals, at 270 lb. pressure, extended 0.0047 in. and 0.0042 in. respectively, against 0.0036 in. and 0.0028 in. displayed on the diverging gaged lengths.

70 The location of the diagonal gaged lengths on course *D* are shown in Fig. 14, similar lengths having been laid off on course *B*. These results are entered in Fig. 30, in addition to the longitudinal strains. The longitudinal strains, all being those of extension, observed on the top of the boiler, have been entered on diagram, Fig. 31. The strains for each pressure, 90, 180, and 270 lb. respectively, are given. The range and variability of these measurements are seen to be very pronounced.

71 A series of lightly printed photographs, Figs. 32 to 37 inclusive, are presented, on which are entered the measured tangential strains observed at pressures of 90, 180 and 270 lb. respectively.

72 The strains observed on both the right and the left sides are entered, however, on prints representing the right side of the boiler. It will be understood that the longitudinal seams of the left side were the reverse of those on the right side as regards their respective heights. That is, on the left side the seams of course *B* and *D*, were three rivets above instead of three rivets below the others, as shown in illustrations of the right side. The tangential strains called for by computation based on a 30,000,000 modulus of elasticity are stated for each pressure in the captions of the figures.

73 The range in measured strains above and below the computed amount will be noted upon inspection of Figs. 32–37. The strains were least in amount at the heads, and generally greater rigidity was displayed at the intermediate girth seams than in the solid sheets, under the earlier pressures. At the middle of the length of the longitudinal seams the maximum extensions were developed, witnessed in this examination of the behavior of the shell.

74 The results thus far presented, with the exception of those on Fig. 26, have included both the elastic strains and the permanent sets of the different measured lengths.

75 The permanent sets have been subtracted from the extensions and the stresses corresponding to these resiliences computed, and the results entered on another series of diagrams, Figs. 38 to 46 inclusive. These results show the tangential stresses in pounds per square inch which were found in different parts of the solid sheets of the shell, when the boiler was subjected to pressures of 90, 180 and 270 lb., respectively.

76 In looking over those results the usual influence of longitudinal seams, such as were used in this boiler, in intensifying the tangential stresses in the adjacent solid sheets, may be pointed out. The excessive stress at the side of the single-riveted manhole patch is

clearly shown in the results. The high stresses at the sides of the safety-valve nozzle under the maximum pressure will also be noted.

77 While the results are consistent, nevertheless as an engineering structure the distribution of stresses exhibits a range far beyond that which is expected in other classes of constructive work. The type of boiler being one of the simplest, the extension of this method of test to other types would seem desirable. Such tests might assist in establishing satisfactory rules for steam boiler construction and might reasonably be expected to aid in the framing of regulations governing allowable pressures.

78 Additional tests were carried out, in which the effect of changes in the manner of supporting the boiler was inquired into. It was supported on the four end lugs in one test, and again in another test most of the weight was carried by the middle lugs. In each case there was a modification in the measured strains, although not in a marked degree. At the end of the test the several courses were seen to have been visibly extended in diameter between the girth seams.

79 The chemical composition of the steel in course *C*, was as follows:

| | |
|---|---|
| Carbon | 0.22 |
| Manganese | 0.43 |
| Silicon | 0.046 |
| Sulphur | 0.028 |
| Phosphorous | 0.043 |

It is recalled that this particular brand of steel, at the time of its manufacture was not infrequently found to possess a decidedly laminated structure. The laminations were not large, nor likely to cause blisters in the boiler, but they were in places quite numerous.

80 The metal from course *C*, the only sheet yet examined, was found to have a laminated structure. Fig. 47 shows the appearance of some fractured strips from this course, which were bent while at a blue heat, in order to develop the lamination of the plate in a pronounced manner. The metal drifts well, a $\frac{3}{4}$-in. diameter punched hole having been drifted cold to $1\frac{1}{4}$-in. diameter without rupture.

81 The services of Mr. P. W. Brunner, and J. W. Herrity are acknowledged, whose skill as manipulators is shown by the internal evidence of reliability which these measurements, taken by them, furnish.

# SOME EXPERIENCES WITH THE PITOT TUBE ON HIGH AND LOW AIR VELOCITIES

Frank H. Kneeland

ABSTRACT OF PAPER

This paper relates to the use of the Pitot tube for the measurement of flow of large volumes of air. The tests were made at plants of the United States Coal & Coke Company, Gary, W. Va., largely in connection with the flow of air through an experimental pipe line erected for the study of the problem of conveying coal by means of an air blast. Other tests were made in mine headings and in measuring the discharge from fan chimneys. Six different types of Pitot tubes were employed. The paper discusses the practical use of the Pitot tube and gives formulae applicable to it.

# SOME EXPERIENCES WITH THE PITOT TUBE ON HIGH AND LOW AIR VELOCITIES

By Frank H. Kneeland, Gary, W. Va.

**Junior Member of the Society**

As is well known the Pitot tube is an instrument for measuring the velocity of moving fluids. Its general principle is well understood; but we believe that, possibly on account of fancied difficulties in its manipulation, it has never received the thoughtful consideration from the majority of engineers, nor been put to the practical use to which its merits justly entitle it. This paper, therefore, will deal rather more with the practical side of the instrument than with the theoretical.

2 The tests herein described were made in part in connection with the flow of air through an experimental pipe line erected for the study of the problem of conveying coal by means of an air blast. The idea of transporting coal by this means from the workings of the mine to a tipple or bin is not a new one, several patents having been issued for such schemes. During the spring of 1909 one of the officials of the United States Coal & Coke Company conceived the idea of transporting the coal cut by a mining machine, by means of suction, on a principle similar to the Darley ash conveyor, or the better known vacuum carpet sweeper. Under certain conditions, this method of mining possesses many obvious advantages over present practice.

3 After carefully studying this problem in the light of available data, it appeared so good on paper that it was deemed justifiable to build an experimental plant for the purpose of determining:

*a* The velocity of air current necessary to carry coal in pipes of a given diameter.

*b* The amount of coal which could be transported by a given amount of air, in pipes of given diameter, but at varying velocities.

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*c* The loss of pressure due to friction of air in the pipes while carrying coal.

4 Accordingly the plant shown in plan and profile in Fig. 1 was constructed. It consisted essentially of a mining machine, a mine pipe for transporting the coal, a suction head to separate the coal from the air and a positive blower, or rather a "sucker," for creating the air blast. The mining machine above referred to cut the coal in sizes ranging from fine powder to lumps equivalent to about 2-in. cubes. The machine used in our experiments was originally designed for loading the coal into mine cars and was, therefore, equipped with a conveyor extending from its rear end. In our early experiments, it discharged its coal into a hopper mounted on 6-in., 8-in. or 12-in. ordinary wrought-iron pipe, as shown in Fig. 2. Later on it was arranged to discharge into a pipe of rectangular section, with approx-

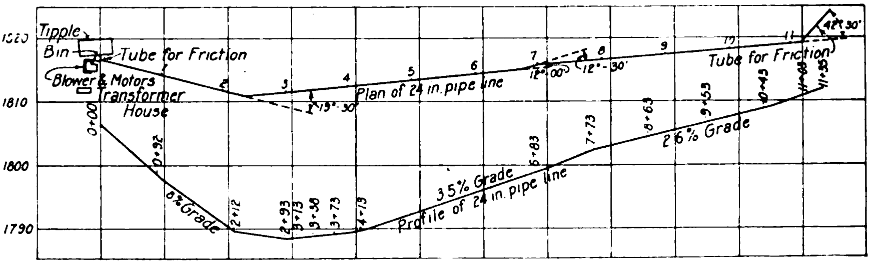


FIG. 1 PLAN AND PROFILE OF EXPERIMENTAL PIPE LINES

imately the same area as the 24-in. mine pipe. As will be seen in Fig. 2, above mentioned, only two pipes were used at a time, one carrying the coal and the other for the purpose of "spilling in" air to the 24-in. main mine pipe, to which the two smaller pipes were connected by means of a plate flange. The 24-in. mine pipe was made up of 30-ft. sections, except sections of special length, of which three were used. Each section was composed of six plates, each plate extending throughout the complete circumference and being lapped and riveted at the joint. Each of these longitudinal seams were placed 180 deg. from those of the plates next joining it. All transverse or girth seams were single riveted at the joints; all edges of plates inside the pipe were beveled and all rivets countersunk on the inside. Each section or length of pipe was provided with wrought-iron flanges at each end riveted to the pipe, the flange rivets being countersunk on the inside like all the others. The sections were put together with $\frac{1}{8}$-in. rubber gaskets between all flanges, which made an extremely tight mine pipe and one on which repeated tests as the work progressed failed to show any perceptible leakage.

5 The outer or tipple end of this mine pipe was connected with a square wooden suction head. At the upper end of the suction head a 36-in. cast-iron pipe connected it to a No. 11 Roots positive blower. This machine was driven through gearing by two 200-h.p. 720-r.p.m. induction motors. Two ratios of gearing were employed, one driving the blower somewhat below 90 r.p.m. and the other somewhat above 100 r.p.m. The normal displacement of the blower was 300 cu. ft. per revolution. This, however, was when the machine was operating under no pressure. Fig. 3 shows its capacity in cubic feet of free air per revolution under varying vacua. In the 36-in. pipe line and directly above the blower was a 36 in. by 16 in. by 36 in. tee with its 16-in. branch looking up. On the upper flange of this tee was

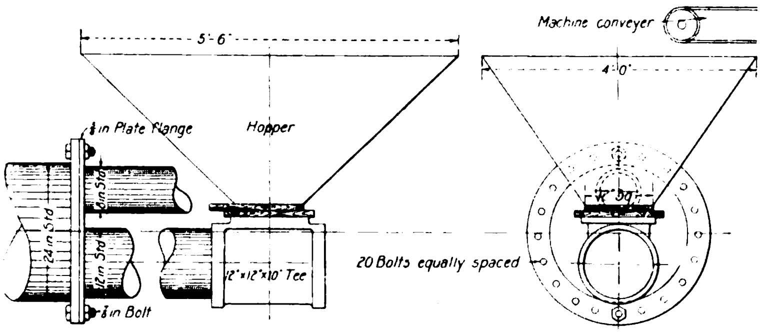


Fig. 2 Arrangement of 8-in. and 12-in. Pipes and Hopper at End of 24-in. Pipe Line

mounted a 16-in. straightway valve, upon which was placed a length of 16-in. pipe somewhat over 12 ft. long. The whole external arrangement except the motors and gearing may be clearly seen in Fig. 4.

6 The experimental plant has been carefully described in order that the manipulation of apparatus, etc. may be clearly understood. The velocity of air in a pipe carrying coal or other foreign substances cannot be measured by any direct means, and we, therefore, had to resort to indirect; that is to say, to determine the capacity of the blower per revolution and deduct from the quantity handled by the blower, the sum of the leakage and admission of air other than that through the mine pipe carrying the coal. The resulting quantity was, of course, that passing through the coal-carrying pipe. There were four points or places of admission of air, namely, the coal pipe,

the admission pipe parallel to it, the admission above the blower, and the suction head. Although this suction head was built up of a double thickness of tongued and grooved flooring with all joints laid in white lead, it leaked considerably and it became necessary before the experiments were over to cover the whole structure completely with tar paper laid in thick tar paint. Tests for leakage in this part of the apparatus were run at frequent intervals and corrections made for it in all calculations. It was necessary then while using the two pipes at the end of the mine pipe, to measure the velocity of the air at two places, in one of the pipes above mentioned and in the pipe above the blower. In order that all observations might be taken simultaneously, a system of signals was installed whereby the closing of a small knife switch at a point near the mining machine flashed

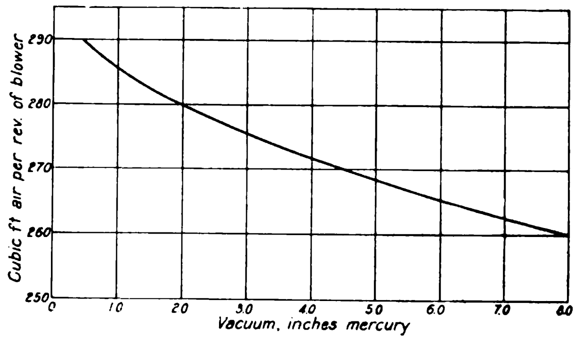


FIG. 3 CURVE FOR DISCHARGE OF ROOTS BLOWER PER REVOLUTION AT VARIOUS VACUA

ordinary incandescent lamps in front of each observer, both inside and outside the mine. Not only were observations taken on the velocity of air but also at three different points on the vacuum as well. A direct-reading water manometer was connected to the 24-in. pipe a short distance behind the mining machine; a differential mercury manometer, multiplying five times, was attached to the 24-in. pipe just outside its connection with the suction head, as shown at *A* in Fig. 4, and an ordinary direct-reading U-tube manometer attached to the 36-in. pipe a short distance above the blower, as shown at *B* in Fig. 4. In addition to the manometers above mentioned, there were used in connection with the Pitot tubes glass manometers of the U-type where one leg is enclosed within the other. These instruments were 16 in. long and provided with scales reading to one-tenth of an inch. Either water or mercury was used as a working fluid, depend-

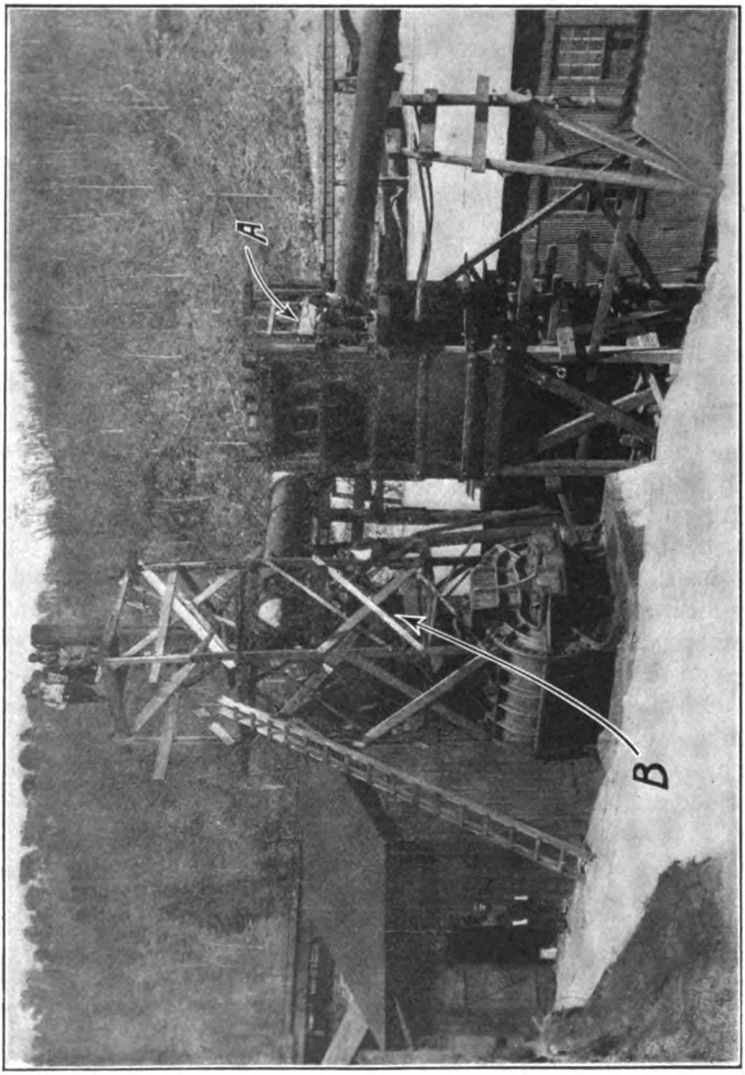


Fig. 4 General View showing Blower and Connections with Pipe Lines

ing upon the velocity of the air being measured. Although not appearing on the data sheets, corrections were always made for capillarity of the fluid in the manometers.

## ON THE USE OF THE PITOT TUBE

7 In general the Pitot tube consists essentially of two devices: (*a*) for converting the energy of a moving fluid into a pressure; and (*b*) for measuring the pressure on the fluid under consideration. In this paper the first will be known as the Dynamic Nozzle and the pressure registered by it will be called the Dynamic Head; and the second as the Static or Piezometer Nozzle and the pressure registered by it will be called the Static Head. In our work at Gary, we used six tubes of three distinct types, shown in Fig. 5, known as the United States No. 1, the Gebhardt Nos. 1 and 2, and the Taylor Nos. 1, 2 and 3. The United States No. 1 tube was made at our own shops and consisted of the dynamic nozzle *A* and the static nozzle *B*. In use the dynamic nozzle was placed in the holder *C*, which was screwed firmly into the wall of the pipe in which a test was being made. It was clamped into the holder by the small set screw shown in the drawing, (Fig. 5). The static nozzle was screwed into the wall of the pipe, like the holder above mentioned, until its inner end came flush with the inner surface of the pipe. The static and dynamic nozzles of this tube were always placed on the same girth line of the pipe and approximately 90 deg. from each other. The Gebhardt tubes, designed by Prof. G. D. Gebhardt and purchased from the Armour Institute of Technology, were practically identical with each other. They had been carefully calibrated and re-calibrated in gas mains and were said by their designer to possess a coefficient of unity. It will be observed that the static nozzles of these tubes were beveled; this was done in order to avoid aspiration in this part of the tube. In a paper[1] entitled The Pitot Tube as a Steam Meter, when speaking of the beveling of the static nozzle of the tube to prevent aspiration, Professor Gebhardt stated that further experiments were necessary to show whether any fixed angle is applicable to all velocities. Our experiments would bear out the above statement as this seems to be the weak or inaccurate part of the apparatus. The other details of the tube are shown with sufficient clearness in the drawing.

8 The Taylor tubes were, like the Gebhardt tubes, practically

[1] Trans. Am.Soc.M.E., vol. 31, p. 601.

identical with each other. These tubes were kindly loaned to us by Capt. D. W. Taylor, naval constructor at the United States Navy Yard, Washington, D. C., and had been used very successfully in testing ventilating fans for warships. This type of tube was very much more difficult to manipulate than the other two. Due to its shape, it had to be adjusted with extreme care when dealing with the high velocities employed by us, and at such times the writer and his associates were in constant fear lest its long point, or nose,

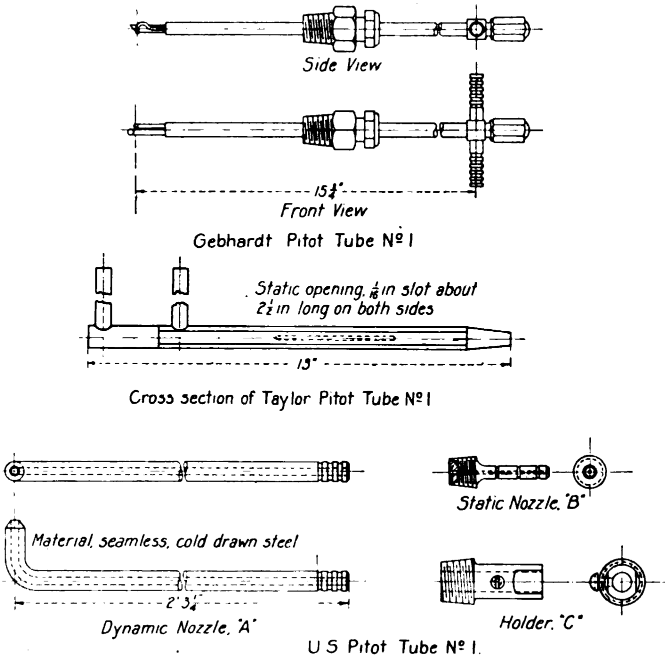


Fig. 5 Types of Pitot Tubes Used

be turned sidewise and the tube capsize, so to speak. Fortunately no such accident occurred, but it is possible that some of the erroneous readings of these tubes may have been caused by the tube taking a slightly sidewise position when subjected to the enormous wind pressures developed. It might, also, be mentioned that we made three other tubes, none of which were ever used on account of their large size and consequent clumsiness and difficulty of manipulation. Also in one test five dynamic nozzles were used, similar to those of the United States No. 1 tube, arranged one in each of the five positions shown in Table 1.

9 These five nozzles were connected to the automatic averaging block shown in Fig. 6, which in turn was connected to a manometer. The static pressure was obtained from a static nozzle exactly similar to that of the United States No. 1 tube. This arrangement of the apparatus, although apparently possessing some advantages over the ordinary method, is not only rather clumsy but is also inherently inaccurate, since the average velocity in a pipe is not dependent on the square root of the average dynamic pressures obtained at any

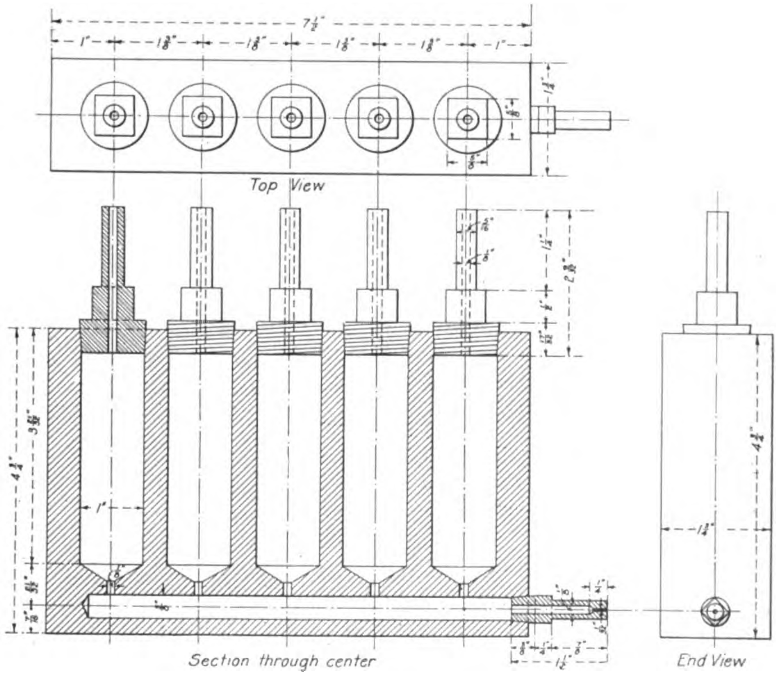


Fig. 6 Automatic Averaging Manometer

given number of points, but upon the average square roots of these pressures. It will also be seen that the liability of errors caused by leakages in the joints between the instrument and rubber tubing connecting it to its averaging block and manometer is at least six times as great in this apparatus as in the simpler tubes.

11 To obtain the average velocity existing in a pipe from the use of a Pitot tube, recourse may be had to two methods. The first of these is to divide the diameter of the pipe into a given number of equal parts and take one or more readings at each division point. Thus, supposing the work is being done with a 16-in. pipe, the tube

would first be placed as near the side wall of the pipe as possible and a reading, or a series of readings, taken. It would then be placed, say 1 in. from the side wall and an equal series of readings taken, and so on across the diameter of the pipe. The average velocity would then be considered as the average of the different velocities obtained at the several points of observation. It will readily be seen that this average is not strictly true, since the outer rings of the cross-section are of equal width with the inner ones, consequently, they are unequal in area, yet all were given equal weight in the calculations. The second, and better method, is to divide the cross-section of the pipe into a given number of equal areas and place the dynamic nozzle of the tube in the center of gravity, so to speak, of the circle being tested. To again illustrate: The pipe used above the blower in our experiments had an external diameter of 16 in., the wall being $\frac{1}{4}$ in. thick. This gave an internal diameter of $15\frac{1}{2}$ in. and an area of 188.69 sq. in. Dividing this into five equal parts, each

TABLE 1 PIPE SIZES AND POSITIONS OF TUBE

| Nominal Pipe Size, In. | Actual Internal Diameter, In. | Internal Area | | First Position | Second Position from Center, In. | Third Position from Center, In. | Fourth Position from Center, In. | Fifth Position from Center, In. |
|---|---|---|---|---|---|---|---|---|
| | | Sq. In. | Sq. Ft. | | | | | |
| 8 | $8\frac{3}{8}$ | 55.088 | 0.382 | Center | $2\frac{1}{4}$ | $2\frac{15}{16}$ | $3\frac{1}{2}$ | $3\frac{15}{16}$ |
| 12 | 12 | 107.33 | 0.745 | Center | $3\frac{3}{16}$ | $4\frac{1}{8}$ | $4\frac{7}{8}$ | $5\frac{1}{2}$ |
| 16 | $15\frac{1}{2}$ | 188.69 | 1.31 | Center | $4\frac{3}{16}$ | $5\frac{7}{16}$ | $6\frac{7}{16}$ | $7\frac{3}{16}$ |

part would have an area of 37.738 sq. in. Taking the first position of the Pitot tube at the center of the pipe, we assume that the velocity of air is constant over the circle or disc whose area is 37.738 sq. in. The second position of the tube is found by dividing the next ring or part into two equal areas and adding one of these to the central disc, and finding the radius of this sum. In the above case expressed mathematically this becomes

$$R^2 = \frac{37.738 + \frac{37.738}{2}}{3.1416}$$

$$R = \sqrt{\frac{37.738 + \frac{37.738}{2}}{3.1416}}$$

$$= 4\frac{3}{16}$$

12 These positions for the different sized pipes used, as well as the principal dimensions of the pipes, are shown in Table 1.

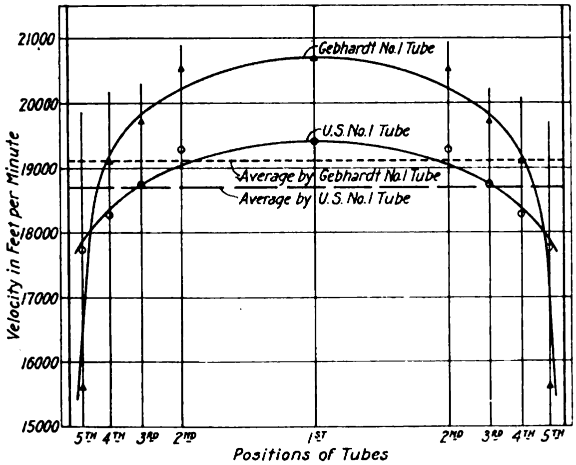


FIG. 7 CURVES SHOWING VELOCITY CHANGES ACROSS DIAMETER OF PIPE WITH GEBHARDT NO. 1 AND UNITED STATES NO. 1 PITOT TUBES

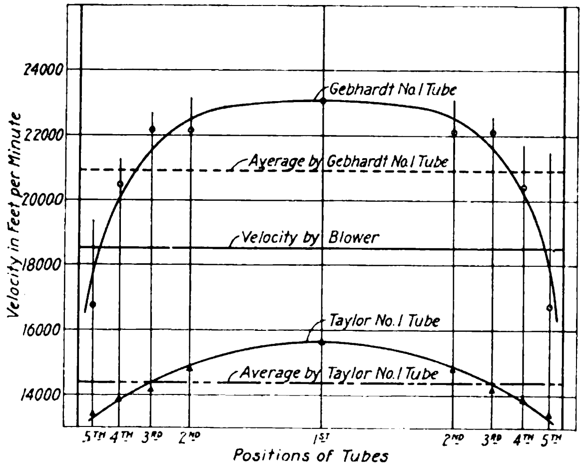


FIG. 8 SHOWING VELOCITY CHANGES ACROSS DIAMETER OF PIPE WITH GEBHARDT NO. 1 AND TAYLOR NO. 1 PITOT TUBES; ALSO VELOCITY AS SHOWN BY BLOWER

13 In Figs. 7, 8 and 9 are plotted the results of tests in the 16-in. pipe above the blower showing how the velocities vary across the diameter of the pipe as determined by the different tubes used. The data sheets from which these curves are plotted are found in the ap-

pendix. These are typical and fair averages of all tests made on the different sized pipes used.

14 The common formula for the Pitot tube is

$$v = \sqrt{2gh}$$

where

$v$ = velocity in ft. per sec.
$g$ = acceleration due to gravity in ft. per sec.
$h$ = head in ft. causing flow

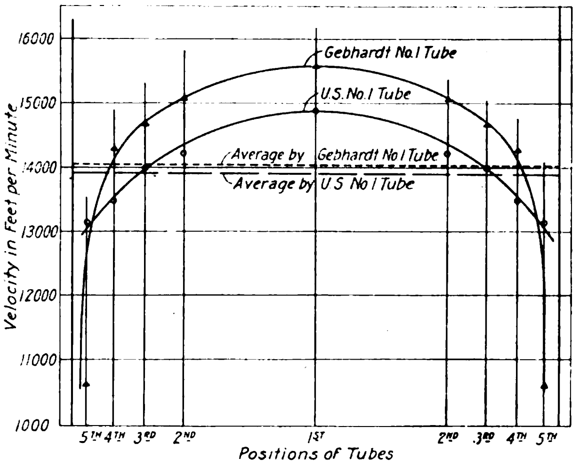


FIG. 9 CURVES SHOWING VELOCITY CHANGES ACROSS DIAMETER OF PIPE WITH GEBHARDT NO. 1 AND UNITED STATES NO. 1 PITOT TUBES

But in air measurement $h$ is a head of air in feet but is measured by $h_1$, which is a head of water (or mercury) in inches. Denoting the weight of the air per cubic feet by $w$, taking the density of water as 62.4 lb. per cu. ft. and letting $V$ = velocity of flow in ft. per min. we have

$$V = 60 \sqrt{2gh}$$

$$= 60 \sqrt{\frac{2 \times 32.16 \times 62.4 \times h_1}{12 \times w}}$$

$$= k \sqrt{h_1}$$

Now

$$w = \frac{1.3253 \times B}{459.2 + T}$$

where

$B$ = height of barometer

$T$ = temperature, deg. fahr.

1.3253 = weight in lb. of 459.2 cu. ft. of air at 0 deg. fahr. and 1 in. barometric pressure.[1] This gives the weight of dry air.

15 In the Smithsonian Meteorological Tables[2] a formula is given for the weight of humid air which, changing metric to English units, is

$$P = \frac{0.080723}{1 + 0.0020389\,(t - 32)} \times \frac{b - 0.378\,e}{29.921}$$

where $t$ is temperature deg. fahr., $b$ is corrected height of barometer in inches of mercury, and $e$ is the pressure due to the vapor in the air in inches of mercury.

16 This formula was used for determining the weight of air in all of our calculations; the humidity of the air being determined by psychrometric observations and the use of the Smithsonian tables above referred to.

17 In a paper entitled Experiments with Ventilating Fans and Pipes[3] Capt. D. W. Taylor, naval constructor, gives an exact formula for the Pitot tube. The following is quoted in part from Captain Taylor

$$\frac{v_1^2 - v_2^2}{2g} = \frac{y}{y-1} \times \frac{p_2}{P_2}\left\{1 - \left(\frac{p_1}{p^2}\right)^{\frac{y-1}{y}}\right\}$$

where

$v_1$ = velocity in ft. per sec. at a point where the pressure = $p_1$ in lb. per sq. ft., $p_2$ = pressure in lb. per sq. ft. at any other point

$v_2$ = velocity

and

$P_2$ = weight in lb. per cu. ft. where pressure = $p_2$

$y$ = ratio between specific heats of air under constant pressure and constant volume = 1.408

$g$ = acceleration due to gravity in ft. per sec.

18 Now if $p_2$ is the pressure at the impact opening of the Pitot tube, $v_2 = 0$. Also take $p_1$ as the pressure in the unchecked stream measured by the manometer connected with the pressure openings on the side of the Pitot tube. Also let $p_a$, $P_a$, $T_a$ be the pressure,

[1] Kent's Mechanical Engineers Pocket Book, ed. 7, p. 481.

[2] p. 55.

[3] Society of Naval Arch. and Marine Engrs., 1905, p. 35.

weight per cubic foot and absolute temperature of the atmosphere; $T_1$ and $T_2$ absolute temperatures corresponding to $p_1$ and $p_2$. Then

$$\frac{p_2}{P_2T_2} = \frac{p_1}{P_1T_1} = \frac{p_a}{P_aT_a} = x$$

and from well-known formulae for air

$$\frac{T_2}{T_1} = \left(\frac{p_2}{p_1}\right)^{\frac{y-1}{y}}$$

the change of pressure from $p_1$ to $p_2$ being adiabatic. Then from the above

$$\frac{p_2}{P_2} = xT_2 = xT_1\left(\frac{p_2}{p_1}\right)^{\frac{y-1}{y}}$$

$$\frac{v_1^2}{2g} = \frac{y}{y-1}\,xT_1\left\{\left(\frac{p_2}{p_1}\right)^{\frac{y-1}{y}} - 1\right\}$$

Let

$$p_2 = p_1(1+k)$$

Then

$$\frac{v_1^2}{2g} = \frac{y}{y-1}\,xT_1\left\{(1+k)^{\frac{y-1}{y}} - 1\right\}$$

Expanding and reducing

$$\frac{v_1^2}{2g} = xT_1\left\{k - \frac{k^2}{2y} + k^3\frac{1+y}{6y^2} - k^4\frac{(1+y)(1+2y)}{24y^3}\right\}$$

Now

$$y = 1.408$$

$$\frac{1}{2y} = 0.355$$

Therefore

$$v_1 = \sqrt{2g\,\frac{p_1k}{P_1}\left\{1 - \frac{k}{2y} + k^2\frac{1+y}{6y^2} - k^3\frac{(1+y)(1+2y)}{24y^3}\right\}}$$

19 Let $V_1$ = velocity in ft. per min. and the readings of $p_2$ and $p_1$ be expressed in in. of mercury instead of in lb. per sq. ft. Then

$$V_1 = 60\sqrt{64.32\times\frac{p_2-p_1}{P_1}\left\{1 - \frac{k}{2y} + k^2\frac{1+y}{6y^2} - k^3\frac{(1+y)(1+2y)}{24y^3}\right\}\times 70.708}$$

$$= 4046.16\sqrt{\frac{p_2-p_1}{P_1}\left\{1 - \frac{k}{2y} + k^2\frac{1+y}{6y^2} - k^3\frac{(1+y)(1+2y)}{24y^3}\right\}}$$

$$= 4046.16\sqrt{\frac{p_2-p_1}{P_1}\left\{1 - 0.355\,k + 0.202\,k^2 - 0.137\,k^3\right\}}$$

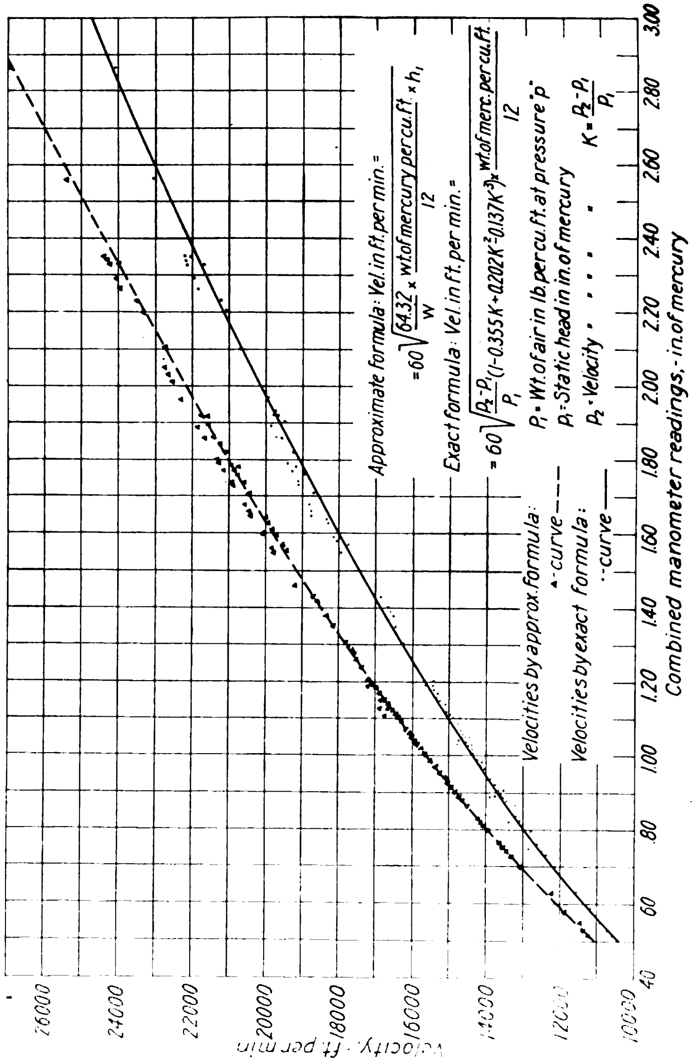


FIG 10 CURVES FOR AIR VELOCITIES AS CALCULATED BY APPROXIMATE AND EXACT PITOT TUBE FORMULAE

The values above given are for a temperature of 70 deg. fahr., a barometer of 29.921 in., and a humidity of 70 per cent.

20 Curves in Fig. 10 show a comparison of the velocities of air as calculated by the two formulae already given. It will be seen that at a velocity of 23,000 ft. per min. these formulae give results varying by over 15 per cent, while at 11,000 ft. per min. the variation is only about 6 per cent. For velocities below 6000 ft. per min. there seems to be no good reason for using the exact formula as given above, since the difference between it and the common formula is well within the limit of error in observation.

### FRICTION IN EXPERIMENTAL PIPE LINE

21 When designing the experimental plant, calculations were

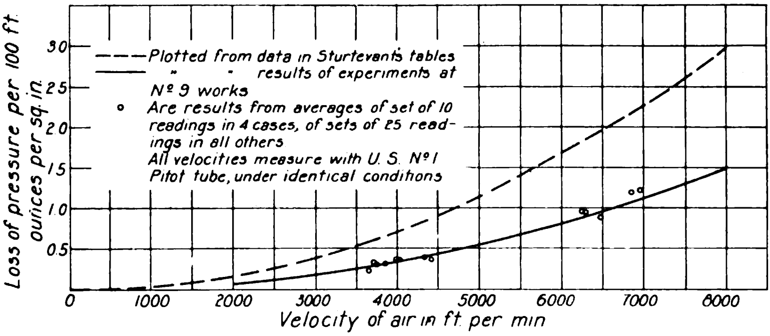


Fig. 11 Curves of Loss of Pressure Due to Friction in 24-in. Pipe

made for the loss of head due to friction in the pipe line. These calculations were based on Sturtevant's tables on air friction, since they were the most reliable data at hand. The experiments on the plant, however, gave an excellent opportunity to test not only the loss due to friction when carrying varying amounts of coal, but to check the calculated loss when the air was flowing alone and unburdened. Accordingly, observations were taken on the manometers at each end of the 24-in. mine pipe with this end in view, the results of which are shown in Fig. 11. This, however, does not give the loss from friction when carrying coal.

22 Some time after conducting the experiments described on the flow of air in pipes, the necessity arose for accurate measurement of the flow of air in mine headings in connection with fan tests, also of the air discharged from the chimney or outlet of fans, and we naturally turned to the Pitot tube as being the most accurate means at hand.

USE OF PITOT TUBE IN MINES

23 When we come to use the Pitot tube in mines we find several conditions not existing in large or small pipes. The floor, ribs and roof of a heading or room are always more or less rough and uneven, which causes innumerable eddies and swirls in the air current similar to those seen in the water along the sides of a swift stream flowing over a rocky or uneven bed. It is impossible, also, to determine from the appearance of an airway just where or why you will find the stronger air current. The velocity at which the air is flowing may also cause a decided difference in the contour of average velocity even though all other conditions remain the same. This is well illustrated in fan tests Nos. 9 and 10, Figs. 13 and 14 in the appendix. Of course, the ideal section of a heading in which to take a test would be a long, straight, smooth, rectangular passage. This can never be found and the nearest approximation available is the one to be chosen. At one side of the heading and preferably just behind the test section a "cubby-hole" or operating room should be dug out of the rib, principally for the convenience and comfort of the operator or operators. At the same time, however, the cubby-hole not only shields the operator and makes a convenient place to set up manometers, but also when it is used there are no corrections to be made for the operator's body and no eddy currents are caused by him. By stretching a series of strings or wires from floor to roof and from rib to rib, the test section may be divided into a number of smaller sections of equal, or nearly equal, area. The number of these smaller sections will depend entirely on the area of the test section. It is advisable, however, to have the small sections not much over 4 sq. ft. and less if possible. The smaller the sections the greater is the accuracy.

24 For holding the Pitot tube we built a telescoping stand of pipe and pipe fittings with a holding block that could be raised and lowered or clamped rigidly upon either part of the standard. We also made an anemometer holder provided with a spring which held the anemometer out of gear until a string attached to the operating lever was pulled. Upon release of the tension on this string, the spring pulled the instrument out of gear again and stopped its registration. The Pitot tube passed through the holding block and extended a very short distance beyond the anemometer. It will thus be seen that the Pitot tube could be successively placed in the center of each of the small sections and that in each one the anemometer was immediately beside it and subjected as nearly as possible to the same ve-

locity of air as the Pitot tube. The static head of the Pitot tube readings was taken direct on the manometer connected to it, since the whole apparatus was inside the heading in which measurements were being taken and, therefore, subject to the same pressure. Trial was made with the Gebhardt No. 1 tube (in place of the United States No. 1 regularly used) to ascertain if the taking of the static head beside the velocity head or in the cubby-hole on the manometer made any difference in the manometer reading, with the result that the readings in both cases were the same, as might have been expected. We also checked the accuracy of both instruments with smoke and carbon di-sulphide. The method of making this test was as follows:

25 A distance of 200 ft. was measured off along one of the main haulage roads of a mine. The cross-section of this heading was as nearly uniform as a mine heading in this kind of coal (Pocahontas) can well be and the floor and roof were free of obstructions and very even. Midway of this distance and opposite a safety pocket, a hole excavated in the rib for the miners to stand in when a locomotive or trip is passing, the stand bearing the Pitot tube and anemometer was set up and a series of readings taken on both instruments. One observer then stationed himself at the upper end of the 200-ft. distance and another at the lower end. The former was provided with a revolver and blank cartridges loaded with black powder while the latter held a watch. At a signal from the man at the lower end, the one at the upper end of the trial distance fired across the heading and the time was noted when the odor of the powder reached the lower end. The smoke was entirely dissipated before it had traveled half the distance. As a check on the above method, it was repeated, except that instead of using the revolver, a bottle of carbon di-sulphide ($CS_2$) was used. This was not as satisfactory as the former, since an appreciable amount of time was lost in uncorking the bottle and throwing the liquid into the air. However, the results checked fairly close if an allowance be made for lost time. The above was repeated in a heading with very much lower velocity, about 200 ft., and the Pitot tube found to be almost worthless. The anemometer, on the other hand, gave results which were very fairly accurate.

## MEASURING DISCHARGE FROM FAN CHIMNEYS

26 In measuring the discharge from fan chimneys we employed a method very similar to that used in mine headings. Instead of the

telescoping stand, however, we used two ⅜-in. pipes extending transversely across the fan chimney and held firmly at each end with a specially forged clamp. Upon these pipes or guides was mounted a runner or slide arranged to hold both the Pitot tube and anemometer holder. The top of the chimney was divided into a given number of approximately equal areas by stretching strings or wires across in both directions, as shown in Fig. 12, and the two instruments placed successively in each of the areas. It will be observed from the results of these tests shown in the appendix, that the velocity in these chimneys is always greatest on the tangent side, decreases to a minimum near the center and then increases on the front side. Trans-

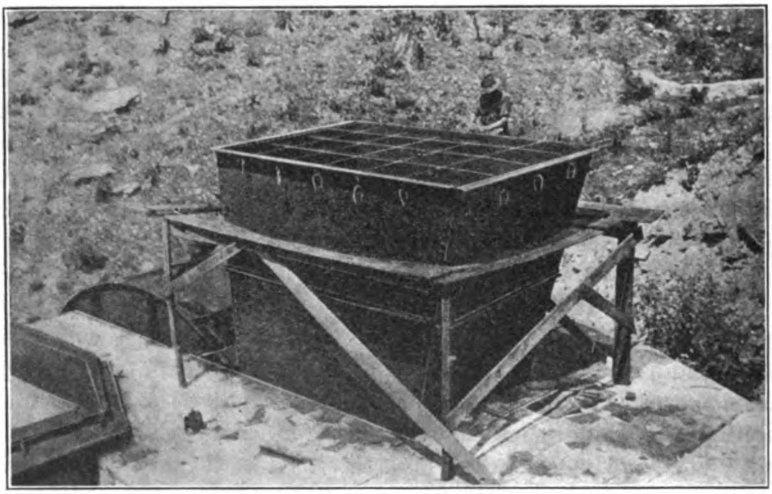

Fig. 12 Division of Top of Chimney into Equal Areas

versely, the velocity of air seems to follow no fixed law, but in general seems to be greater in the outside areas. When the fan is delivering a large quantity of air also, the velocity near the center of the chimney becomes so low as to be unmeasurable with the Pitot tube and is gusty and variable in its nature, the anemometer frequently halting, and even running backward for some seconds at a time. It should be stated also, that all the tests we have made thus far are upon fans of the Clifford-Capel type.

27 In all of the tests on fans, shown in the appendix a differential manometer reading to 1/100 in. was used. This instrument used a special mineral oil as a working fluid but the angle of inclina-

tion was such as to cause it to read correct for water. Careful comparison with a direct-reading water manometer, proved that this angle was the proper one and that the instrument read correctly.

28 In the tests on headings a board was nailed to the wall of the cubby-hole and the manometer screwed to it, care being taken that this instrument was kept perfectly level. In taking measurements on the fan chimneys a board was fastened to the side of the chimney and the manometer fastened thereto as in the mine headings.

## CONCLUSIONS

29 From our experience with the three types of Pitot tubes, we would draw the following conclusions:

*a* The Taylor tube, although probably very accurate and extremely sensitive on the air velocities for which it was designed, say up to 3000 ft. per min., is clumsy, difficult of manipulation, fragile, and altogether unsuited to high velocity measurement.

*b* Tubes of the Gebhardt type are light, compact, very portable, convenient and easy of manipulation. They are very accurate when used on velocities up to say, 6000 ft. per min. Beyond this point or beyond the limits of the common formula, their accuracy is somewhat problematical.

*c* The United States No. 1 tube is less convenient and portable than the Gebhardt. It is, however, much simpler in construction and will stand much more abuse. It does not require anywhere near as much care in manipulation as either of the other two types. It has been found accurate on air velocities as low as 600 ft. per min. The upper limit of its accuracy is unknown but it has been successfully used on velocities exceeding 25,000 ft. per min.

*d* The exact formula, as explained above, is much more accurate, especially on the higher velocities, than the one usually employed.

*e* Present data on the friction of air in pipes are largely in error. Our tests showed for the length and size of pipe used that the friction of the air was just about one-half what it was calculated to be. Additional accurate data along this line are sadly needed.

The writer wishes to acknowledge his indebtedness to Mr. Edward O'Toole, general superintendent of the United States Coal & Coke Company of Gary, W. Va., and to Mr. Howard N. Eavenson, chief engineer of the same company, under whose direct supervision the work above described was conducted. He also wishes to thank Mr. George C. Hicks of the P. H. & F. M. Roots Company, of Connersville, Ind., Capt. D. W. Taylor, naval constructor of the United States Navy Yard, Washington, D. C., and Mr. J. H. Klepinger, Great Falls, Mont., for valuable suggestions and aid.

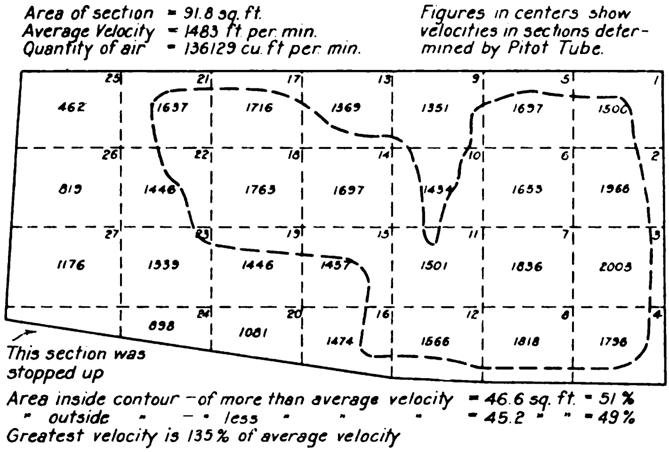


FIG. 13 SECTION AND VELOCITIES IN AIRWAY, FAN TEST NO. 9

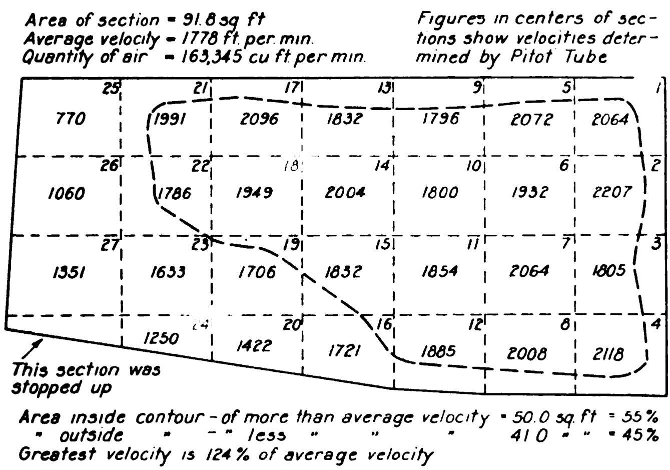


FIG. 14 SECTION AND VELOCITIES IN AIRWAY, FAN TEST NO. 10

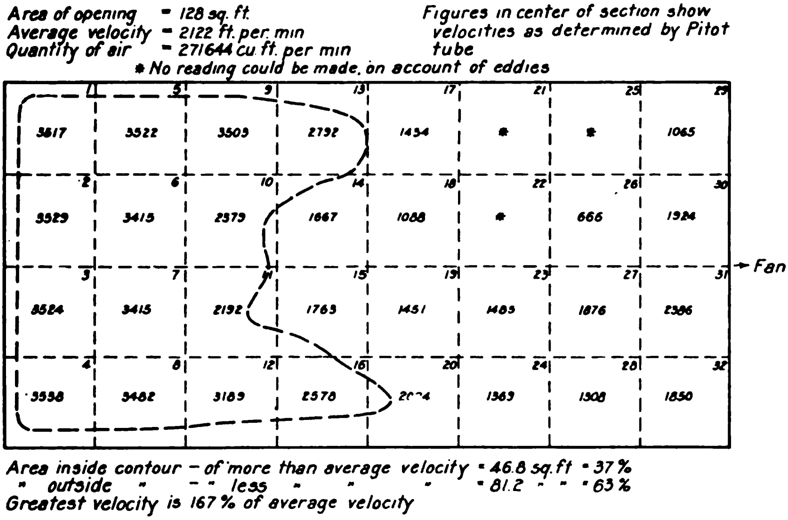


FIG. 15 SECTION AND VELOCITIES AT TOP OF CHIMNEY, FAN TEST NO. 11

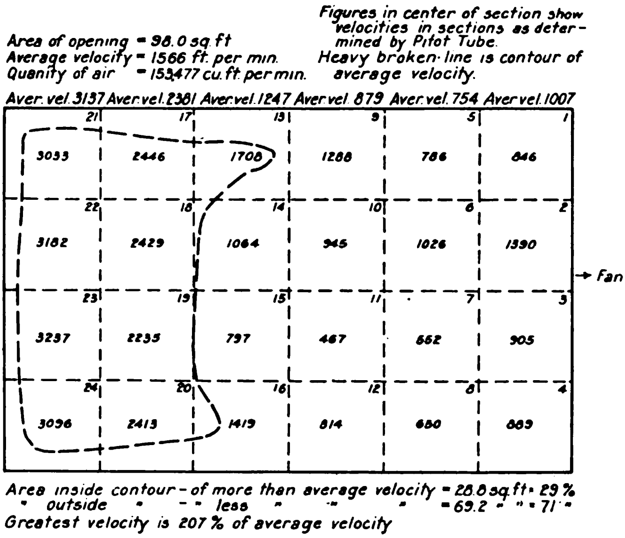


FIG. 16 SECTION AND VELOCITIES AT TOP OF CHIMNEY, FAN TEST NO. 5

**TABLE 2 TESTS OF BLOWER WITH 36-IN. PIPE BLANKED**

**No. 9 Works, United States Coal & Coke Company, April 10, 1910**

| No. of Run | U. S. Pitot Tube No. 1: Vacuum in 36-in. Pipe (In. Mercury) | Dynamic Readings, 16-in. Pipe (In. Mercury) | Averages (In. Mercury) | Static Readings (In. Mercury) | Averages (In. Mercury) | Combined Averages (In. Mercury) | Weight of Air per Cu. Ft., Lb. | Velocity in 16-in. Pipe, Ft. per Minute | Gebhardt Pitot Tube No. 1.: Dynamic Readings (In. Mercury) | Averages (In. Mercury) | Static Readings (In. Mercury) | Averages (In. Mercury) | Combined Averages (In. Mercury) | Weight of Air per Cu. Ft., 605 | Velocity Air in 16-in. Pipe, Ft. per Minute | Blower, R.P.M. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 2.40 | 1.20 | | 3.00 | | | | | 1.10 | | 3.30 | | | | | |
| 2 | 2.40 | 1.15 | | 3.02 | | | | | 1.10 | | 3.20 | | | | | |
| 3 | 2.40 | 1.25 | 1.24 | 3.03 | 3.03 | 1.79 | 0.0646 | 19410 | 1.20 | 1.17 | 3.20 | 3.22 | 2.05 | 0.0641 | 20710 | .... |
| 4 | 2.40 | 1.40 | | 3.07 | | | | | 1.25 | | 3.20 | | | | | |
| 5 | 2.40 | 1.20 | | 3.02 | | | | | 1.20 | | 3.20 | | | | | |
| 6 | 2.40 | 1.30 | | 3.00 | | | | | 1.10 | | 3.10 | | | | | |
| 7 | 2.40 | 1.25 | | 2.97 | | | | | 1.10 | | 3.10 | | | | | |
| 8 | 2.40 | 1.15 | 1.22 | 3.00 | 2.99 | 1.77 | 0.0647 | 19290 | 1.10 | 1.11 | 3.16 | 3.14 | 2.03 | 0.0643 | 20540 | 87 |
| 9 | 2.40 | 1.20 | | 2.96 | | | | | 1.10 | | 3.12 | | | | | |
| 10 | 2.40 | 1.20 | | 3.04 | | | | | 1.15 | | 3.20 | | | | | |
| 11 | 2.40 | 1.30 | | 3.02 | | | | | 1.15 | | 3.05 | | | | | |
| 12 | 2.40 | 1.40 | | 3.00 | | | | | 1.20 | | 3.05 | | | | | |
| 13 | 2.40 | 1.35 | 1.35 | 3.00 | 3.00 | 1.65 | 0.0647 | 18740 | 1.25 | 1.19 | 3.03 | 3.05 | 1.86 | 0.0646 | 19730 | 86.5 |
| 14 | 2.40 | 1.30 | | 2.97 | | | | | 1.20 | | 3.07 | | | | | |
| 15 | 2.40 | 1.40 | | 3.00 | | | | | 1.15 | | 3.07 | | | | | |
| 16 | 2.40 | 1.45 | | 2.97 | | | | | 1.30 | | 3.00 | | | | | |
| 17 | 2.40 | 1.40 | | 3.00 | | | | | 1.25 | | 3.00 | | | | | |
| 18 | 2.40 | 1.40 | 1.42 | 3.00 | 2.98 | 1.56 | 0.0648 | 18280 | 1.25 | 1.27 | 2.98 | 3.00 | 1.73 | 0.0647 | 19110 | 87 |
| 19 | 2.40 | 1.40 | | 2.97 | | | | | 1.30 | | 3.03 | | | | | |
| 20 | 2.40 | 1.45 | | 2.98 | | | | | 1.25 | | 3.00 | | | | | |
| 21 | 2.40 | 1.55 | | 2.94 | | | | | 1.55 | | 2.70 | | | | | |
| 22 | 2.36 | 1.50 | | 2.94 | | | | | 1.60 | | 2.70 | | | | | |
| 23 | 2.36 | 1.45 | 1.47 | 2.94 | 2.93 | 1.46 | 0.0649 | 17740 | 1.60 | 1.59 | 2.70 | 2.70 | 1.11 | 0.0655 | 15600 | 87 |
| 24 | 2.36 | 1.45 | | 2.91 | | | Aver. 18692 | | 1.60 | | 2.70 | | | Aver. 19138 | | |
| 25 | 2.36 | 1.40 | | 2.93 | | | | | 1.60 | | 2.70 | | | | | |

**Barometer, 28.64; temperature, 64 deg.; humidity, 41 per cent; mercury, 846.5.**

$$V = 4041.6 \sqrt{\frac{p_2 - p_1}{P_1}} \ (1 - \text{etc.})$$

TABLE 3 TESTS OF BLOWER WITH 36-IN. PIPE BLANKED

No. 9 Works, United States Coal & Coke Company, April 10, 1910

| | Gebhardt Pitot Tube No 1. | | | | | | | | Taylor Pitot Tube No. 3 | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| No. of Run | Vacuum in 36-In. Pipe | Dynamic Readings 16-In. Pipe | Averages | Static Readings | Averages | Combined Averages | Velocity in 16-In. Pipe, Ft. per Minute | Weight of Air per Cu. Ft., Lb. | Dynamic Readings | Averages | Static Readings | Averages | Combined Averages | Weight of Air per Cu. Ft., Lb. | Velocity in 16-In. Pipe, Ft. per Minute | Blower R.P.M |
| | In. Mercury | | | | | | | | In. Mercury | | | | | | | |
| 1 | 2.40 | 1.10 | | 3.75 | | | | | 1.00 | | 2.17 | | | | | |
| 2 | 2.40 | 1.10 | | 3.65 | | | | | 1.00 | | 2.21 | | | | | |
| 3 | 2.40 | 1.10 | 1.10 | 3.65 | 3.66 | 2.56 | 23080 | 0.0631 | 0.95 | 0.99 | 2.20 | 2.18 | 1.19 | 0.0668 | 15670 | 87 |
| 4 | 2.40 | 1.10 | | 3.65 | | | | | 0.95 | | 2.18 | | | | | |
| 5 | 2.40 | 1.10 | | 3.62 | | | | | 1.05 | | 2.15 | | | | | |
| 6 | 2.40 | 1.25 | | 3.55 | | | | | 1.13 | | 2.17 | | | | | |
| 7 | 2.40 | 1.25 | | 3.55 | | | | | 1.10 | | 2.18 | | | | | |
| 8 | 2.38 | 1.20 | 1.22 | 3.55 | 3.55 | 2.33 | 22140 | 0.0633 | 1.15 | 1.16 | 2.18 | 2.19 | 1.03 | 0.0668 | 14780 | 87 |
| 9 | 2.40 | 1.20 | | 3.55 | | | | | 1.25 | | 2.21 | | | | | |
| 10 | 2.40 | 1.20 | | 3.55 | | | | | 1.15 | | 2.19 | | | | | |
| 11 | 2.36 | 1.15 | | 3.55 | | | | | 1.45 | | 2.29 | | | | | |
| 12 | 2.40 | 1.15 | | 3.55 | | | | | 1.35 | | 2.27 | | | | | |
| 13 | 2.36 | 1.20 | 1.19 | 3.52 | 3.53 | 2.34 | 22150 | 0.0634 | 1.25 | 1.32 | 2.20 | 2.25 | 0.93 | 0.0666 | 14150 | 87 |
| 14 | 2.36 | 1.20 | | 3.50 | | | | | 1.30 | | 2.20 | | | | | |
| 15 | 2.36 | 1.25 | | 3.55 | | | | | 1.25 | | 2.29 | | | | | |
| 16 | 2.36 | 1.40 | | 3.40 | | | | | 1.35 | | 2.27 | | | | | |
| 17 | 2.36 | 1.40 | | 3.35 | | | | | 1.40 | | 2.24 | | | | | |
| 18 | 2.36 | 1.40 | 1.40 | 3.35 | 3.36 | 1.96 | 20460 | 0.0638 | 1.35 | 1.35 | 2.24 | 2.24 | 0.89 | 0.0666 | 13880 | 87.5 |
| 19 | 2.36 | 1.40 | | 3.35 | | | | | 1.30 | | 2.24 | | | | | |
| 20 | 2.36 | 1.40 | | 3.35 | | | | | 1.35 | | 2.21 | | | | | |
| 21 | 2.40 | 1.65 | | 2.93 | | | | | 1.35 | | 2.21 | | | | | |
| 22 | 2.38 | 1.65 | | 2.95 | | | | | 1.45 | | 2.24 | | | | | |
| 23 | 2.40 | 1.65 | 1.65 | 2.92 | 2.93 | 1.28 | 16760 | 0.0649 | 1.50 | 1.44 | 2.27 | 2.26 | 0.82 | 0.0666 | 13390 | 87 |
| 24 | 2.36 | 1.65 | | 2.92 | | | | | 1.45 | | 2.29 | | | | | |
| 25 | 2.40 | 1.65 | | 2.92 | | Aver. | 20918 | | 1.45 | | 2.27 | | | Aver. | 14371 | 87.1 |

Barometer, 28.64; temperature, 64 deg.; humidity, 41 per cent; mercury, 846.5.

$$V = 4041.6\sqrt{\frac{p_2 - p_1}{P_1}}\ (1 - \text{etc.})$$

**TABLE 4 TESTS OF BLOWER FOR LEAKAGE, 16-IN. PIPE OPEN, OTHERS CLOSED**

**No. 9 Works, United States Coal & Coke Company, April 10, 1910**

| | U. S. Pitot Tube No. 1 | | | | | | | | Gebhardt Pitot Tube No. 1 | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| No. of Run | Vacuum in 36-in. Pipe (In. Mercury) | Dynamic Readings 16-in. Pipe (In. Mercury) | Averages (In. Mercury) | Static Readings (In. Mercury) | Averages (In. Mercury) | Combined Averages (In. Mercury) | Weight of Air per Cu. Ft., Lb. | Velocity in 16-in. Pipe, Ft. per Min. | Dynamic Readings (In. Mercury) | Averages (In. Mercury) | Static Readings (In. Mercury) | Averages (In. Mercury) | Combined Averages (In. Mercury) | Weight of Air per Cu. Ft., Lb. | Velocity of Air in 16-in. Pipe, Ft. per Min. | Blower R.P.M. |
| 1 | 1.60 | 0.58 | | 1.70 | | | | | 0.65 | | 1.80 | | | | | |
| 2 | 1.60 | 0.63 | | 1.75 | | | | | 0.60 | | 1.80 | | | | | |
| 3 | 1.56 | 0.58 | 0.60 | 1.73 | 1.72 | 1.12 | 0.0680 | 14820 | 0.60 | 0.61 | 1.85 | 1.85 | 1.24 | 0.0676 | 15590 | ...... |
| 4 | 1.56 | 0.58 | | 1.71 | | | | | 0.60 | | 1.90 | | | | | |
| 5 | 1.56 | 0.63 | | 1.71 | | | | | 0.61 | | 1.90 | | | | | |
| 6 | 1.56 | 0.75 | | 1.78 | | | | | 0.65 | | 1.70 | | | | | |
| 7 | 1.60 | 0.80 | | 1.77 | | | | | 0.65 | | 1.85 | | | | | |
| 8 | 1.60 | 0.75 | 0.77 | 1.75 | 1.77 | 1.00 | 0.0679 | 14210 | 0.65 | 0.65 | 1.80 | 1.80 | 1.15 | 0.0677 | 15080 | 87.5 |
| 9 | 1.60 | 0.80 | | 1.78 | | | | | 0.65 | | 1.83 | | | | | |
| 10 | 1.56 | 0.75 | | 1.78 | | | | | 0.65 | | 1.80 | | | | | |
| 11 | 1.56 | 0.80 | | 1.78 | | | | | 0.70 | | 1.80 | | | | | |
| 12 | 1.56 | 0.85 | | 1.78 | | | | | 0.70 | | 1.80 | | | | | |
| 13 | 1.56 | 0.85 | 0.82 | 1.78 | 1.78 | 0.96 | 0.0679 | 13980 | 0.75 | 0.71 | 1.78 | 1.79 | 1.08 | 0.0678 | 14690 | 87.5 |
| 14 | 1.58 | 0.80 | | 1.78 | | | | | 0.72 | | 1.78 | | | | | |
| 15 | 1.56 | 0.80 | | 1.78 | | | | | 0.70 | | 1.78 | | | | | |
| 16 | 1.56 | 0.90 | | 1.78 | | | | | 0.72 | | 1.75 | | | | | |
| 17 | 1.60 | 0.90 | | 1.78 | | | | | 0.72 | | 1.70 | | | | | |
| 18 | 1.60 | 0.90 | 0.90 | 1.78 | 1.78 | 0.88 | 0.0679 | 13470 | 0.72 | 0.72 | 1.75 | 1.74 | 1.02 | 0.0679 | 14300 | 87.5 |
| 19 | 1.60 | 0.95 | | 1.78 | | | | | 0.72 | | 1.75 | | | | | |
| 20 | 1.60 | 0.85 | | 1.78 | | | | | 0.72 | | 1.75 | | | | | |
| 21 | 1.60 | 0.95 | | 1.78 | | | | | 0.95 | | 1.48 | | | | | |
| 22 | 1.56 | 1.00 | | 1.78 | | | | | 0.95 | | 1.48 | | | | | |
| 23 | 1.56 | 0.95 | 0.95 | 1.78 | 1.78 | 0.83 | 0.0679 | 13140 | 0.95 | 0.95 | 1.48 | 1.48 | 0.53 | 0.0686 | 10610 | 86.5 |
| 24 | 1.56 | 0.95 | | 1.78 | | | Aver. | 13924 | 0.95 | | 1.48 | | | Aver. | 14054 | 87.2 |
| 25 | 1.56 | 0.90 | | 1.78 | | | | | 0.95 | | 1.48 | | | | | |

Barometer, 28.64: temperature, 64 deg.; humidity, 41 per cent; mercury, 846.5.

$$V = 4041.6 \sqrt{\frac{p_1 - p_1}{P_1}} \; (1 - \text{etc.})$$

TABLE 5 DATA FOR FAN TEST NO. 5

No. 4 Works, United States Coal & Coke Company, January 28, 1911

| Section Number | Area, Sq. Ft. | Pitot Tube | | | Anemometer | |
|---|---|---|---|---|---|---|
| | | Reading, In. Water | Velocity, Ft. per Min. | Quantity, Cu. Ft. per Min. | Velocity, Ft. per Min. | Quantity, Cu. Ft. per Min. |
| 1 | 4.08 | 0.0447 | 846 | 3452 | 1150 | 4692 |
| 2 | 4.08 | 0.1207 | 1390 | 5671 | 1680 | 6854 |
| 3 | 4.08 | 0.0511 | 905 | 3692 | 890 | 3631 |
| 4 | 4.08 | 0.0493 | 889 | 3627 | 1190 | 4855 |
| 5 | 4.08 | 0.0386 | 786 | 3207 | 895 | 3652 |
| 6 | 4.08 | 0.0657 | 1026 | 4186 | 1120 | 4570 |
| 7 | 4.08 | 0.0190 | 552 | 2250 | 690 | 2815 |
| 8 | 4.08 | 0.0264 | 650 | 2652 | 770 | 3142 |
| 9 | 4.08 | 0.1036 | 1288 | 5255 | 1400 | 5712 |
| 10 | 4.08 | 0.0558 | 945 | 3856 | 1170 | 4774 |
| 11 | 4.08 | 0.0136 | 467 | 1905 | 840 | 3427 |
| 12 | 4.08 | 0.0414 | 814 | 3321 | 1080 | 4406 |
| 13 | 4.08 | 0.1821 | 1708 | 6969 | 1810 | 7385 |
| 14 | 4.08 | 0.0707 | 1064 | 4341 | 1290 | 5263 |
| 15 | 4.08 | 0.0397 | 797 | 3252 | 1065 | 4345 |
| 16 | 4.08 | 0.1257 | 1419 | 5790 | 1780 | 7262 |
| 17 | 4.08 | 0.3737 | 2446 | 9980 | 3100 | 12648 |
| 18 | 4.08 | 0.3686 | 2429 | 9910 | 3080 | 12566 |
| 19 | 4.08 | 0.3118 | 2235 | 9119 | 2780 | 11342 |
| 20 | 4.08 | 0.3636 | 2413 | 9845 | 3090 | 12607 |
| 21 | 4.08 | 0.5743 | 3033 | 12375 | 3760 | 15341 |
| 22 | 4.08 | 0.6321 | 3182 | 12983 | 4095 | 16708 |
| 23 | 4.08 | 0.6543 | 3237 | 13207 | 4050 | 16524 |
| 24 | 4.08 | 0.5984 | 3096 | 12632 | 3765 | 15361 |
| | 98.00 | | 1566 | 153477 | 1937 | 189882 |

Conditions: Fan on mine, but doors at back of fan open, allowing all air possible to enter fan.

| Air: Measured at top of chimney. | Beginning | Ending | Barometer 28.94 |
|---|---|---|---|
| Temperature outside, 44 deg. from chimney...... | 46½ deg. | 53½ deg. | |
| Humidity outside, 71 per cent from chimney.... | 72 per cent | 58 per cent | $V = 4002 \sqrt{h}$ |
| Weight of air per cu. ft., 0.0762 lb................. | 0.0758 | 0.0747 | |

Average weight of air from chimney, 0.0752 lb. per cu. ft.

TABLE 6 DATA FOR FAN TEST NO. 9

NO. 6 WORKS, UNITED STATES COAL & COKE COMPANY, FEBRUARY 18, 1911

| Section Number | Area, Sq. Ft. | Pitot Tube | | | Anemometer | |
|---|---|---|---|---|---|---|
| | | Reading, In. Water | Velocity, Ft. per Min. | Quantity, Cu. Ft. per Min. | Velocity, Ft. per Min. | Quantity, Cu. Ft. per Min. |
| 1 | 3.49 | 0.138 | 1506 | 5256 | 2213 | 7723 |
| 2 | 3.52 | 0.235 | 1966 | 6920 | 2475 | 8712 |
| 3 | 3.55 | 0.244 | 2003 | 7111 | 2490 | 8839 |
| 4 | 3.53 | 0.196 | 1796 | 6340 | 2485 | 8772 |
| 5 | 3.44 | 0.175 | 1697 | 5838 | 2508 | 8628 |
| 6 | 3.50 | 0.166 | 1653 | 5785 | 2445 | 8557 |
| 7 | 3.50 | 0.205 | 1836 | 6426 | 2402 | 8407 |
| 8 | 3.36 | 0.201 | 1818 | 6108 | 2368 | 7956 |
| 9 | 3.40 | 0.111 | 1351 | 4593 | 2345 | 7973 |
| 10 | 3.50 | 0.125 | 1434 | 5019 | 2225 | 7787 |
| 11 | 3.50 | 0.137 | 1501 | 5253 | 2260 | 7910 |
| 12 | 3.24 | 0.149 | 1566 | 5074 | 2355 | 7630 |
| 13 | 3.38 | 0.114 | 1369 | 4627 | 2300 | 7774 |
| 14 | 3.50 | 0.175 | 1697 | 5939 | 2438 | 8533 |
| 15 | 3.50 | 0.129 | 1457 | 5100 | 2313 | 8095 |
| 16 | 2.86 | 0.132 | 1474 | 4216 | 2207 | 6312 |
| 17 | 3.38 | 0.179 | 1716 | 5800 | 2615 | 8839 |
| 18 | 3.50 | 0.189 | 1763 | 6170 | 2464 | 8624 |
| 19 | 3.50 | 0.127 | 1446 | 5061 | 2286 | 8001 |
| 20 | 2.24 | 0.071 | 1081 | 2421 | 2065 | 4626 |
| 21 | 3.40 | 0.163 | 1637 | 5566 | 2375 | 8075 |
| 22 | 3.50 | 0.127 | 1446 | 5061 | 2225 | 7788 |
| 23 | 3.50 | 0.109 | 1339 | 4687 | 2175 | 7612 |
| 24 | 1.62 | 0.049 | 898 | 1455 | 1875 | 3037 |
| 25 | 3.86 | 0.013 | 462 | 1783 | 1400 | 5404 |
| 26 | 4.20 | ..... | 819* | 3440 | 1055 | 4431 |
| 27 | 4.32 | 0.084 | 1176 | 5080 | 1925 | 8316 |
| 28 | .... | .... | .... | .... | .... | .... |
| | 91.79 | | 1483 | 136129 | 2226 | 204361 |

* Average velocity of Nos. 25 and 27. Could not obtain reading on account of eddies.

Conditions: normal, fan on mine. Temperature, outside 57 deg. fahr. Temperature, inside 53½ deg. fahr.; humidity, outside 88 per cent, inside 100 per cent; barometer, 28.46, weight of inside air per cu. ft. 0.0732 lb., for Pitot tube $V = 4056 \sqrt{h}$.

Measurement made in airway leading to fan section was divided by strings into approximately equal parts. Section No. 28 was stopped up, as it was very small and at the bottom.

Readings taken by Pitot tube and anemometer held in center of each section by a stand. Readings taken for period of one minute in each position. Could get no reading by tube in section No. 26, evidently on account of eddy currents; velocity given is average of those in the two adjoining sections. Fan running exhausting. Airway makes a slight turn a short distance beyond the section, causing velocities to be higher on one side than on the other.

TABLE 7 DATA FOR FAN TEST NO. 10

No. 6 Works, United States Coal & Coke Company, February 18, 1911

| Section Number | Area, Sq. Ft. | Pitot Tube | | | Anemometer | |
|---|---|---|---|---|---|---|
| | | Reading, In. Water | Velocity, Ft. per Min. | Quantity, Cu. Ft. per Min. | Velocity, Ft. per Min. | Quantity, Cu. Ft. per Min. |
| 1 | 3.49 | 0.259 | 2064 | 7203 | 2940 | 10261 |
| 2 | 3.52 | 0.296 | 2207 | 7769 | 3082 | 10849 |
| 3 | 3.55 | 0.198 | 1805 | 6409 | 2684 | 9528 |
| 4 | 3.53 | 0.273 | 2119 | 7480 | 3160 | 11155 |
| 5 | 3.44 | 0.261 | 2072 | 7128 | 2680 | 9219 |
| 6 | 3.50 | 0.227 | 1932 | 6762 | 2580 | 9030 |
| 7 | 3.50 | 0.259 | 2064 | 7224 | 2635 | 9222 |
| 8 | 3.36 | 0.245 | 2008 | 6747 | 2745 | 9223 |
| 9 | 3.40 | 0.196 | 1796 | 6106 | 2330 | 7922 |
| 10 | 3.50 | 0.197 | 1800 | 6300 | 2465 | 8627 |
| 11 | 3.50 | 0.209 | 1854 | 6489 | 2450 | 8565 |
| 12 | 3.24 | 0.216 | 1885 | 6107 | 2490 | 8068 |
| 13 | 3.38 | 0.204 | 1832 | 6192 | 2705 | 9143 |
| 14 | 3.50 | 0.244 | 2004 | 7014 | 2765 | 9677 |
| 15 | 3.50 | 0.204 | 1832 | 6412 | 2490 | 8715 |
| 16 | 2.86 | 0.180 | 1721 | 4922 | 2355 | 6735 |
| 17 | 3.38 | 0.267 | 2096 | 7084 | 2660 | 8991 |
| 18 | 3.50 | 0.231 | 1949 | 6821 | 2565 | 8977 |
| 19 | 3.50 | 0.177 | 1706 | 5971 | 2430 | 8505 |
| 20 | 2.24 | 0.123 | 1422 | 3185 | 2343 | 5248 |
| 21 | 3.40 | 0.241 | 1991 | 6769 | 2629 | 8939 |
| 22 | 3.50 | 0.194 | 1786 | 6251 | 2455 | 8592 |
| 23 | 3.50 | 0.162 | 1633 | 5715 | 2400 | 8400 |
| 24 | 1.62 | 0.095 | 1250 | 2025 | 2110 | 3418 |
| 25 | 3.86 | 0.036 | 770 | 2972 | 2000 | 7720 |
| 26 | 4.20 | ..... | 1060 | 4452 | 1675 | 7035 |
| 27 | 4.32 | 0.111 | 1351 | 5836 | 2245 | 9698 |
| | 91.79 | | 1778 | 163345 | 2521 | 231462 |

Conditions: fan on mine-doors on main heading between 1st and 2d return and on 1st return open, allowing air to short circuit through mine. Temperature inside 53½ deg. fahr.; humidity inside 100 per cent; barometer 28.46; for Pitot tube $V = 4056\sqrt{h}$.

Same conditions of measurement as test No. 9.

TABLE 8 DATA FOR FAN TEST NO. 11

No. 6 Works, United States Coal & Coke Company, February 18, 1911

| Section Number | Area, Sq. Ft. | Pitot Tube | | | Anemometer | |
|---|---|---|---|---|---|---|
| | | Reading, In. Water | Velocity, Ft. per Min. | Quantity, Cu. Ft. per Min. | Velocity, Ft. per Min. | Quantity, Cu. Ft. per Min. |
| 1 | 4.0 | 0.752 | 3517 | 14068 | 5414 | 21656 |
| 2 | 4.0 | 0.757 | 3529 | 14116 | 3920 | 15680 |
| 3 | 4.0 | 0.755 | 3524 | 14096 | 3696 | 14784 |
| 4 | 4.0 | 0.761 | 3538 | 14152 | 4140 | 16560 |
| 5 | 4.0 | 0.754 | 3522 | 14088 | 3564 | 14256 |
| 6 | 4.0 | 0.709 | 3415 | 13660 | 3058 | 12232 |
| 7 | 4.0 | 0.709 | 3415 | 13660 | 3132 | 12528 |
| 8 | 4.0 | 0.737 | 3482 | 13928 | 3374 | 13496 |
| 9 | 4.0 | 0.746 | 3503 | 14012 | 3392 | 13568 |
| 10 | 4.0 | 0.344 | 2379 | 9516 | 2468 | 9872 |
| 11 | 4.0 | 0.292 | 2192 | 8768 | 2536 | 10144 |
| 12 | 4.0 | 0.618 | 3189 | 12756 | 3324 | 13296 |
| 13 | 4.0 | 0.474 | 2792 | 11168 | 2890 | 11560 |
| 14 | 4.0 | 0.169 | 1667 | 6668 | 2090 | 8360 |
| 15 | 4.0 | 0.189 | 1763 | 7052 | 2060 | 8240 |
| 16 | 4.0 | 0.404 | 2578 | 10312 | 2816 | 11264 |
| 17 | 4.0 | 0.125 | 1434 | 5736 | 1560 | 6240 |
| 18 | 4.0 | 0.072 | 1088 | 4352 | 1540 | 6160 |
| 19 | 4.0 | 0.128 | 1451 | 5804 | 1920 | 7680 |
| 20 | 4.0 | 0.244 | 2004 | 8016 | 2060 | 8240 |
| 21 | 4.0 | ..... | ..... | ..... | 476 | 1904 |
| 22 | 4.0 | ..... | ..... | ..... | 760 | 3040 |
| 23 | 4.0 | 0.134 | 1485 | 5940 | 1770 | 7080 |
| 24 | 4.0 | 0.114 | 1369 | 5476 | 1630 | 6520 |
| 25 | 4.0 | ..... | .... | ..... | 310 | 1240 |
| 26 | 4.0 | 0.027 | 666 | 2664 | 830 | 3320 |
| 27 | 4.0 | 0.214 | 1876 | 7504 | 1960 | 7840 |
| 28 | 4.0 | 0.104 | 1308 | 5232 | 1570 | 6280 |
| 29 | 4.0 | 0 069 | 1065 | 4260 | 1250 | 5000 |
| 30 | 4.0 | 0.225 | 1924 | 7696 | 2070 | 8280 |
| 31 | 4.0 | 0.346 | 2386 | 9544 | 2450 | 9800 |
| 32 | 4.0 | 0.208 | 1850 | 7400 | 2000 | 8000 |
| | 128.0 | | 2122 | 271644 | | 304120 |

**Conditions: doors to fan and doors inside mine all open, allowing all air possible to reach fan. Air measured at top of chimney. Temperature, 53½ deg. fahr.; humidity, 100 per cent; barometer, 28.46; for Pitot tube, $V = 4056 \sqrt{h}$.**

**Measurement made on top of chimney of fan. Area was divided by strings into 32 equal parts and readings were taken in center of each section for periods of 30 seconds. Both anemometer and tube were held in plane of top of chimney. Pitot tube readings could not be obtained in sections Nos. 21, 22 and 25, on account of eddies. These were very noticeable, as the anemometer in the same sections would stop, reverse itself, stop, run properly, etc.**

# TESTS OF LARGE BOILERS AT THE DETROIT EDISON COMPANY

By D. S. Jacobus

## ABSTRACT OF PAPER

The tests described in this paper were made on two boilers at the plant of the Detroit Edison Company. Each of the boilers has a rated capacity of 2365 h.p. on the basis of 10 sq. ft. of boiler heating surface per horsepower, and in every day practice carry a load of 6000 kw. and in the evening from 7000 to 8000 kw. The preliminary and regular tests required that the boiler room of a large power house be under the control of the observers for three months and for six weeks over 50 men worked in 8-hour shifts night and day, exclusively on the tests. The magnitude of the undertaking may be appreciated when attention is drawn to the total quantities measured, which aggregated about 5000 tons of coal weighed and 45,000 tons of water.

One of the boilers tested was fitted with Roney stokers and the other with Taylor stokers. The test results secured indicated that the efficiency obtainable with each stoker is about the same. The combined efficiency of the boiler and furnace varied from about 80 per cent at slightly below rating to about 76 per cent at double rating, on the basis of 10 sq. ft. of boiler heating surface per rated horsepower. In obtaining these efficiencies the steam used for driving the stokers and for producing the forced blast in the Taylor stokers has not been deducted from the total steam generated by the boiler. The amount of steam used by the Roney stokers was about 1½ per cent of the total steam generated by the boilers, and for the Taylor stokers about 2½ to 3 per cent.

# TESTS OF LARGE BOILERS AT THE DETROIT EDISON COMPANY

By D. S. Jacobus, New York

Member of the Society

Many engineers have held the opinion that eventually much larger steam boilers will be used than those in service. The size of turbo-electric generating sets has increased by rapid strides and it might seem that an increase in the size of boilers would naturally follow. There has been a strong feeling, however, that it would be unwise to employ very large boiler units, as a failure of one of the large units would throw out of use a much greater proportion of power than the failure of a smaller unit.

2 Each of the boilers described in this paper is required, in the all-day practice of the power plant, to carry a load of 6000 kw. and in the evening to carry 7000 or 8000 kw. The experience in regular service of 18 months with the first boiler and of nine months with the second and third boilers has proven this to be good practice. The rated capacity of each boiler is 2365 h.p. on the basis of 10 sq. ft. of boiler heating surface per horsepower. Fourth and fifth boilers are now being erected and it is expected to complete the installation of ten boilers of this size within the next two years.

3 The engineering world is greatly indebted to the Detroit Edison Company and to Alex Dow, the general manager of that company, member of this Society, for pioneer work in installing boilers of two or three times the capacity of the largest boilers heretofore used, and for the opportunity of conducting the most elaborate and painstaking series of tests ever made on a boiler. The preliminary and regular tests required that the boiler room of a large power house be under the control of the observers for nearly three months, and for six weeks over 50 men worked in eight-hour shifts, night and day, exclusively on the tests. All the water and coal was accurately weighed, and much work was done about the plant to avoid the possi-

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bility of leakage affecting the results. The magnitude of the undertaking may be appreciated when attention is drawn to the total quantities measured, which were as high as an average per hour of eight tons of coal, 75 tons of feedwater and one ton of ashes, the totals amounting to about 5000 tons of coal weighed and 45,000 tons of water.

4 The tests were run under the direct supervision of the writer, assisted by men chosen from the engineering staff of The Babcock & Wilcox Company. In addition to the men furnished by the Detroit Edison Company, The Solvay Process Company provided a number of observers. Their experimental engineer, Lewis C. Rogers, coöperated in securing the results and rendered most valuable assistance. Westinghouse, Church, Kerr & Company coöperated in designing apparatus and in making arrangements for the tests and was represented in the tests. The Solvay Process Company made heat determinations and analyses of the coal used in each test, and of the ashes. Duplicate samples were taken and the work was done a second time in the laboratory of The Babcock & Wilcox Company. The average of the results secured by the two laboratories was used in working up the tests. The tanks for weighing the water had each a capacity of 20,000 lb. Three such tanks and scales were provided, two being used regularly and the third held for a spare in case any irregularity developed in either of the other two. The coal was weighed by means of four special scales carrying overhead hoppers, each of about 2500 lb. capacity. The coal was conducted from the regular chutes into the hoppers, which were provided with hinged bottoms held in place by latches.

5 Two series of tests were made, one on a boiler fitted with Roney stokers, the other on a boiler fitted with Taylor stokers. Front and side views of the former are shown in Figs. 1 and 2. Fig. 3 shows a side view of the boiler fitted with Taylor stokers. Four Roney stokers were used in the furnace, two being at the front and two at the rear of the boiler. There was a low division wall between the stokers, and between the two sets of stokers a bridge wall. The Taylor stokers had 13 retorts on the front side and 13 on the rear, or 26 in all. The retorts on each side were set in a continuous row so as to provide an unbroken fire surface from one side of the boiler to the other. There was no bridge wall between the stokers, and when the dumping plates at the rear of each of the Taylor stokers were covered with fuel there was a continuous fuel bed beneath the entire boiler. The width of the furnace from one side to the other of the boiler was about 26½

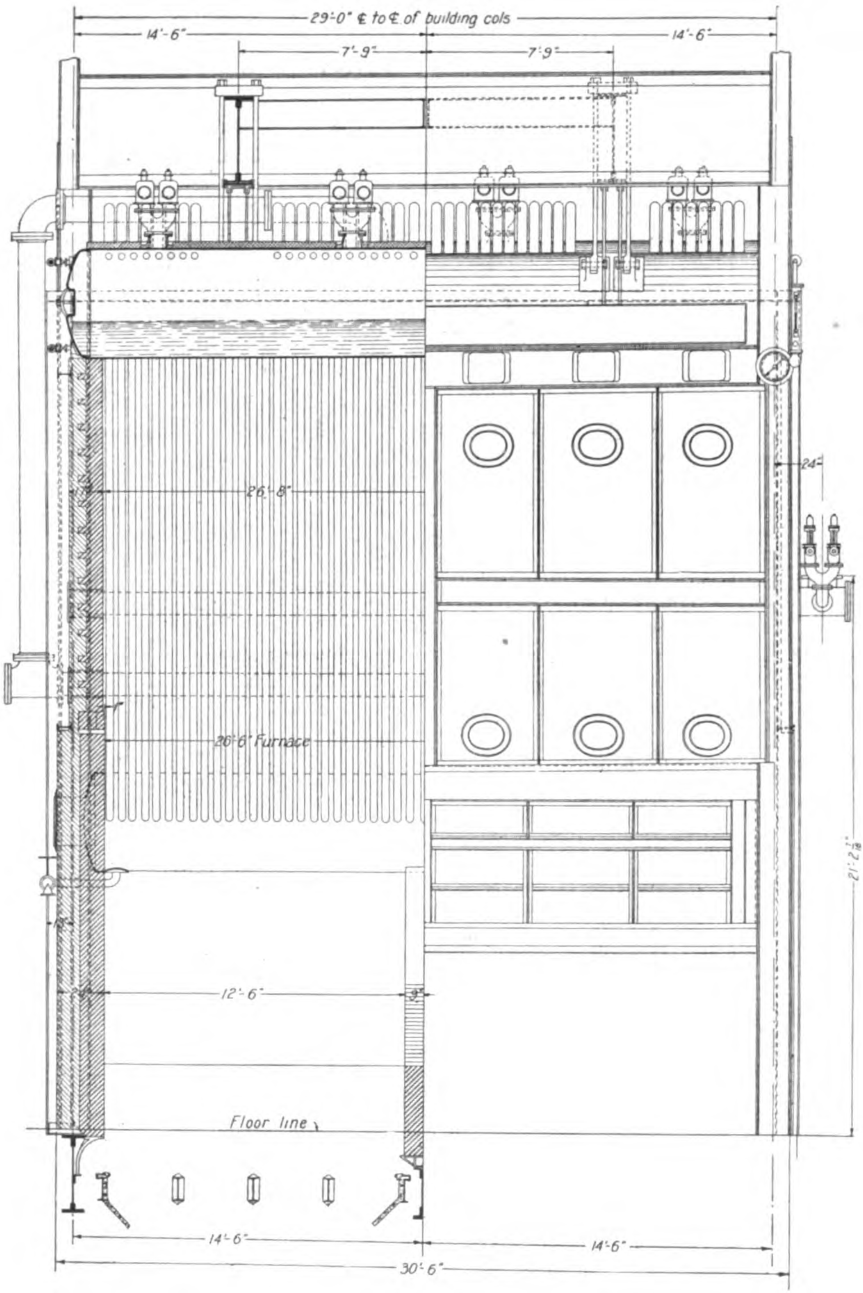


**Fig. 1 Front and Half-Section of Boiler of 2365 Rated Horsepower, Fitted with Roney Stoker**

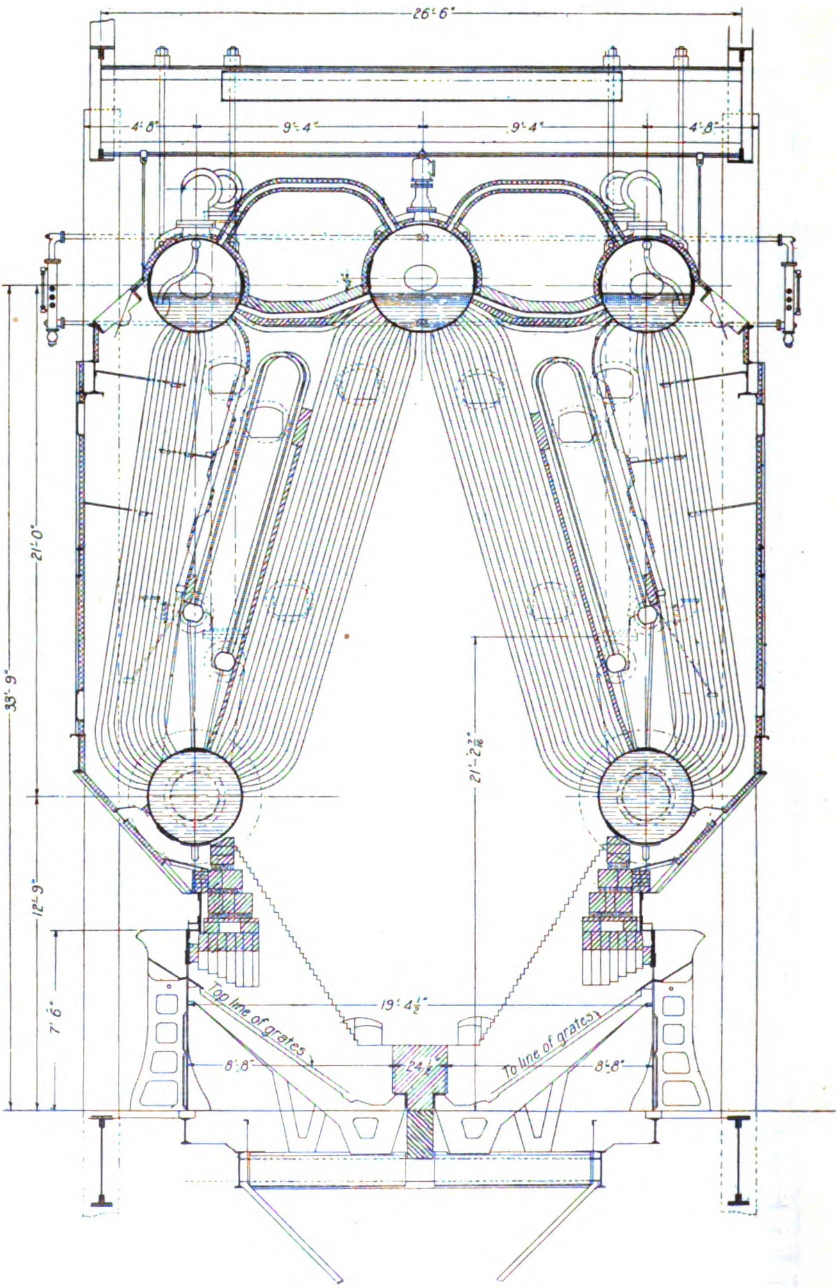


Fig. 2 Longitudinal Section of Boiler Fitted with Roney Stoker

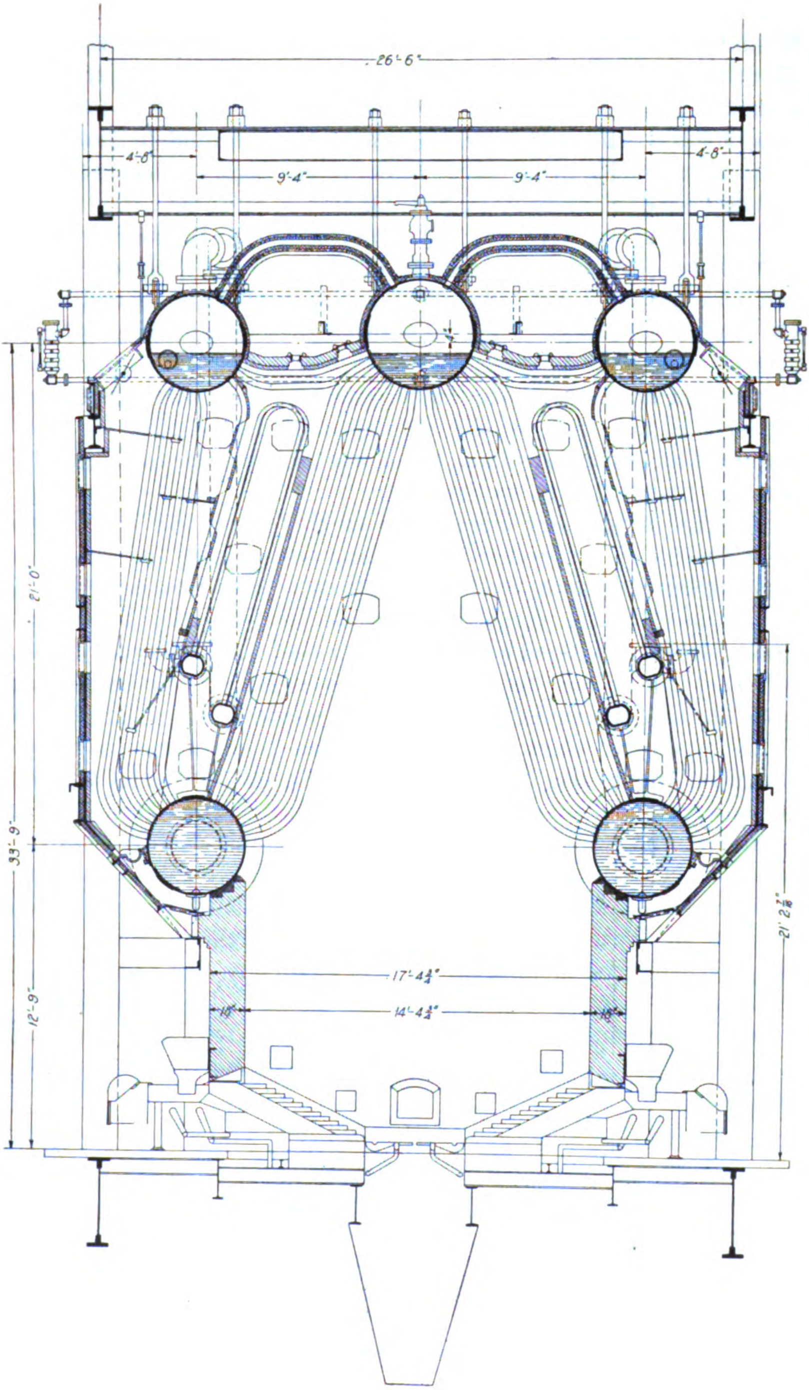


FIG. 3 LONGITUDINAL SECTION OF BOILER FITTED WITH TAYLOR STOKER

ft., and the depth of the furnace from the front to the rear of the boiler about 14 ft. The height of the furnace, measured above the dumping grates to the top of the first baffle, was about 29 ft. The large furnace volume combined with the particular form and height of the furnace had much to do with obtaining the high efficiencies. This will be treated more fully in Par. 13.

6 The boilers were built by The Babcock & Wilcox Company. Each boiler contained 23,654 sq. ft. of effective boiler heating surface and was provided with superheaters for supplying approximately 150 deg. of superheat. The grate surface, measured from the beginning to the rear of the dumping grates was 446 sq. ft. for the Roney stokers and 405 sq. ft. for the Taylor stokers. This method of measurement is not that usually employed in determining the grate surface of an underfeed stoker, but it was used in order to obtain comparative figures for the two stokers.

7 The design and installation of the plant and the general arrangement of the boilers and piping were under the charge of Westinghouse, Church, Kerr & Company. This firm designed the arrangement of the furnace brickwork for both the Taylor and Roney stokers; supervised the construction and followed up and corrected the minor defects which developed. Their engineering work in this connection involved the solution, on a large scale, of the problems which have always been troublesome to furnace designers, and it also involved the working out of special methods of construction demanded by the exceptionally high furnace temperatures. The ability of Westinghouse, Church, Kerr & Company to meet and dispose of the furnace and stoker problems which were anticipated and which arose was an important factor in determining both the makers and the users of boilers to undertake the new departure. Westinghouse, Church, Kerr & Company also coöperated in working out many of the construction details. This work and the general arrangement of the apparatus for the tests was under the charge of Henry O. Pond, to whom the author is indebted for valuable assistance.

8 In the development of the large units at Detroit, Mr. Dow expected an increase in economy due to minimizing the radiation losses, and to the high temperature obtainable in the large furnaces and combustion chamber. He also expected a reduction in the first cost, not on account of a reduced cost per unit of boiler surface, but to a less cost of the settings, floor space, suspension structures, valves and piping. Troubles through brickwork were anticipated and there were troubles which, in the main, have been overcome.

9 Another most important feature that had to be considered with so large a boiler unit was the possibility of tube troubles. In dealing with this point Mr. Dow inferred that their experience at the plant with the feedwater used in connection with boilers of a similar general type, warranted the conclusion that they should have practically no trouble with the tubes. This has been borne out by the experience with the boilers in actual service.

10 Mr. Dow credits his friend, Mr. W. H. Patchell, for the first idea of the possibilities of large boilers. The boilers and settings at Detroit have no similarity to those installed by Mr. Patchell, but Mr. Dow says that to him is due the first conception of the economical possi-

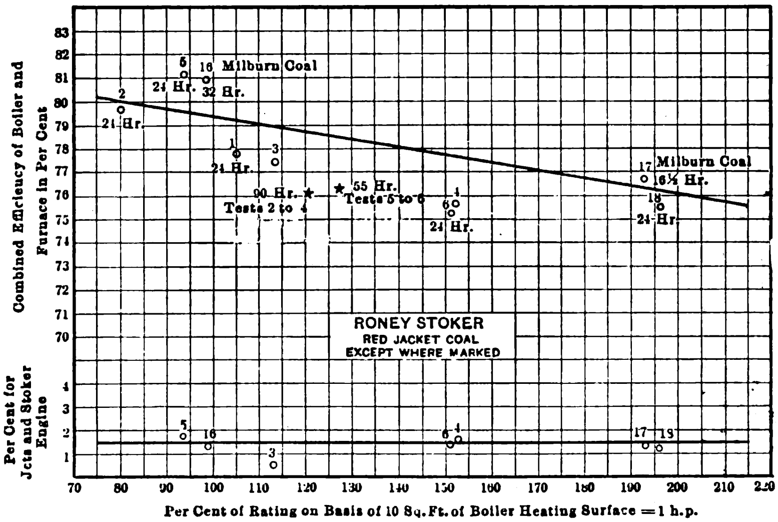


FIG. 4 RESULTS OF TESTS OF BOILER WITH RONEY STOKER

bilities of the large units and the capacity obtainable through utilizing the whole floor area for the furnace.

11 A résumé of the results obtained is given in Tables 1 and 2 in the Appendix. Table 1 contains the results of tests of the boiler run with Roney stokers, and Table 2 of a boiler run with Taylor stokers. Figs. 4 and 5 show the results of these tests graphically.

12 It will be seen on examining the tables and figures that the combined efficiency of the boiler and furnace varies from about 80 per cent at slightly below rating, to about 76 per cent at double rating. In obtaining these efficiencies, the steam used for driving the stokers and for producing the forced blast for the Taylor stokers

has not been deducted from the total steam generated by the boiler. The amount of steam used by the Roney stokers was about 1½ per cent of the total steam generated by the boiler, and for the Taylor stokers about 2½ to 3 per cent. The effect that this steam would have on the plant economy depends on the ability to utilize the same for heating the feedwater. In a plant where the heat in the steam exhausted from the auxiliaries is returned to the feedwater there would be but little loss. In the case of the Taylor stokers all of the exhaust steam from the turbines driving the forced-blast fans may be carried to the feedwater heater, whereas with the Roney stokers only about ⅓ of 1 per cent of the 1½ per cent used may be so returned, since the

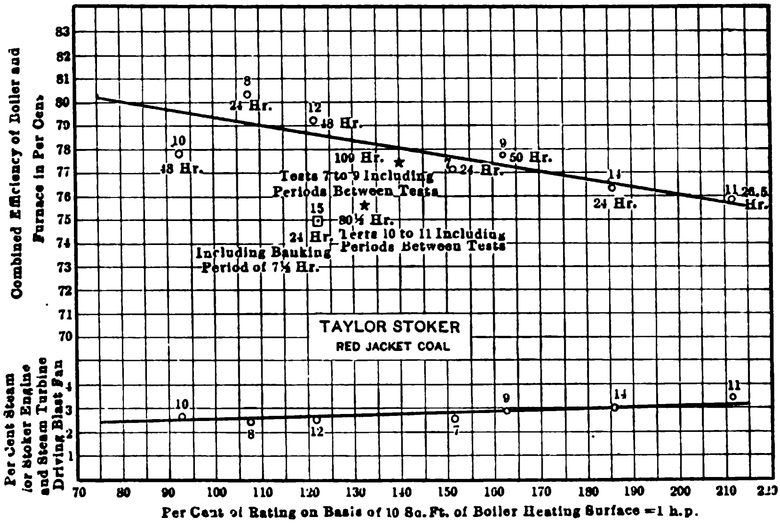


FIG. 5 RESULTS OF TESTS OF BOILER WITH TAYLOR STOKER

greater part of the steam is used in the jets which supply steam beneath the ignition arches of the stokers, and passes away with the chimney products. In a plant in which the auxiliaries are electrically driven, any power to operate the forced-blast apparatus would be a direct loss and, assuming in the case of the Taylor stoker that the steam consumption corresponding to the current required to drive the electrical auxiliaries is one-half of that found in the tests, the steam required to operate each of the stokers would be about the same. It therefore follows that the effect of the steam for driving the stokers on the station economy cannot be generalized, but that each plant must be considered by itself.

13 The efficiencies secured are exceptionally high, and the question may be asked whether this is due entirely to the large size of the boiler units. A careful study of the test data shows that the efficiencies were obtained with the most economical furnace conditions and that the thoroughness with which the fuel was consumed in the furnace had much to do with the attainment of the high figures. On examining Figs. 1, 2 and 3, showing the general arrangement of the boilers and settings, it will be seen that the roof of the furnace has an *A* shape, and that the coal is fired at the front and rear of the boiler setting. With this arrangement, the character of the combustion may be maintained constant from one side of the boiler to the other, and the loss so often experienced through a stream or lane of excess air or unconsumed combustible gases passing through the boiler and escaping to the stacks will be avoided. Those conversant with the subject know that in ordinary boiler furnaces there is a great variation in analyses taken from different points in the path of the flue gases leaving the furnace, whereas with the present furnace arrangement this action is reduced to a minimum, as any irregularity from the front to the rear of the grates disappears before the gases pass from the upper part of the combustion chamber, and as the composition of the gases for uniform firing conditions will be uniform from one side of the boiler to the other, or from right to left in Fig. 1, it follows that the composition of the entire volume of the gases leaving the furnace will be substantially uniform.

14 A straight reference line is drawn in Figs. 4 and 5 in order that the results obtained by the two stokers may be readily compared, this line being the same on both diagrams. It will be noted that the test results fall on both sides of the line, and that the efficiency obtainable with each stoker is about the same. Naturally a curve should be used instead of a straight line to show the variation in the efficiency, but the accidental variation in the test results is such that it would be impossible to trace an exact curve.

15 On examining Fig. 4, it will be seen that the efficiencies, where several tests are worked out together, including the periods between the tests, are only about 1½ per cent lower than would be indicated by averaging the results for the separate tests by passing a straight line between the points. The same follows for the tests which are worked up together for the Taylor stoker. This shows that including the periods between the tests, during which the dust was blown from the exterior of the tubes and the firing was not watched as carefully as it was during the tests, did not greatly lower the efficiency.

It was proposed at first to run a test of a week or more on each of the stokers, but this plan was abandoned, since there was trouble through leakage in the feed pump which made it necessary to shut down, and on reconsidering the matter it was deemed advisable to give up running as long a test as this since it developed that a week would be too long a period to run without blowing down the boilers. Test No. 15, with the Taylor stoker, included a banking period of 7½ hours. It will be noted that the efficiency including the banking period is about 75 per cent. The capacity of the boiler for each hour of this test is shown in Fig. 6.

16 It will be seen (Figs. 4 and 5) that the average amount of steam used for driving the Roney stoker was about 1½ per cent at all loads, and that it varied from about 2½ per cent at rating to about 3 per cent double rating for the Taylor stoker. Saturated steam

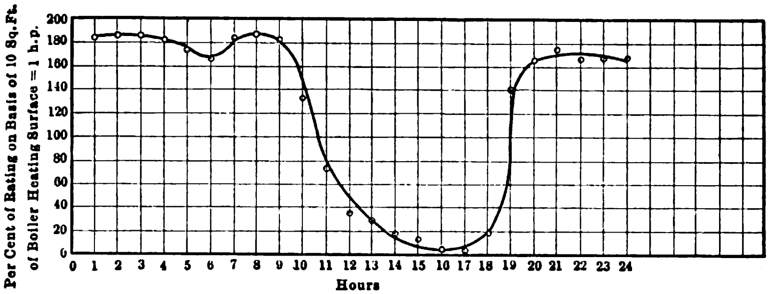


FIG. 6 CAPACITY OF BOILER WITH TAYLOR STOKER FOR EACH HOUR OF A TEST WHERE THE FIRES WERE BANKED FOR 7½ HOURS

from another boiler was used for driving the auxiliaries. The saturated steam was reduced to its equivalent weight of superheated steam in determining the percentages above given.

17 The minimum length of a regular test was 24 hours. The efficiency for a test of 16½ hours is plotted in one diagram. In this particular test a special coal was used which ran out and thus brought the test to a close. Some of the tests were of 48 hours' duration and over. A continuous record was kept and, as stated in Par. 15, the efficiency was determined for periods embracing several of the tests including the intervals between them. Intervals were selected from some of the tests and were worked up to obtain comparative results. Figures derived in this way are given in Table 3, and it will be noted that there is a substantial agreement between the results secured in the regular tests and the results for the selected intervals. It must not be inferred from this that sufficient accuracy would

be secured by shortening the length of the tests. The tests reported in this paper were made after a painstaking series of preliminary tests with both of the stokers, and the operators were well trained in maintaining uniform conditions. Twenty-four hours is none too long an interval for obtaining accurate results with an underfeed stoker of the class tested, as one can readily appreciate when the fact is called to his attention that the generation of steam will continue after no more coal is fed to the furnace with but little difference in the appearance of the fire. There is no method whereby the fire can be measured except by sizing it up by the eye, as one must form an estimate of the amount of clinker present. One of the operators at the plant was earnest in his opinion that the fires as balanced up by the author for the Taylor stoker contained from 2½ to 5 tons more coal at the end of a test than at the beginning, a contention that was shown beyond doubt to be in error by the heat balances. This goes to show how far the estimates of the amount of coal may affect the results and that consequently there is great danger of obtaining erroneous figures in short tests. That an error in estimating the fire may cause a considerable error in a short test is exemplified in test No. 13 where, on account of a leakage at the feed pump, it was necessary to shut down after running 11½ hr. The author was not present to make the final coal balance, and it will be noted that the efficiency is several per cent higher than it should be on the basis of the more accurate tests, and, further, that the efficiency secured would not have the proper margin for radiation, etc., in a heat balance. Where the fire may be kept in a comparatively uniform condition, as in the Roney stoker, it might seem that the tests could be shortened, but even in such cases the author is in favor of making 24-hour tests.

18 Great care was taken to prevent the possibility of leakage affecting the tests. All fittings where there might be leakage were either blanked off or two valves were provided with an open drip between them. The boilers were tested with hydraulic pressure both before and after the tests. Special leakage tests were also made in which the hot boilers were completely filled with water and the full pressure maintained on the boilers and feed mains, and in each case there was no leakage indicated in tests of several hours' duration.

19 Tables 4 and 5 give the average analyses of the flue gases. It will be seen that the furnace efficiency was exceptionally high for both of the stokers.

20 Tables 6 and 7 give the analyses of the coal and the heats of

combustion as determined in the laboratories of The Solvay Process Company and The Babcock & Wilcox Company, as well as the average figures used in computing the results of the tests.

21 Table 8 gives a comparison of the results secured for the heat of combustion of the coal as determined in The Solvay Process Company laboratory and in the laboratory of The Babcock & Wilcox Company. In this table the values are worked out per pound of

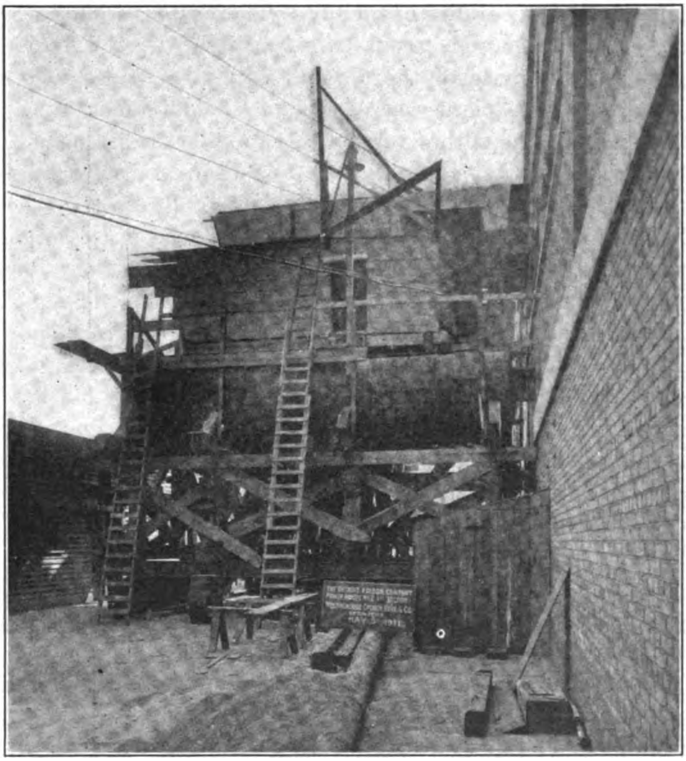

Fig. 7 Special Apparatus for Weighing Feedwater

combustible, the percentage of ash in each case being that determined by the individual laboratory. The heat of combustion per pound of combustible, computed from the results of the ultimate analyses made by the two laboratories, is given, and it may be seen that the figures obtained by the oxygen-bomb calorimeter correspond very closely with the computed ones. The coal samples were obtained by taking a small amount of coal each time it was weighed and placing it in a covered air-tight receptacle. Smaller samples for the two laboratories were obtained independently from the large sample of coal collected during the test and the results of the two laboratories were therefore influenced by any variation in the smaller samples.

22 Tables 9 to 11, inclusive, contain the average test data and computed results for the tests with the Roney stoker, and Tables 12 to 14, inclusive, the average test data and computed results for the tests with the Taylor stoker.

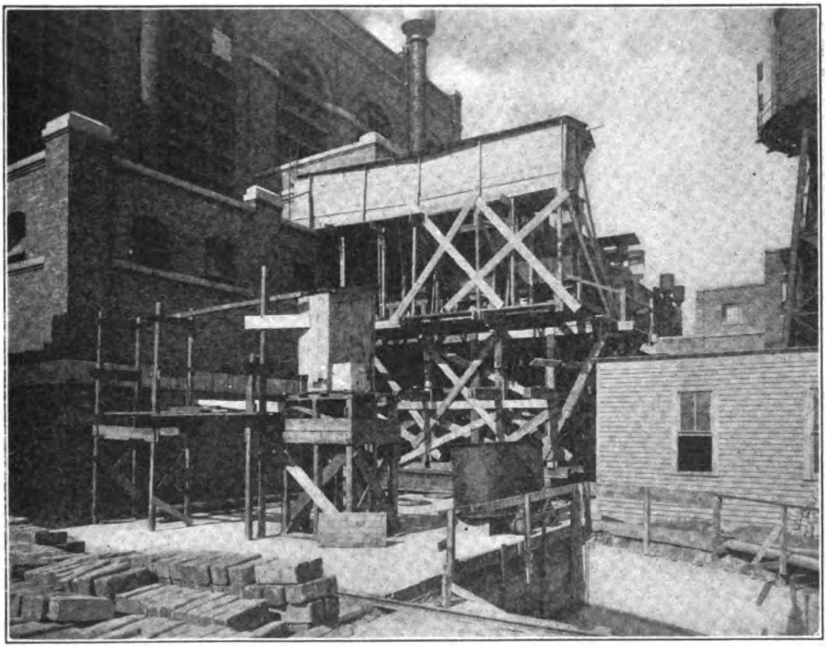

Fig. 8 Special Apparatus for Weighing Feedwater

23 Tables 15 and 16 give the results of heat balances. Two sets of heat balances were made, one applying to the gases after they left the boiler dampers, and the other to the gases at the top of the second pass directly beneath the boiler dampers. The analyses of the gases after leaving the boiler dampers were made with an Orsat apparatus, the samples of gas being obtained from the middle points of the flues. The temperature of the gases directly beneath the boiler dampers at the top of the second pass was determined by means of electrical couples, two sets being used at each side of the boiler.

The analyses of the flue gases at this point were made by a Hempel apparatus, an average sample being obtained by drawing the gas from six points at the front and six points at the rear of the boiler. The gas was drawn through the collecting piping with an aspirator, and a sample of the mixed gases was drawn into a collecting bottle for analysis. In order to make sure that the same weight of gas entered each of the six sampling tubes, a throttling cock was adjusted to make the suction on each tube a given amount, as indicated by a

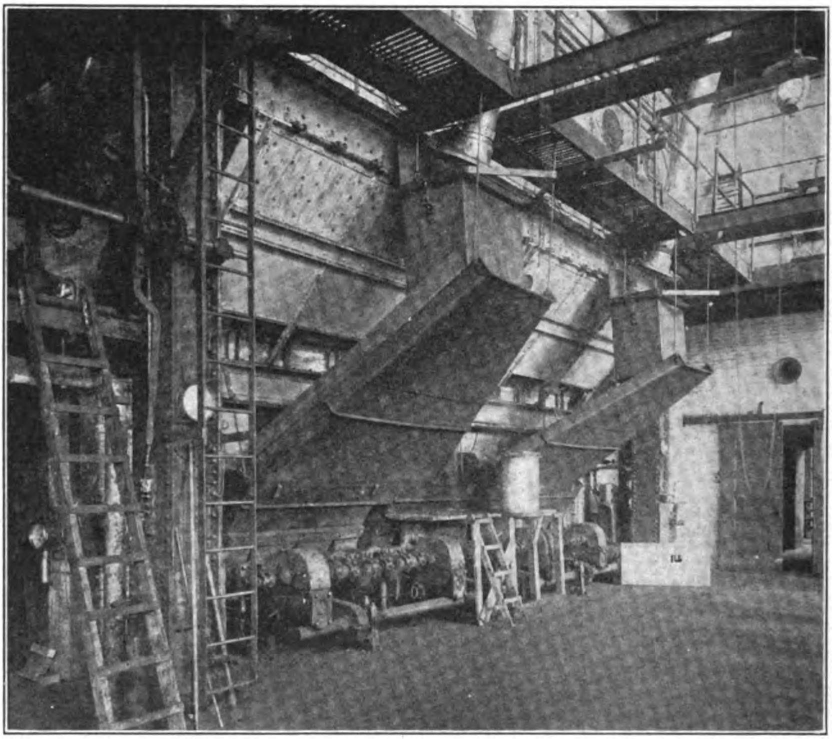

Fig. 9 Special Hoppers and Coal-Weighing Scales

water gage. The Hempel apparatus was also used in the way just described for analyzing the gases at the bottom of the second pass. The apparatus for obtaining the average samples was constructed by The Solvay Process Company.

24 The results of the heat balances show that the average radiation and unaccounted-for losses are only about 2½ to 3 per cent. There is naturally a variation one way or the other due to accidental

errors, but the results are as uniform as could be expected in work of the sort.

25 Preliminary tests were first made on the boiler with the Taylor stoker. The apparatus was then shifted and preliminary tests were made on the boiler with the Roney stoker. A careful study of the operating conditions for the best economy was made in the preliminary tests. The results of the regular tests only are given in this paper.

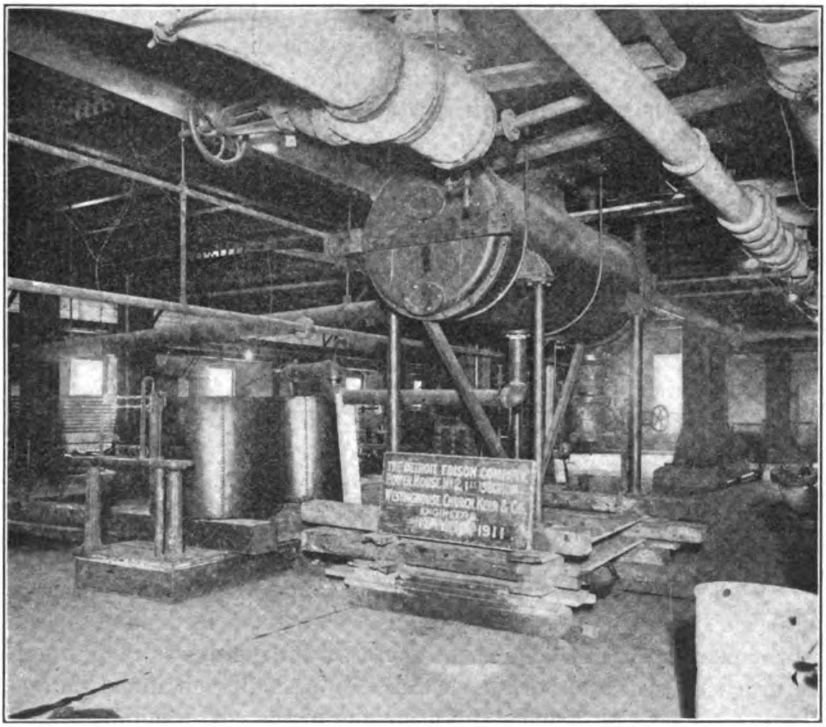


FIG. 10 SPECIAL CONDENSER AND WEIGHING APPARATUS FOR DETERMINING QUANTITY OF STEAM USED BY STOKER AUXILIARIES

26 Readings of temperatures, pressures, etc., were taken every half hour. The water was balanced each hour. The coal weighed per hour and supplied to the hoppers was balanced each hour and recorded, but no attempt was made to obtain a correct coal balance except at the beginning and ending of the tests, as this necessitated running the coal quite low in the hoppers of the stokers. As soon as

the data were taken, a copy was made on a large sheet in the boiler room, so that those conducting the tests could, at a glance, note whether the conditions were uniform. Marks and Davis steam tables were used in working up the results.

27 Two views of the special apparatus erected for weighing the feed water are shown in Figs. 7 and 8. Water from the heater was elevated by means of a centrifugal pump specifically provided for the purpose and discharged into tanks supported on special platform scales. Two of these tanks appear in Fig. 8, the third being in the shadow of the building. The men weighing the water were protected from the weather by a rough housing placed above the level of the tanks, the scale beams being inside this housing. The water from the tanks ran into two lower horizontal tanks, one of which is plainly visible in Fig. 7. The lower tanks were provided

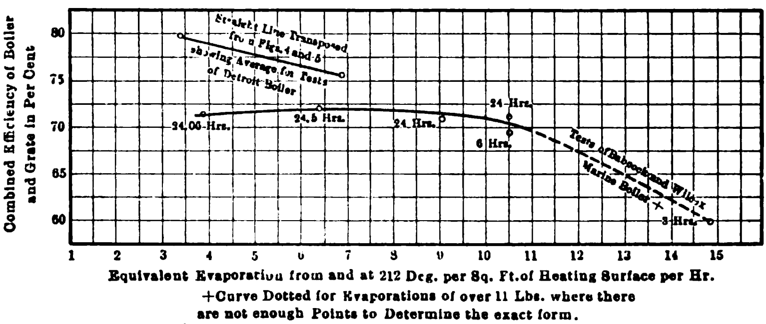


FIG. 11 COMPARISON OF RESULTS WITH THOSE FROM A B. & W. MARINE BOILER

with gage glasses and the water was brought to an accurate level every hour. The water from the lower tanks was pumped directly into the boilers by one of the regular centrifugal feed pumps used at the plant. Any leakage in the glands of the pump was caught and returned to the large horizontal tanks by a small centrifugal pump. Two of the special hoppers and a portion of the coal-weighing scales are shown in Fig. 9. Fig. 10 shows a special condenser and weighing apparatus erected for determining the amount of steam used by the stoker auxiliaries. All scales were accurately calibrated to their full capacity before and after the tests of each of the boilers by means of standard weights.

28 In order to compare the results with others where high efficiencies have been secured, Fig. 11 is presented. In this figure the straight line shown in Figs. 4 and 5 is transferred and marked, Average for Tests of Detroit Boiler. The plotted results for individual tests

shown in Fig. 7, are for tests made by a Board of United States Naval Officers on a hand-fired Babcock & Wilcox marine boiler and reported in the Journal of the American Society of Naval Engineers, November 1910. By combining the results secured with the two boilers it will be seen that the efficiency varies from about 80 per cent at an evaporation of 3 lb. per sq. ft. of heating surface per hour from and at 212 deg. fahr. to 76 per cent at 7 lb., 72 per cent at 10 lb. and 60 per cent at 14.7 lb. It therefore follows that if the performance of the two boilers could be combined, a boiler could be run from about 80 per cent of the ordinary rating to over four times this rating, and for most classes of central power-plant service it would be possible to run all of the boilers in the plant all of the time, thus eliminating the loss occasioned through having to carry a number of boilers under banked fires. The writer is now working on the development of a boiler of this sort.

# APPENDIX

## TABLES GIVING DATA AND RESULTS OF TESTS

### TABLE 1 TESTS WITH RONEY STOKER. RÉSUMÉ OF PRINCIPAL RESULTS

| No. of Test | Length, Hr. | Per Cent Rating | B.t.u. in Coal | Per Cent Ash in Dry Coal | Efficiency | Per Cent Steam used by Stoker Engines and Steam Jets | Per Cent Combustible in Ash | Temp. of Flue Gases Leaving Boiler, Deg. Fahr. |
|---|---|---|---|---|---|---|---|---|
| 1 | 25 | 105.0 | 14362 | 5.98 | 77.84 | .... | 19.6 | 576 |
| 2 | 24 | 80.0 | 14225 | 6.52 | 79.88 | .... | 17.9 | 480 |
| 3 | 24 | 113.8 | 14308 | 7.40 | 77.45 | 0.63 | 24.4 | 542 |
| 4 | 30 | 152.4 | 13756 | 6.54 | 75.78 | 1.58 | 30.8 | 670 |
| 5 | 24 | 94.0 | 13896 | 6.89 | 81.15 | 1.75 | 31.6 | 483 |
| 6 | 24 | 150.7 | 14037 | 6.13 | 75.28 | 1.45 | 26.7 | 662 |
| 16 | 32 | 98.6 | 14476 | 9.68 | 80.98 | 1.34 | 34.1 | 460 |
| 17 | 16.5 | 193.3 | 14493 | 8.24 | 76.73 | 1.39 | 24.6 | 636 |
| 18 | 24 | 195.7 | 13689 | 9.81 | 75.57 | 1.32 | 23.2 | 694 |
| 2–4† | 90 | 119.8 | 14098 | 6.81 | 76.13 | .... | 25.8 | 572 |
| 5–6† | 55 | 127.3 | 13977 | 6.84 | 76.23 | .... | 29.4 | 575 |

† Including periods between tests.

### TABLE 2 TESTS WITH TAYLOR STOKER. RÉSUMÉ OF PRINCIPAL RESULTS

| No. of Test | Length, Hr. | Per Cent Rating | B.t.u. in Coal | Per Cent Ash in Dry Coal | Efficiency | Per Cent Steam used by Stoker Auxiliaries* | Per Cent Combustible in Ash | Temp. of Flue Gases Leaving Boiler, Deg. Fahr. |
|---|---|---|---|---|---|---|---|---|
| 7 | 24 | 151.2 | 14000 | 7.03 | 77.07 | 2.61 | 31.5 | 575 |
| 8 | 24 | 107.9 | 13965 | 6.34 | 80.28 | 2.44 | 27.1 | 493 |
| 9 | 50 | 162.8 | 13998 | 6.75 | 77.85 | 2.87 | 31.3 | 574 |
| 10 | 48 | 92.9 | 14188 | 9.90 | 77.90 | 2.63 | 27.2 | 487 |
| 11 | 26.5 | 211.3 | 14061 | 9.55 | 75.84 | 3.41 | 36.1 | 651 |
| 12 | 48 | 121.3 | 14010 | 8.09 | 79.24 | 2.57 | 27.6 | 535 |
| 14 | 24 | 185.2 | 14272 | 8.71 | 76.42 | 2.95 | 28.8 | 647 |
| 15† | 24 | 123.1 | 14213 | 8.34 | 74.90 | 2.77 | 30.1 | 561 |
| 7–9‡ | 109 | 140.0 | 13983 | 7.22 | 77.66 | 2.68 | 29.9 | 545 |
| 10–11‡ | 80.5 | 132.8 | 14095 | 9.58 | 75.66 | 3.04 | 31.1 | 542 |

* Engines driving stokers and steam turbine driving fan.
† In test No. 15 the fires were banked for 7½ hr. and the averages include this period.
‡ Including periods between tests.

## TABLE 3 TESTS WITH TAYLOR STOKER

RESULTS OF REGULAR TESTS COMPARED WITH RESULTS FOR INTERVALS, SELECTED FROM THE REGULAR TESTS, AND RESULTS FOR A SHORT TEST WHERE THE COAL ON GRATES WAS NOT ACCURATELY BALANCED

| Test No. | Date of Trial and Time | Length, Hr. | Per Cent Rating | B.t.u. in Coal | Per Cent Ash in Dry Coal | Efficiency | Per Cent Steam used by Stoker Auxiliaries | Per Cent Combustible in Ash | Temp. of Flue Gases leaving Boiler, Deg. Fahr. |
|---|---|---|---|---|---|---|---|---|---|
| 10A | 6–8, 1 p.m. to 6–9, 1 p.m. | 24 | 94.4 | 14250 | 9.84 | 77.63 | 2.64 | 26.9 | 489 |
| 10 | 6–7, 4 p.m. to 6–9, 4 p.m. | 48 | 92.9 | 14188 | 9.90 | 77.90 | 2.63 | 27.2 | 487 |
| 11A | 6-10, 10.30 a.m. to 10.30 p.m. | 12 | 214.8 | 14049 | 10.48 | 76.18 | 3.66 | 36.1 | 668 |
| 11 | 6–9, 10 p.m. to 6–11, 12.30 a.m. | 26.5 | 211.3 | 14061 | 9.55 | 75.84 | 3.41 | 36.1 | 651 |
| 12A | 6-12, 3 p.m. to 6-13, 3 p.m. | 24 | 117.0 | 14027 | 7.73 | 79.21 | 2.52 | 29.7 | 514 |
| 12B | 6–13, 3 p.m. to 6–14, 3 p.m. | 24 | 125.5 | 13994 | 8.45 | 79.19 | 2.62 | 25.4 | 555 |
| 12 | 6-12, 3 p.m. to 6–14, 3 p.m. | 48 | 121.3 | 14010 | 8.09 | 79.24 | 2.57 | 27.6 | 535 |
| 13 | 6–14, 9 p.m. to 6–15, 8.30 a.m. | 11.5 | 203.2 | 14056 | 8.11 | 79.6† | 3.29 | 35.3 | 641 |

† Efficiency inaccurate on account of error in estimating the amount of coal on the grate at the end of the test.

## TABLE 4 FLUE GAS ANALYSES—RONEY STOKER

| No. of Test | Bottom of Last Pass | | | Top of Last Pass | | | In Flue | | |
|---|---|---|---|---|---|---|---|---|---|
| | $CO_2$ | O | CO | $CO_2$ | O | CO | $CO_2$ | O | CO |
| 1 | 13.22 | 5.29 | 0.00 | 12.41 | 6.48 | 0.00 | 11.95 | 7.55 | 0.05 |
| 2 | 15.18 | 3.00 | 0.06 | 14.31 | 4.01 | 0.07 | 14.33 | 4.54 | 0.11 |
| 3 | 14.50 | 3.50 | 0.09 | 12.25 | 6.12 | 0.02 | 13.05 | 6.46 | 0.18 |
| 4 | 14.45 | 3.44 | 0.35 | 13.51 | 4.68 | 0.20 | 14.74 | 3.96 | 0.54 |
| 5 | 15.65 | 2.27 | 0.25 | 14.68 | 3.40 | 0.20 | 14.40 | 4.54 | 0.35 |
| 6 | 14.77 | 3.23 | 0.20 | 14.28 | 3.87 | 0.15 | 14.66 | 4.23 | 0.31 |
| 16 | 13.82 | 4.88 | 0.00 | 13.82 | 4.88 | 0.00 | 13.55 | 5.92 | 0.07 |
| 17 | 14.25 | 4.06 | 0.40 | 13.98 | 4.48 | 0.25 | 14.69 | 4.55 | 0.20 |
| 18 | ..... | .... | .... | ..... | .... | .... | 14.16 | 5.04 | 0.16 |

## TABLE 5 FLUE GAS ANALYSES—TAYLOR STOKER

| No. of Test | Bottom of Last Pass | | | Top of Last Pass | | | In Flue | | |
|---|---|---|---|---|---|---|---|---|---|
| | $CO_2$ | O | CO | $CO_2$ | O | CO | $CO_2$ | O | CO |
| 7 | 15.46 | 2.83 | 0.08 | 12.16 | 6.64 | 0.00 | 14.00 | 5.50 | 0.42 |
| 8 | 15.04 | 3.35 | 0.02 | 12.74 | 5.83 | 0.01 | 13.69 | 5.82 | 0.10 |
| 9 | 15.84 | 2.40 | 0.03 | 13.88 | 4.62 | 0.02 | 14.74 | 4.57 | 0.12 |
| 10A | 13.40 | 5.38 | 0.00 | 12.09 | 6.79 | 0.00 | 12.05 | 7.74 | 0.06 |
| 10 | 13.14 | 5.59 | 0.00 | 11.91 | 6.96 | 0.00 | 11.86 | 7.96 | 0.06 |
| 11A | 16.50 | 1.55 | 0.24 | 15.18 | 3.01 | 0.17 | 15.39 | 3.98 | 0.13 |
| 11 | 15.25 | 2.92 | 0.25 | 14.62 | 3.30 | 0.21 | 15.45 | 3.86 | 0.17 |
| 12A | 14.85 | 3.61 | 0.00 | 13.30 | 5.30 | 0.00 | 13.73 | 5.81 | 0.04 |
| 12B | 14.80 | 3.59 | 0.00 | 13.27 | 5.41 | 0.00 | 13.86 | 5.64 | 0.04 |
| 12 | 14.83 | 3.59 | 0.00 | 13.28 | 5.35 | 0.00 | 13.79 | 5.73 | 0.04 |
| 13 | 15.43 | 2.96 | 0.09 | 13.85 | 4.65 | 0.37 | 15.17 | 3.90 | 0.19 |
| 14 | 15 07 | 3.33 | 0.17 | 12.90 | 5.67 | 0.06 | 14.20 | 5.08 | 0.08 |
| 15 | 11.70 | 7.16 | 0.12 | 10.35 | 8.79 | 0.01 | 10.83 | 8.93 | 0.09 |

TABLE 6 RONEY STOKER. COAL AND ASH ANALYSES, PERCENTAGES BY WEIGHT

| No. of Test | | Proximate Analysis of Coal: Fixed Carbon | Volatile Matter | Moisture | Ash | B.t.u. in Coal | Combustible in Ash | Moisture in Ash | Ultimate Analysis of Dry Coal: C | H | O | N | S | Ash |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1* | S | 59.50 | 35.24 | 1.82 | 5.26 | 14369 | 18.04 | 23.37 | 80.35 | 5.22 | 7.03 | 0.96 | 0.88 | 5.56 |
| | B | 63.69 | 31.15 | 2.17 | 5.16 | 14354 | 21.27 | 24.39 | 78.67 | 6.15 | 7.76 | 1.20 | 1.06 | 5.16 |
| | A | 61.59 | 33.19 | 2.00 | 5.22 | 14362 | 19.65 | 23.88 | 79.51 | 5.69 | 7.39 | 1.08 | 0.97 | 5.36 |
| 2 | S | 59.44 | 34.08 | 1.30 | 6.48 | 14225 | 15.56 | 24.37 | 79.45 | 5.15 | 6.36 | 1.06 | 1.08 | 6.90 |
| | B | 63.55 | 30.31 | 2.36 | 6.14 | 14224 | 20.23 | 23.93 | 77.69 | 6.04 | 7.67 | 1.17 | 1.29 | 6.14 |
| | A | 61.49 | 32.19 | 1.83 | 6.32 | 14225 | 17.90 | 24.15 | 78.57 | 5.60 | 7.02 | 1.11 | 1.18 | 6.52 |
| 3 | S | 59.31 | 34.95 | 1.58 | 5.74 | 14400 | 29.72 | 21.96 | 80.73 | 5.30 | 5.56 | 1.06 | 1.00 | 6.35 |
| | B | 61.01 | 32.78 | 1.83 | 6.21 | 14215 | 19.18 | 20.56 | 76.80 | 6.10 | 8.61 | 1.19 | 1.09 | 6.21 |
| | A | 60.16 | 33.86 | 1.71 | 5.98 | 14308 | 24.45 | 21.26 | 78.76 | 5.70 | 7.09 | 1.13 | 1.04 | 6.28 |
| 4 | S | 58.01 | 33.98 | 1.94 | 8.01 | 13529 | 32.84 | 22.44 | 77.21 | 4.89 | 7.02 | 1.15 | 0.94 | 8.79 |
| | B | 62.89 | 31.13 | 1.66 | 5.98 | 13984 | 28.76 | 23.46 | 76.42 | 5.67 | 9.80 | 1.04 | 1.09 | 5.98 |
| | A | 60.45 | 32.56 | 1.80 | 6.99 | 13756 | 30.80 | 22.95 | 76.81 | 5.28 | 8.41 | 1.10 | 1.02 | 7.38 |
| 5 | S | 58.56 | 34.83 | 1.52 | 6.61 | 13747 | 28.63 | 23.23 | 79.14 | 4.72 | 6.51 | 1.13 | 1.42 | 7.08 |
| | B | 62.73 | 32.23 | 2.08 | 5.04 | 14045 | 34.50 | 26.86 | 74.74 | 5.98 | 9.92 | 1.09 | 1.34 | 6.93 |
| | A | 60.65 | 33.53 | 1.80 | 5.82 | 13896 | 31.57 | 25.05 | 76.94 | 5.35 | 8.22 | 1.11 | 1.38 | 7.00 |
| 6 | S | 60.02 | 33.40 | 2.35 | 6.58 | 13572 | 24.94 | 23.04 | 79.14 | 4.85 | 6.65 | 1.15 | 1.18 | 7.03 |
| | B | 62.17 | 33.23 | 2.09 | 4.60 | 14501 | 28.54 | 23.65 | 79.68 | 6.34 | 7.62 | 1.22 | 1.11 | 4.03 |
| | A | 61.10 | 33.31 | 2.22 | 5.59 | 14037 | 26.74 | 23.34 | 79.41 | 5.60 | 7.14 | 1.18 | 1.14 | 5.53 |
| 16 | S | 63.57 | 27.81 | 2.78 | 8.62 | 14155 | 38.82 | 15.79 | 79.95 | 5.31 | 4.36 | 1.25 | 0.64 | 8.49 |
| | B | 66.94 | 27.84 | 2.47 | 5.22 | 14797 | 29.33 | ...... | 78.86 | 5.72 | 8.36 | 1.04 | 0.80 | 5.22 |
| | A | 65.25 | 27.83 | 2.62 | 6.92 | 14476 | 34.08 | 15.79 | 79.41 | 5.51 | 6.36 | 1.15 | 0.72 | 6.85 |
| 17 | S | 63.29 | 28.76 | 2.28 | 7.95 | 14265 | 28.25 | 16.67 | 80.98 | 5.37 | 3.49 | 1.27 | 0.61 | 8.28 |
| | B | 66.49 | 27.70 | 2.62 | 5.81 | 14721 | 20.96 | 12.08 | 81.25 | 5.65 | 5.27 | 1.10 | 0.92 | 5.81 |
| | A | 64.89 | 28.23 | 2.45 | 6.88 | 14493 | 24.61 | 14.38 | 81.12 | 5.51 | 4.38 | 1.18 | 0.77 | 7.04 |
| 18 | S | 57.36 | 31.63 | 2.06 | 11.01 | 13385 | 25.29 | 17.33 | 75.74 | 5.09 | 5.27 | 1.12 | 1.17 | 11.61 |
| | B | 62.30 | 29.75 | 2.28 | 7.95 | 13993 | 21.08 | 14.68 | 77.44 | 5.43 | 7.18 | 0.99 | 1.01 | 7.95 |
| | A | 59.83 | 30.69 | 2.17 | 9.48 | 13689 | 23.19 | 16.01 | 76.59 | 5.26 | 6.22 | 1.06 | 1.09 | 9.78 |
| 2–4† | S | 58.81 | 34.38 | 1.61 | 6.81 | 14042 | 27.04 | 22.80 | ...... | ...... | ...... | ...... | ...... | ...... |
| | B | 62.18 | 31.53 | 1.90 | 6.29 | 14155 | 24.54 | 22.92 | ...... | ...... | ...... | ...... | ...... | ...... |
| | A | 60.50 | 32.95 | 1.75 | 6.55 | 14098 | 25.79 | 22.86 | ...... | ...... | ...... | ...... | ...... | ...... |
| 5-6† | S | 59.14 | 34.22 | 1.95 | 6.64 | 13677 | 27.32 | 23.18 | ...... | ...... | ...... | ...... | ...... | ...... |
| | B | 62.35 | 32.77 | 2.08 | 4.88 | 14277 | 31.52 | 23.00 | ...... | ...... | ...... | ...... | ...... | ...... |
| | A | 60.74 | 33.50 | 2.01 | 5.76 | 13977 | 29.42 | 23.09 | ...... | ...... | ...... | ...... | ...... | ...... |

* *S*, Determined by The Solvay Process Co.; *B*, Determined by The Babcock & Wilcox Co.; *A*, Average used in working up results.

† Includes periods between tests and figures are based on analyses of all of the coal used.

TABLE 7 TAYLOR STOKER. COAL AND ASH ANALYSES, PERCENTAGES BY WEIGHT

| No. of Test | | Proximate analysis of Coal | | | | B.t.u. in Coal | Combustible in Ash | Moisture in Ash | Ultimate Analysis of Dry Coal | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Fixed Carbon | Volatile Matter | Moisture | Ash | | | | C | H | O | N | S | Ash |
| 7* | S | 60.27 | 34.88 | 1.70 | 4.85 | 14240 | 31.54 | 22.12 | 79.90 | 5.06 | 7.71 | 1.16 | 1.03 | 5.14 |
| | B | 62.09 | 31.35 | 2.13 | 6.56 | 13759 | ..... | ..... | 76.95 | 6.06 | 8.79 | 1.02 | 0.97 | 6.21 |
| | A | 61.18 | 33.11 | 1.91 | 5.71 | 14000 | 31.54 | 22.12 | 78.42 | 5.56 | 8.25 | 1.09 | 1.00 | 5.68 |
| 8 | S | 59.63 | 33.76 | 1.78 | 6.61 | 14009 | 27.07 | 49.36 | 78.91 | 5.13 | 6.87 | 1.05 | 1.15 | 6.89 |
| | B | 63.64 | 31.15 | 2.04 | 5.21 | 13920 | ..... | ..... | 75.48 | 5.52 | 11.24 | 1.18 | 1.37 | 5.21 |
| | A | 61.63 | 32.46 | 1.91 | 5.91 | 13965 | 27.07 | 49.36 | 77.19 | 5.33 | 9.05 | 1.12 | 1.26 | 6.05 |
| 9 | S | 58.34 | 33.29 | 2.12 | 8.37 | 13769 | 35.46 | 40.79 | 78.25 | 4.80 | 6.33 | 0.99 | 1.22 | 8.41 |
| | B | 61.25 | 32.63 | 2.13 | 6.12 | 14227 | 27.16 | 32.00 | 77.04 | 5.64 | 9.14 | 1.12 | 0.93 | 6.13 |
| | A | 59.80 | 32.96 | 2.12 | 7.24 | 13998 | 31.31 | 36.40 | 77.64 | 5.22 | 7.74 | 1.05 | 1.08 | 7.27 |
| 10A | S | 59.95 | 33.54 | 1.71 | 6.51 | 13892 | 28.83 | 18.61 | ..... | ..... | ..... | ..... | ..... | ..... |
| | B | 60.32 | 33.92 | 2.10 | 5.76 | 14607 | 24.90 | 20.75 | ..... | ..... | ..... | ..... | ..... | ..... |
| | A | 60.14 | 33.73 | 1.90 | 6.13 | 14250 | 26.87 | 19.68 | ..... | ..... | ..... | ..... | ..... | ..... |
| 10 | S | 58.98 | 34.17 | 1.92 | 6.85 | 13876 | 29.07 | 19.51 | 79.28 | 5.14 | 6.27 | 1.19 | 1.11 | 7.01 |
| | B | 60.26 | 33.97 | 2.20 | 5.77 | 14500 | 25.42 | 20.42 | 78.76 | 5.85 | 7.57 | 1.13 | 0.92 | 5.77 |
| | A | 59.62 | 34.07 | 2.06 | 6.31 | 14188 | 27.25 | 19.97 | 79.02 | 5.50 | 6.92 | 1.16 | 1.01 | 6.39 |
| 11A | S | 57.79 | 35.39 | 1.76 | 6.82 | 13862 | 37.63 | 18.58 | ..... | ..... | ..... | ..... | ..... | ..... |
| | B | 60.32 | 33.75 | 2.04 | 5.93 | 14235 | 34.62 | 18.76 | ..... | ..... | ..... | ..... | ..... | ..... |
| | A | 59.06 | 34.57 | 1.90 | 6.37 | 14049 | 36.13 | 18.67 | ..... | ..... | ..... | ..... | ..... | ..... |
| 11 | S | 58.80 | 34.49 | 1.70 | 6.71 | 13889 | 37.63 | 18.58 | 79.89 | 4.86 | 6.36 | 1.18 | 0.90 | 6.81 |
| | B | 62.36 | 32.47 | 2.10 | 5.17 | 14232 | 34.62 | 18.76 | 77.44 | 5.80 | 9.30 | 1.13 | 1.06 | 5.27 |
| | A | 60.58 | 33.48 | 1.90 | 5.94 | 14061 | 36.13 | 18.67 | 78.66 | 5.33 | 7.83 | 1.16 | 0.98 | 6.04 |
| 12A | S | 57.59 | 33.38 | 1.90 | 9.03 | 13585 | 31.62 | 15.77 | ..... | ..... | ..... | ..... | ..... | ..... |
| | B | 62.10 | 32.32 | 2.07 | 5.58 | 14469 | 27.76 | 28.20 | ..... | ..... | ..... | ..... | ..... | ..... |
| | A | 59.84 | 32.85 | 1.98 | 7.31 | 14027 | 29.69 | 21.99 | ..... | ..... | ..... | ..... | ..... | ..... |
| 12B | S | 60.05 | 33.74 | 1.76 | 6.21 | 13996 | 28.26 | 15.43 | ..... | ..... | ..... | ..... | ..... | ..... |
| | B | 63.62 | 31.37 | 2.06 | 5.01 | 13991 | 22.54 | 16.16 | ..... | ..... | ..... | ..... | ..... | ..... |
| | A | 61.84 | 32.55 | 1.91 | 5.61 | 13994 | 25.40 | 15.80 | ..... | ..... | ..... | ..... | ..... | ..... |
| 12 | S | 58.82 | 33.56 | 1.83 | 7.62 | 13790 | 29.94 | 15.60 | 78.89 | 5.10 | 5.83 | 1.30 | 1.13 | 7.75 |
| | B | 62.86 | 31.84 | 2.06 | 5.30 | 14230 | 25.15 | 22.18 | 76.00 | 5.81 | 10.79 | 1.06 | 1.05 | 5.29 |
| | A | 60.84 | 32.70 | 1.95 | 6.46 | 14010 | 27.55 | 18.90 | 77.44 | 5.46 | 8.31 | 1.18 | 1.09 | 6.52 |
| 13 | S | 60.18 | 33.16 | 1.79 | 6.66 | 14141 | 41.61 | 16.00 | ..... | ..... | ..... | ..... | ..... | ..... |
| | B | 62.89 | 31.92 | 2.06 | 5.19 | 13970 | 29.10 | 16.30 | ..... | ..... | ..... | ..... | ..... | ..... |
| | A | 61.54 | 32.54 | 1.92 | 5.92 | 14056 | 35.35 | 16.15 | ..... | ..... | ..... | ..... | ..... | ..... |
| 14 | S | 59.82 | 34.34 | 2.00 | 5.84 | 14111 | 32.75 | 13.70 | 80.73 | 5.10 | 6.03 | 1.27 | 1.01 | 5.86 |
| | B | 63.24 | 32.09 | 1.80 | 4.67 | 14433 | 24.92 | 14.71 | 76.80 | 5.71 | 10.14 | 1.02 | 1.01 | 5.32 |
| | A | 61.53 | 33.21 | 1.90 | 5.26 | 14272 | 28.84 | 14.21 | 78.77 | 5.41 | 8.08 | 1.14 | 1.01 | 5.59 |
| 15 | S | 61.30 | 33.24 | 1.97 | 5.46 | 14231 | 32.27 | 23.08 | ..... | ..... | ..... | ..... | ..... | ..... |
| | B | 62.99 | 31.75 | 2.38 | 5.26 | 14194 | 28.77 | 19.88 | ..... | ..... | ..... | ..... | ..... | ..... |
| | A | 62.14 | 32.50 | 2.18 | 5.36 | 14213 | 30.52 | 21.48 | ..... | ..... | ..... | ..... | ..... | ..... |
| 7-9† | S | 59.18 | 33.65 | 1.95 | 7.17 | 13900 | 32.12 | 36.72 | ..... | ..... | ..... | ..... | ..... | ..... |
| | B | 61.70 | 32.19 | 2.11 | 6.11 | 14067 | 27.82 | 29.11 | ..... | ..... | ..... | ..... | ..... | ..... |
| | A | 60.44 | 32.92 | 2.03 | 6.64 | 13983 | 29.97 | 32.91 | ..... | ..... | ..... | ..... | ..... | ..... |
| 10-11† | S | 58.82 | 34.12 | 1.90 | 7.06 | 13830 | 32.65 | 19.17 | ..... | ..... | ..... | ..... | ..... | ..... |
| | B | 61.07 | 33.19 | 2.20 | 5.74 | 14361 | 29.49 | 19.92 | ..... | ..... | ..... | ..... | ..... | ..... |
| | A | 59.95 | 33.65 | 2.05 | 6.40 | 14095 | 31.07 | 19.54 | ..... | ..... | ..... | ..... | ..... | ..... |

* *S* Determined by The Solvay Process Co.; *B*, Determined by The Babcock & Wilcox Co.; *A*, Average used in working up results.

† Includes periods between tests and figures are based on the analyses of all of the coal used.

TABLE 8 COMPARISON OF THE HEATS OF COMBUSTION OF THE COAL DETERMINED BY THE SOLVAY PROCESS COMPANY AND THE BABCOCK & WILCOX COMPANY

| Test No. | B.t.u. per Lb. of Dry Coal* | | Ash in Coal by Proximate Analysis | | B.t.u. per Lb. of Combustible | | B.t.u. per Lb. of Combustible from Ultimate Anal.† | |
|---|---|---|---|---|---|---|---|---|
| | Solvay | B.&W. | Solvay | B.&W. | Solvay | B.&W. | Solvay | B.&W. |
| 1 | 14369 | 14354 | 5.26 | 5.16 | 15167 | 15135 | 15308 | 15542 |
| 2 | 14225 | 14224 | 6.48 | 6.14 | 15211 | 15154 | 15413 | 15497 |
| 3 | 14400 | 14215 | 5.74 | 6.21 | 15277 | 15156 | 15677 | 15322 |
| 4 | 13529 | 13984 | 8.01 | 5.98 | 14707 | 14873 | 15125 | 14844 |
| 5 | 13747 | 14045 | 6.61 | 5.04 | 14720 | 14790 | 15103 | 14939 |
| 6 | 13572 | 14501 | 6.58 | 4.60 | 14528 | 15200 | 15159 | 15648 |
| 7 | 14240 | 13759 | 4.85 | 6.56 | 14966 | 14725 | 15021 | 15291 |
| 8 | 14009 | 13920 | 6.61 | 5.21 | 15000 | 14685 | 15266 | 14381 |
| 9 | 13769 | 14227 | 8.37 | 6.12 | 15027 | 15154 | 15233 | 14988 |
| 10 | 13876 | 14500 | 6.85 | 5.77 | 14896 | 15388 | 15400 | 15463 |
| 11 | 13889 | 14232 | 6.71 | 5.17 | 14888 | 15008 | 15257 | 15011 |
| 12 | 13790 | 14230 | 7.62 | 5.30 | 14927 | 15026 | 15472 | 14682 |
| 14 | 14111 | 14433 | 5.84 | 4.67 | 14986 | 15140 | 15427 | 14793 |
| 16 | 14155 | 14797 | 8.62 | 5.22 | 15490 | 15612 | 16007 | 15240 |
| 17 | 14265 | 14721 | 7.95 | 5.81 | 15497 | 15629 | 16244 | 15910 |
| 18 | 13385 | 13993 | 11.01 | 7.95 | 15041 | 15202 | 15663 | 15378 |
| Gen. Avg. | 13960 | 14259 | 7.07 | 5.68 | 15020 | 15117 | 15423 | 15183 |

* Secured with an oxygen bomb calorimeter.

† From formula B.t.u. = $14600\,C + 62000\,(H - \frac{O}{8}) + 4000\,S$

TABLE 9 RONEY STOKER TEST DATA

| Test No. | Date of Trial | Duration of Trial, Hr. | Steam Pressure by Gage, Lb. per Sq. In. | | | Barometric Pressure, In. Mercury at Temp. of Boiler Room | Average Draft, In. of Water | | | Temperature, Deg. Fahr. | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | In Boiler | Entering Superheater | Leaving Superheater | | Below the Two Dampers | In Furnace | In Ash Pit | Fire Room | Saturated Steam Corresponding to Outlet, Gage Pressure | Superheated Steam | Superheated Steam at Outlet Y | Superheat | Feed Water Entering Boiler | Gases Leaving Boiler | Gases Entering Rear Bank of Tubes | Gases below Damper |
| 1 | 5-17-18-11 | 25 | 195 | 193.5 | 190 | 29.26 | 0.42 | 0.32 | 0.16 | 82 | 383.7 | 519 | 515 | 135.3 | 184 | 576 | 903 | 602 |
| 2 | 5-18-19-11 | 24 | 192 | 190.2 | 188 | 29.17 | 0.05 | 0.16 | 0.06 | 81 | 382.8 | 498 | 497 | 115.2 | 180 | 480 | 851 | 479 |
| 3 | 5-20-21-11 | 24 | 198 | 196.1 | 192 | 29.23 | 0.51 | 0.39 | 0.21 | 80 | 384.5 | 515 | 516 | 130.5 | 184 | 542 | 992 | 565 |
| 4 | 5-21-22-11 | 30 | 201 | 199.0 | 192 | 29.39 | 0.55 | 0.22 | 0.02 | 81 | 384.6 | 521 | 520 | 136.4 | 181 | 670 | 1064 | 709 |
| 5 | 5-24-25-11 | 24 | 199 | .... | 187 | 29.45 | 0.16 | 0.24 | 0.10 | 73 | 382.5 | 490 | 491 | 107.5 | 183 | 483 | 847 | 501 |
| 6 | 5-25-26-11 | 24 | 200 | 197.8 | 191 | 29.37 | 0.57 | 0.26 | 0.16 | 79 | 384.2 | 521 | 515 | 136.8 | 185 | 662 | 1085 | 668 |
| 16 | 6-18-19-11 | 32 | 193 | 191.4 | 188 | 29.37 | 0.17 | 0.23 | 0.12 | 79 | 382.9 | 485 | 482 | 102.1 | 177 | 460 | 678 | 467 |
| 17 | 6 - 20 - 11 | 16.5 | 207 | 205.5 | 194 | 29.39 | 0.95 | 0.34 | 0.06 | 79 | 385.4 | 518 | 521 | 132.6 | 179 | 636 | 927 | 622 |
| 18 | 6-20-21-11 | 24 | 207 | 205.2 | 194 | 29.48 | 1.11 | 0.33 | 0.05 | 73 | 385.4 | 543 | 540 | 157.6 | 178 | 694 | 1029 | 709 |
| 2-4† | 5-18-22-11 | 90 | 199 | 195.7 | 191 | 29.27 | 0.38 | 0.28 | 0.06 | 81 | 384.1 | 515 | 514 | 130.9 | 182 | 572 | .... | ... |
| 5-6† | 5-24-26-11 | 55 | 209 | 195.9 | 189 | 29.40 | 0.38 | 0.25 | 0.05 | 76 | 383.3 | 509 | 503 | 125.7 | 183 | 575 | .... | ... |

† Includes periods between tests.

TABLE 10 RONEY STOKER. TEST DATA AND RESULTS

| Test No. | Relative Humidity of Atmosphere, Per Cent | Feed Water, Lb. per Hr. | Moist Coal, Lb. per Hr. | Dry Coal, Lb. per Hr. | Dry Coal, Lb. per Hr. per Sq. Ft. of Grate | Ash (Wet), Lb. per Hr. | Ash (Dry), Lb. per Hr. | Per Cent Ash based on Dry Coal | Steam used by Stoker Engines, Lb. per Hr: Saturated Steam | Steam used by Stoker Engines: Equivalent in Superheated Steam | Steam used by Stoker Engines: Per Cent of Total Steam | Steam Used by Jets, Lb. per Hr.: Saturated Steam | Steam Used by Jets: Equivalent in Superheated Steam | Steam Used by Jets: Per Cent of Total Steam |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 60.3 | 74208 | 7615 | 7463 | 16.73 | 586 | 446 | 5.98 | 123 | 114 | 0.15 | ...... | ...... | ...... |
| 2 | 64.8 | 57036 | 5714 | 5609 | 12.58 | 483 | 366 | 6.52 | 112 | 105 | 0.18 | ...... | ...... | ...... |
| 3 | 66.7 | 80318 | 8271 | 8130 | 18.23 | 764 | 602 | 7.40 | 141 | 131 | 0.16 | 400 | 373 | 0.47 |
| 4 | 64.5 | 107056 | 11794 | 11582 | 25.97 | 982 | 757 | 6.54 | 173 | 161 | 0.15 | 1650 | 1534 | 1.43 |
| 5 | 62.4 | 67099 | 6727 | 6606 | 14.81 | 607 | 455 | 6.89 | 136 | 128 | 0.19 | 1110 | 1045 | 1.56 |
| 6 | 66.5 | 106196 | 11551 | 11295 | 25.32 | 903 | 692 | 6.13 | 127 | 118 | 0.11 | 1530 | 1420 | 1.34 |
| 16 | 51.6 | 70148 | 6845 | 6665 | 14.92 | 736 | 620 | 9.30 | 136 | 128 | 0.18 | 860 | 813 | 1.16 |
| 17 | 54.4 | 135676 | 14107 | 13761 | 30.85 | 1325 | 1134 | 8.24 | 220 | 205 | 0.15 | 1800 | 1675 | 1.24 |
| 18 | 55.2 | 135770 | 15319 | 14987 | 33.60 | 1750 | 1470 | 9.81 | 195 | 179 | 0.13 | 1750 | 1614 | 1.19 |
| 2–4 | 66.0 | 84401 | 8991 | 8834 | 19.81 | 781 | 602 | 6.81 | 133 | 124 | 0.15 | .... | .... | .... |
| 5–6 | 63.9 | 90039 | 9653 | 9459 | 21.21 | 841 | 647 | 6.84 | 132 | 123 | 0.14 | .... | .... | .... |

TABLE 11 RONEY STOKER. COMPUTED RESULTS

| Test No. | Factor of Evaporation | Equivalent Water Evaporated into Dry Steam from and at 212 Deg. Fahr., Lb. per Hr. | Equivalent Evaporation from and at 212 Deg. Fahr. per Lb. of Dry Coal | Equivalent Water per Hr. from and at 212 Deg. Fahr. per Sq. Ft. of Boiler Heating Surface | Horsepower Developed | Per cent of Rated h.p. Developed on Basis of 10 Sq. Ft. of Boiler Heating Surface per h.p. | Combined Efficiency of Boiler and Furnace |
|---|---|---|---|---|---|---|---|
| 1 | 1.1582 | 85948 | 11.52 | 3.63 | 2491 | 105.0 | 77.84 |
| 2 | 1.1514 | 65671 | 11.71 | 2.78 | 1903 | 80.0 | 79.88 |
| 3 | 1.1559 | 92840 | 11.42 | 3.92 | 2691 | 113.8 | 77.45 |
| 4 | 1.1621 | 124410 | 10.74 | 5.26 | 3606 | 152.4 | 75.78 |
| 5 | 1.1441 | 76768 | 11.62 | 3.24 | 2225 | 94.0 | 81.15 |
| 6 | 1.1581 | 122984 | 10.89 | 5.20 | 3565 | 150.7 | 75.28 |
| 16 | 1.1476 | 80502 | 12.08 | 3.40 | 2333 | 98.6 | 80.98 |
| 17 | 1.1625 | 157722 | 11.46 | 6.67 | 4572 | 193.3 | 76.73 |
| 18 | 1.1766 | 159747 | 10.66 | 6.75 | 4630 | 195.7 | 75.57 |
| 2–4 | 1.1581 | 97745 | 11.06 | 4.13 | 2833 | 119.8 | 76.13 |
| 5–6 | 1.1540 | 103905 | 10.98 | 4.39 | 3012 | 127.3 | 76.23 |

TABLE 12 TAYLOR STOKER. TEST DATA

| Test No. | Date of Trial | Duration of Trial, Hr. | Steam Pressure by Gage, Lb. per Sq. In. | | | Barometric Pressure, In. Mercury at Temp. of Boiler Room | Average Draft, In. of Water | | | Temperature Deg. Fahr. | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | In Boiler | Entering Superheater | Leaving Superheater | | Air Blast in Tuyeres | Suction below Boiler Dampers | Suction in Ash Pit | Fire Room | Saturated Steam Corresponding to Outlet Gage Pressure | Superheated Steam | Superheated Steam at Outlet Y | Superheat | Feed Water Entering Boiler | Gases Leaving Boiler | Gases Entering Rear Bank of Tubes | Gases below Damper |
| 7 | 6- 2- 3-11 | 24 | 205 | 202.6 | 193 | 29.45 | 1.30 | 0.58 | 0.03 | 73 | 384.9 | 540 | 535 | 155.1 | 187 | 575 | 959 | 539 |
| 8 | 6- 3- 4-11 | 24 | 200 | 197 0 | 192 | 29.46 | 0.76 | 0.20 | 0.11 | 70 | 384 6 | 513 | 505 | 128.4 | 181 | 493 | 748 | 466 |
| 9 | 6- 5- 7-11 | 50 | 206 | 202.7 | 192 | 29.31 | 1.73 | 0.53 | 0.06 | 69 | 384.6 | 541 | 538 | 156.4 | 184 | 574 | 934 | 549 |
| 10*A* | 6- 8- 9-11 | 24 | 197 | 195.0 | 191 | 29.50 | 0.65 | 0.20 | 0.15 | 73 | 384.2 | 517 | 513 | 132.8 | 188 | 489 | 732 | 465 |
| 10 | 6- 7- 9-11 | 48 | 195 | 193.5 | 190 | 29.50 | 0.67 | 0.20 | 0.15 | 71 | 383.7 | 518 | 515 | 134.3 | 187 | 487 | 756 | 460 |
| 11*A* | 6 - 10 - 11 | 12 | 210 | 206.5 | 188 | 29.25 | 2.54 | 0.83 | 0.03 | 90 | 382 8 | 549 | 546 | 166.2 | 186 | 668 | 1045 | 626 |
| 11 | 6- 9-11-11 | 26.5 | 210 | 207.5 | 190 | 29.25 | 2.53 | 0.84 | 0.02 | 83 | 383.7 | 549 | 544 | 165.3 | 188 | 651 | 1027 | 611 |
| 12*A* | 6-12-13-11 | 24 | 196 | 194.7 | 189 | 29.04 | 0.80 | 0.24 | 0.08 | 64 | 383.2 | 516 | 516 | 132.8 | 177 | 514 | 789 | 470 |
| 12*B* | 6-13-14-11 | 24 | 198 | 196.1 | 190 | 29.21 | 0.96 | 0.27 | 0.02 | 70 | 383.7 | 523 | 523 | 139.3 | 182 | 555 | 844 | 500 |
| 12 | 6-12-14-11 | 48 | 197 | 195.2 | 189 | 29.13 | 0.88 | 0.26 | 0.05 | 67 | 383.2 | 520 | 519 | 136.8 | 179 | 535 | 816 | 484 |
| 13 | 6-14-15-11 | 11.5 | 197 | 195.3 | 178 | 29.25 | 2.54 | 0.85 | .... | 63 | 378.6 | 545 | 538 | 166.4 | 178 | 641 | 987 | 584 |
| 14 | 6-15-16-11 | 24 | 206 | 203.0 | 189 | 29.30 | 1.56 | 0.84 | 0.20 | 70 | 383.2 | 551 | 544 | 167.8 | 177 | 647 | 994 | 598 |
| 15 | 6-16-17-11 | 24 | 199 | 197.3 | 188 | 29.28 | 1.61 | 0.57 | .... | 69 | 382.8 | 528 | 524 | 145.2 | 176 | 561 | 976 | 510 |
| 7-9† | 6- 2- 7-11 | 109 | 203 | 200.6 | 192 | 29.30 | ... | 0.45 | .... | 70 | 384.6 | 532 | 523 | 147.4 | 184 | 545 | .... | ... |
| 10-11† | 6- 7-11-11 | 80.5 | 200 | 198.6 | 190 | 29.66 | .... | 0.44 | .... | 75 | 383.8 | 528 | 525 | 144.2 | 187 | 542 | .... | .... |

† Includes periods between tests.

TABLE 13 TAYLOR STOKER. TEST DATA AND RESULTS

| Test No. | Relative Humidity of Atmosphere, Per Cent | Feed Water, Lb. per Hr. | Moist Coal, Lb. per Hr. | Dry Coal, Lb. per Hr. | Dry Coal, Lb. per Hr. per Sq. Ft. of Grate | Ash (Wet), Lb. per Hr. | Ash (Dry), Lb. per Hr. | Per Cent Ash Based on Dry Coal | Steam Used by Stoker Engines and Turbines Driving Fans, Lb. per Hr. | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | Saturated Steam | Equivalent in Superheated Steam | Per Cent of Total Steam |
| 7 | 71.3 | 105856 | 11310 | 11094 | 27.39 | 1002 | 780 | 7.03 | 2907 | 2766 | 2.61 |
| 8 | 78.6 | 76052 | 7770 | 7622 | 18.82 | 954 | 483 | 6.34 | 1987 | 1854 | 2.44 |
| 9 | 75.8 | 113668 | 12094 | 11838 | 29.23 | 1257 | 799 | 6.75 | 3528 | 3254 | 2 87 |
| 10*A* | 69 0 | 66618 | 6866 | 6736 | 16.63 | 826 | 663 | 9.84 | 1888 | 1760 | 2.64 |
| 10 | 71.7 | 65663 | 6796 | 6656 | 16.43 | 824 | 659 | 9.90 | 1855 | 1727 | 2 63 |
| 11*A* | 52 0 | 149627 | 16212 | 15904 | 39.27 | 2051 | 1668 | 10.48 | 5970 | 5482 | 3.66 |
| 11 | 60.9 | 147435 | 16000 | 15696 | 38.75 | 1843 | 1499 | 9.55 | 5481 | 5030 | 3.41 |
| 12*A* | 72.3 | 82060 | 8507 | 8339 | 20.59 | 827 | 645 | 7.73 | 2222 | 2071 | 2.52 |
| 12*B* | 61 0 | 88098 | 9143 | 8968 | 22.14 | 899 | 757 | 8.45 | 2483 | 2309 | 2.62 |
| 12 | 66.6 | 85079 | 8825 | 8653 | 21.37 | 863 | 700 | 8 09 | 2352 | 2189 | 2.57 |
| 13 | 65 0 | 140671 | 15239 | 14946 | 36.91 | 1445 | 1212 | 8.11 | 5044 | 4633 | 3.29 |
| 14 | 67.2 | 128105 | 13730 | 13469 | 33.25 | 1367 | 1173 | 8.71 | 4120 | 3782 | 2.95 |
| 15 | 70.6 | 85762 | 9362 | 9158 | 22.61 | 972 | 764 | 8.34 | 2505 | 2378 | 2.77 |
| 7-9 | 75.0 | 98073 | 10421 | 10209 | 25.21 | 1099 | 737 | 7.22 | 2848 | 2634 | 2.68 |
| 10-11 | 67.4 | 93522 | 10075 | 9868 | 24.36 | 1175 | 945 | 9.58 | 3068 | 2844 | 3.04 |

TABLE 14 TAYLOR STOKER. COMPUTED RESULTS

| Test No. | Factor of Evaporation | Equivalent Water Evaporated into Dry Steam from and at 212 Deg. Fahr., Lb. per Hr. | Equivalent Evaporation from and at 212 Deg. Fahr. per Lb. of Dry Coal | Equivalent Water per Hr. from and at 212 Deg. Fahr. per Sq. Ft. of Boiler Heating Surface | Horsepower Developed | Per cent of Rated h.p. Developed on Basis of 10 Sq. Ft. of Boiler Heating Surface per h.p. | Combined Efficiency of Boiler and Furnace |
|---|---|---|---|---|---|---|---|
| 7 | 1.1658 | 123407 | 11.12 | 5.22 | 3577 | 151.2 | 77.07 |
| 8 | 1.1579 | 88061 | 11.55 | 3.72 | 2553 | 107.9 | 80.28 |
| 9 | 1.1695 | 132935 | 11.23 | 5.62 | 3853 | 162.8 | 77.85 |
| 10A | 1.1529 | 76804 | 11.40 | 3.25 | 2226 | 94.4 | 77.63 |
| 10 | 1.1545 | 75808 | 11.39 | 3.22 | 2197 | 92.9 | 77.90 |
| 11A | 1.1719 | 175348 | 11.03 | 7.41 | 5083 | 214.8 | 76.18 |
| 11 | 1.1697 | 172456 | 10.99 | 7.29 | 4999 | 211.3 | 75.84 |
| 12A | 1.1639 | 95510 | 11.45 | 4.04 | 2768 | 117.0 | 79.21 |
| 12B | 1.1624 | 102405 | 11.42 | 4.33 | 2968 | 125.5 | 79.19 |
| 12 | 1.1640 | 99032 | 11.44 | 4.18 | 2870 | 121.3 | 79.24 |
| 13 | 1.1790 | 165851 | 11.09 | 7.01 | 4807 | 203.2 | 76.56 |
| 14 | 1.1822 | 151447 | 11.24 | 6.40 | 4390 | 185.5 | 76.42 |
| 15 | 1.1713 | 100453 | 10.97 | 4.23 | 2912 | 123.1 | 74.90 |
| 7–9 | 1.1648 | 114235 | 11.19 | 4.83 | 3312 | 140.0 | 77.66 |
| 10–11 | 1.1598 | 108467 | 10.99 | 4.58 | 3143 | 132.8 | 75.66 |

TABLE 15 RONEY STOKER. HEAT BALANCE, PERCENTAGES OF TOTAL HEAT IN COAL

FLUE GAS ANALYSES AND TEMPERATURE TAKEN IN BREECHING

| No. of Test | Absorbed by Boiler | Moisture in Coal | Hydrogen in Coal | Heat to Chimney | | | Carbon Monoxide | Carbon in Ash | Radiation, etc. |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Heat to Chimney | Moisture in Air | Total | | | |
| 1 | 77.84 | 0.18 | 4.55 | 13.56 | 0.37 | 13.93 | 0.23 | 1.20 | 2.07 |
| 2 | 79.88 | 0.16 | 4.36 | 9.15 | 0.26 | 9.41 | 0.42 | 1.20 | 4.57 |
| 3 | 77.45 | 0.15 | 4.48 | 11.39 | 0.32 | 11.71 | 0.74 | 1.85 | 3.62 |
| 4 | 75.78 | 0.17 | 4.49 | 12.79 | 0.36 | 13.15 | 1.95 | 2.13 | 2.33 |
| 5 | 81.15 | 0.16 | 4.29 | 9.11 | 0.20 | 9.31 | 1.29 | 2.29 | 1.51 |
| 6 | 75.28 | 0.21 | 4.74 | 13.17 | 0.36 | 13.53 | 1.16 | 1.71 | 3.37 |
| 16 | 80.98 | 0.22 | 4.18 | 8.94 | 0.19 | 9.13 | .0.27 | 3.20 | 2.02 |
| 17 | 76.73 | 0.22 | 4.47 | 12.47 | 0.28 | 12.75 | 0.74 | 2.05 | 3.04 |
| 18 | 75.57 | 0.21 | 4.64 | 14.34 | 0.27 | 14.61 | 0.62 | 2.42 | 1.93 |
| | | | | | | | | Average | 2.72 |

FLUE GAS ANALYSES AND TEMPERATURES TAKEN BELOW DAMPERS

| No. of Test | Absorbed by Boiler | Moisture in Coal | Hydrogen in Coal | Heat to Chimney | Moisture in Air | Total | Carbon Monoxide | Carbon in Ash | Radiation, etc. |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 77.84 | 0.18 | 4.59 | 13.83 | 0.38 | 14.21 | 0.0 | 1.20 | 2.00 |
| 2 | 79.88 | 0.16 | 4.36 | 9.03 | 0.27 | 9.30 | 0.27 | 1.20 | 4.83 |
| 3 | 77.45 | 0.15 | 4.58 | 12.84 | 0.37 | 13.21 | 0.09 | 1.85 | 2.67 |
| 4* | ..... | .... | .... | ..... | .... | ..... | .... | .... | ... |
| 5 | 81.15 | 0.16 | 4.32 | 9.43 | 0.21 | 9.64 | 0.73 | 2.29 | 1.71 |
| 6 | 75.28 | 0.21 | 4.75 | 13.77 | 0.36 | 14.13 | 0.58 | 1.71 | 3.34 |
| 16 | 80.98 | 0.22 | 4.20 | 8.97 | 0.19 | 9.16 | 0.0 | 3.20 | 2.21 |
| 17 | 76.73 | 0.22 | 4.45 | 12.67 | 0.29 | 12.96 | 0.97 | 2.05 | 2.62 |
| 18† | ..... | .... | .... | ..... | .... | ..... | .... | .... | ... |
| | | | | | | | | Average | 2.77 |

* Pyrometer out of order and taken out to be examined.

† Leakage of air into collecting device of gas analyses apparatus.

TABLE 16 TAYLOR STOKER. HEAT BALANCE, PERCENTAGE OF TOTAL HEAT IN COAL

FLUE GAS ANALYSES AND TEMPERATURE TAKEN IN BREECHING

| No. of Test | Absorbed by Boiler | Moisture in Coal | Hydrogen in Coal | Heat to Chimney | | | Carbon Monoxide | Carbon in Ash | Radiation, etc. |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Heat to Chimney | Moisture in Air | Total | | | |
| 7 | 77.07 | 0.18 | 4.58 | 11.54 | 0.28 | 11.82 | 1.61 | 2.31 | 2.43 |
| 8 | 80.28 | 0.17 | 4.28 | 10.12 | 0.24 | 10.36 | 0.40 | 1.80 | 2.71 |
| 9 | 77.85 | 0.20 | 4.31 | 11.21 | 0.25 | 11.46 | 0.44 | 2.20 | 3.54 |
| 10 | 77.90 | 0.18 | 4.34 | 11.35 | 0.26 | 11.61 | 0.27 | 2.77 | 2.93 |
| 11 | 75.84 | 0.18 | 4.47 | 11.91 | 0.35 | 12.26 | 0.59 | 3.58 | 3.08 |
| 12 | 79.24 | 0.18 | 4.46 | 11.05 | 0.21 | 11.26 | 0.16 | 2.32 | 2.38 |
| 14 | 76.42 | 0.18 | 4.51 | 13.15 | 0.27 | 13.42 | 0.31 | 2.57 | 2.59 |
| | | | | | | | | Average | 2.81 |

FLUE GAS ANALYSES AND TEMPERATURES TAKEN BELOW DAMPERS

| No. of Test | Absorbed by Boiler | Moisture in Coal | Hydrogen in Coal | Heat to Chimney | Moisture in Air | Total | Carbon Monoxide | Carbon in Ash | Radiation, etc. |
|---|---|---|---|---|---|---|---|---|---|
| 7 | 77.07 | 0.18 | 4.52 | 12.76 | 0.30 | 13.06 | 0.0 | 2.31 | 2.86 |
| 8 | 80.28 | 0.17 | 4.23 | 10.20 | 0.25 | 10.45 | 0.04 | 1.80 | 3.03 |
| 9 | 77.85 | 0.20 | 4.28 | 11.33 | 0.23 | 11.63 | 0.08 | 2.20 | 3.76 |
| 10 | 77.90 | 0.18 | 4.30 | 10.64 | 0.24 | 10.88 | 0.0 | 2.77 | 3.97 |
| 11 | 75.84 | 0.18 | 4.40 | 11.60 | 0.34 | 11.94 | 0.77 | 3.58 | 3.29 |
| 12 | 79.24 | 0.18 | 4.37 | 10.22 | 0.19 | 10.41 | 0.0 | 2.32 | 3.48 |
| 14 | 76.42 | 0.18 | 4.43 | 13.19 | 0.27 | 13.46 | 0.25 | 2.57 | 2.69 |
| | | | | | | | | Average | 3.29 |

# DIE CASTINGS

By Amasa Trowbridge

## ABSTRACT OF PAPER

A brief summary is given of the state of the art of making small castings in steel molds. The principles are outlined of this process of casting and of hand and automatic easting machines. The composition and characteristics are given of the metals best adapted for use with reference to the effect of temperature and shrinkage together with examples of comparative cost.

# DIE CASTINGS

By Amasa Trowbridge, Hartford, Conn.

Member of the Society

The art of die casting, that is, the making of castings in steel molds to finished size and shape, was first introduced in connection with the manufacture of type. The first attempt at type founding was made in France, followed shortly by manufacturers in other countries. The first successful attempt in the United States was about 1735. As soon as it was established that finished type could be cast in steel molds, inventors naturally turned their attention to machines for doing the work. Such machines were attempted early in the 19th century and by the close of that century the perfected linotype and monotype machines, which are fine examples of die-casting machines, had been evolved. Machines for casting individual pieces of type are also still in use and the most recent ones will cast about 125 to 150 pieces per minute. This gives some idea of the speed with which such castings can be made.

2 When the casting of type was perfected, it saved so much time that its usefulness for making other pieces which were wanted in large quantities was at once evident. Accordingly many men have made efforts to perfect a machine or process by which they could turn out finished castings correct as to size and shape. Since type was first successfully cast it is natural that the same methods should be used for making other castings. So far no material superior to steel, the material used for type molds, has been found for making the matrices, or dies, as they are called. Brass can be and is used where the casting is very intermittent as in a linotype machine, but for continuous work and where accuracy and truth are required, steel is necessary.

3 The next consideration after the material for the dies is that for the castings. Table 1 gives a few facts concerning the materials

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that are of interest in connection with this subject, whether for making dies or castings.

4 There are only a few common metals with a melting point sufficiently low to be cast in steel dies, because these do not have to be brought to their melting point to be spoiled. If improperly treated in making, the dies are very susceptible to injury in use. Fine cracks are sometimes made in hardening the dies, causing them to break when subjected to the constant change of temperature which occurs in their use. Thin places in dies are more apt to get burned than heavy parts. For most work hardened dies are superior to soft, but their cost is very much greater.

TABLE 1 DATA OF MATERIALS USED FOR DIES AND CASTINGS

| Material | | Melting Point | | Strength Lb. per Sq. In. | | Modulus of Elasticity |
|---|---|---|---|---|---|---|
| | | Deg. Cent. | Deg. Fahr. | Tensile | Compressive | |
| Aluminum | Al | 657 | 1214 | 15000 | 12000 | 11000000 |
| Antimony | Sb | 630 | 1166 | ..... | | |
| Bismuth | Bi | 266 | 511 | 6400 | | |
| Cadmium | Cd | 322 | 612 | ..... | | |
| Copper | Cu | 1072 | 1951 | 30000 | | |
| Lead | Pb | 326 | 618 | 2000 | | |
| Magnesium | Mg | 633 | 1171 | ..... | | |
| Tin | Sn | 230 | 446 | 4000 | | |
| Zinc | Zn | 415 | 779 | 5500 | | |
| Iron | Fe | 1505 | 2742 | 52000 | 85000 | 28000000 |
| Nickel | Ni | 1451 | 2644 | ..... | | |
| Steel | | 1427 | 2600 | 65000 | ..... | 33000000 |

5 In general, the method of making a casting is as follows: A suitable die or mold is made in steel. This must be so arranged that when opened, the casting will either drop out or be easily ejected. The die should have the fewest possible partings. This is important because it is easier to hold the casting to correct size when the die is in a few pieces than when it is in many. Also, the fewer the partings, the fewer the fins that will be made on the castings. Fig. 1 shows a complicated casting.

6 Whenever cores are necessary, suitable means must be provided for withdrawing these without deforming the casting. The die must close properly, that is in correct alignment, and be held firmly because the pressure of the fluid metal has to be overcome. The die being held closed in the machine, metal is forced into the die, pressure being provided by a pump which acts directly on the metal, by air

pressure on top of the molten metal or by a head of molten metal. The metal is allowed only to set. The mold is then opened and the casting removed, the casting being left in the mold only as long as is absolutely necessary. If the die is too hot, it is then cooled and the operation repeated. The temperature of the die is important, and should be held constant because the expansion of the die will change the size of the casting. This operation is generally carried on in so-called hand-casting machines, that is, machines operated by manual labor.

7 Automatic machines are in use and have great advantages in producing uniform castings because the conditions do not vary. The

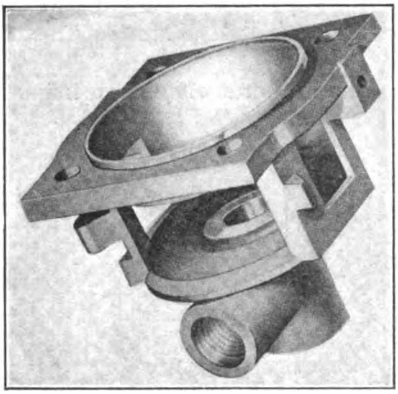

Fig. 1 A Complicated Casting

automatic machine is run at a constant speed and is not subject to varying conditions due to the operator becoming tired. Hand-casting machines produce quantities of 500 per day, more or less, depending on the size and complexity of the piece. Automatic machines produce the castings much more rapidly and save on labor just as does any other type of machinery.

8 While the writer has been able to find only one maker of casting machines who is willing to publish a description of them, a few illustrations are given to indicate the form of machine that is used, and it might be well to say that these actually show only the principles involved in each machine rather than the perfected mechanism.

9 Fig. 2 shows a machine in which the metal is pumped into the mold by hand. *A* is the hot, molten metal; *C* the charging chute; *H* a valve to close this; *E* the pump cylinder; *F* the plunger; *G*

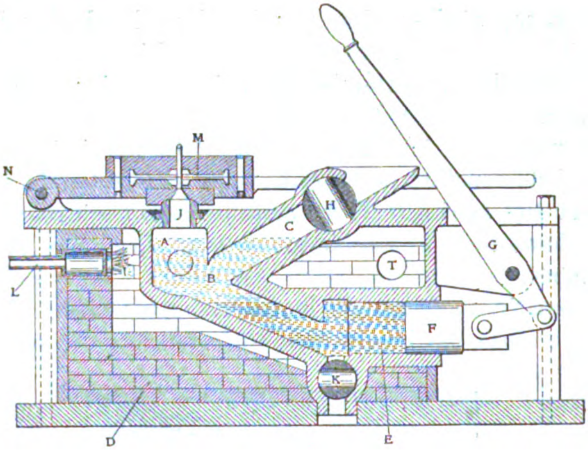


FIG. 2 MOLDING MACHINE WITH MOLD LYING FLAT ON TOP

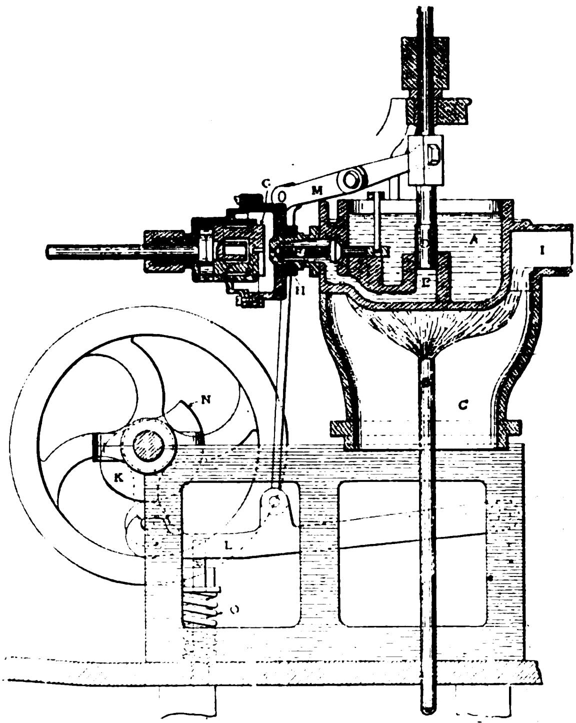


FIG. 3 AUTOMATIC MOLDING MACHINE

the pump lever; *J* the nozzle through which metal is forced into the mold *M*; *K* a valve for emptying the metal pot *B*. The gas for heat is supplied through pipe *L*, and the waste gases escape at *T*.

10 Fig. 3 shows an automatic machine. *A* is the molten metal; *B* the gas pipe; *D* the pump plunger; *E* the pump cylinder; *F* a valve to close the passage between the pump chamber and the metal pot, while metal is forced through the nozzle into the die or mold *G*, which is brought up tightly against the nozzle while the metal is forced in. The left end of *F* closes the nozzle, while metal is drawn into the pump chamber by the raising of the plunger *D*.

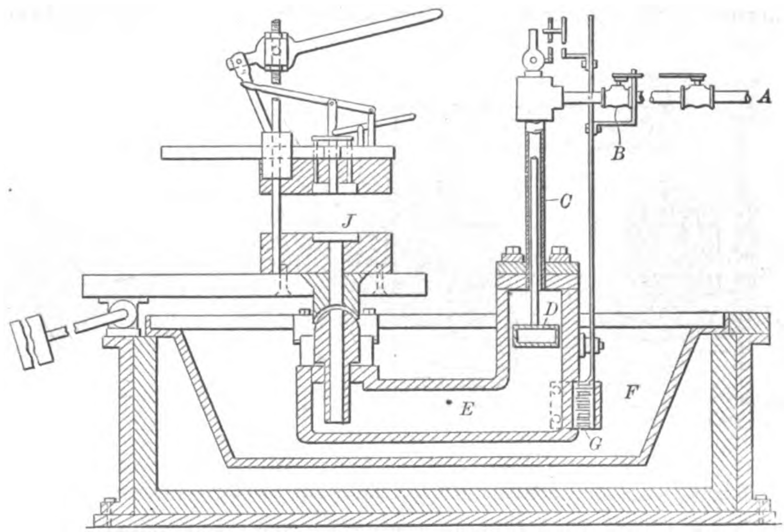


FIG. 4 MACHINE USING AIR PRESSURE TO FILL MOLD

11 Fig. 4 shows a hand machine in which air pressure is used to force the metal into the mold. Air enters at *A* and is controlled by the valve *B*. It comes down through the vertical pipe *C* and exerts a pressure on the loose piston *D*. This piston is hollow and floats on the metal contained in the pump chamber *E*. Metal is admitted to this chamber *E* from the main metal pot *F* through the valve *G*. The metal is forced by the pressure of the piston *D* out of the nozzle *H* into the mold *J*. The use of the piston *D* prevents oxidization of the metal from contact with the air which is admitted to force the metal into the mold. This air pressure is released before the valve *G* is opened so that metal can flow by gravity into the pump chamber.

The metal which is forced directly into the mold is taken from below the top surface of the molten metal and this precludes the oxidized skin on top of the metal from being forced into the dies. Any of this oxidized metal would make bad castings so that this point is important. The entire pump chamber in this arrangement is submerged in molten metal so that it is kept hot. The nozzle is so situated that it is probable extra means would have to be used to keep it heated and prevent the metal from freezing at this point. Undoubtedly in the practical working out of the machine this point was cared for.

12 The feature about die castings which most appeals to the manufacturer is their accuracy. So long as the dies are in good condition,

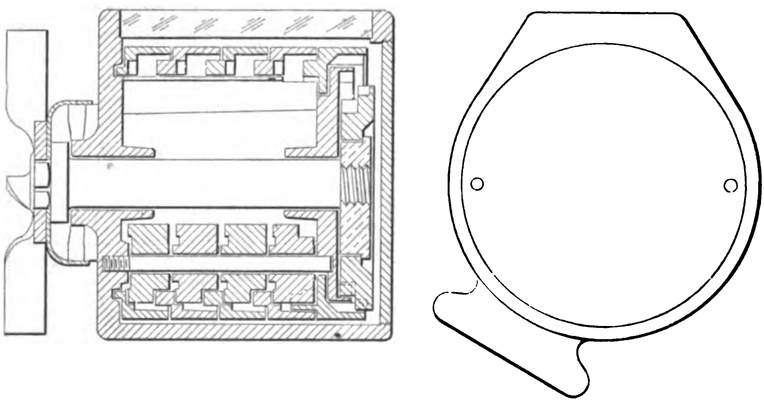

Fig. 5 Veeder Cyclometer with Section View

the castings should be perfectly true, both in size and shape. This does away with the necessity of gaging and makes it possible to use them without their having to be fitted into place by any hand work. A careful inspection is necessary, and this should be done as soon as possible after the castings are made so as to detect any flaws due to a slight failure of the dies. Any fins or burs formed by the necessary joints in the dies can be removed at the same time that the castings are inspected. Usually these fins are not thick and can be taken off thoroughly and quickly with a light hand tool.

13 A difficulty due to shrinkage is sometimes encountered when these castings are to be used in connection with parts made by some other process. While the shrinkage will be the same in two castings made in the same die if the metal is properly handled, it does not

always follow that it is proportionately the same when they are made from different molds. It is affected to a marked degree by the form of the casting, and if the castings are to be used in connection with machined pieces, it is advisable that these be machined to fit the casting. When it is not possible to do this and the casting must be fitted to existing pieces, sample castings should be made, and if these are not correct, the dies can be altered to make castings that are correct. In doing this, sufficient material must be allowed for grinding away, the casting being at first too small, although this makes a great deal of extra work.

14 The greatest gain obtains when an entire machine can be made of such castings. One of the best examples of this is the Veeder cyclometer so universally used on bicycles. This instrument is composed of about a dozen die castings and nearly as many parts of other materials. The number rings have 0.001 in. play, and yet these cast-

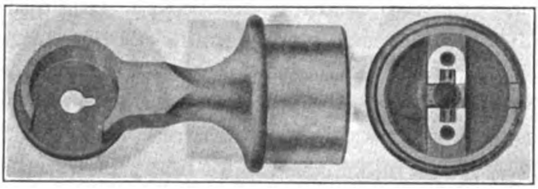

FIG. 6 HEAD FOR DESK TELEPHONE

FIG. 7 A LUG MATCHING FIG. 6

ings are made in enormous lots and, without being gaged, are assembled into the die-cast cases where they fit and work properly. So exact are these castings that when new, the instruments work more easily without lubrication than with it. This would obviously be possible only where the clearances are extremely small. A small dimension on these castings can be maintained to 0.0001 in. This instrument is illustrated in Fig. 5, the section view showing the rings both in their relation to the hub on which they turn and in contact with the transfer pinions. These latter turn on a German silver shaft 0.04 in. in diameter. The hub which forms the bearing for the number rings is so large in proportion to the width of these that they would tip and cramp if much end play were allowed. This makes it necessary to hold the dimensions on the rings correct within less than one-half of 0.001 in. In Figs. 6 and 7 are shown the head for a desk telephone, with a lug matching it.

15 The quality of these castings depends on both the alloy used and the method of making them. The alloys in most common use are those having a zinc base. This metal is useful in certain alloys, particularly with copper, but if alloyed with aluminum is unsuitable for most purposes. Aluminum-zinc alloys are frequently used because aluminum makes the alloy lighter in weight and in color. Some time after manufacture, castings of this alloy begin to disintegrate and will actually fall to pieces. In the disintegrating process they also change shape badly so that they should never, under any circumstances, be used for pieces which are wanted to stay flat or true. This alloy also tarnishes rapidly. Most of the alloys of zinc are too brittle to be of much use for the making of die castings. The usual effect of casting in metal molds is to make harder castings than would be made from the same metal in sand molds. For this reason a fairly ductile metal should be used.

16 The alloys of tin are being used quite extensively for die castings. These alloys possess the two desirable qualities of being quite ductile and of melting at a low temperature. Genuine babbitt metal, as it is commonly called, is an alloy consisting, according to the best authorities, of about 89 per cent tin, 7.3 per cent antimony and 3.7 per cent copper. This is a remarkably fine bearing metal and is possessed of sufficient strength to make it useful for many small parts. By certain changes in the alloy a composition even better for ordinary die-casting use can be produced.

17 The alloys of lead are used to a limited extent but, except for type, this metal is more often used in small proportions than as the foundation of the alloy. It is too heavy and lacks sufficient strength to make a very desirable metal. The percentage of lead in an alloy is sometimes increased for the sake of lowering the melting point and the price per pound.

18 Antimony is a common constituent of all die-cast alloys. The addition of this metal in the proper proportions, makes the alloy hard enough to machine well and increases the fluidity of the metal in its molten state. This makes it possible to obtain sharp castings such as are made from type metal, which is an alloy consisting of lead, 87½ per cent, and antimony, 12½ per cent.

19 In making an alloy of any two metals, when they are in correct proportions, there is formed an eutectic, the melting point of which is lower than that of either of the constituent metals. In some cases by the addition of a third metal, the melting point may be still further lowered.

20 The strength of die castings is of course largely dependent on the alloy, and also on the method of casting. Unless proper precautions are taken to insure sound castings, much trouble will be encountered from blow holes. To prevent these is often very difficult and sometimes impossible. They are caused both by the form of casting and by the tendency of the molten metal to hold minute bubbles of air or other gases which are carried into the mold and do

Fig. 8 Set of Number Wheels and Pinions

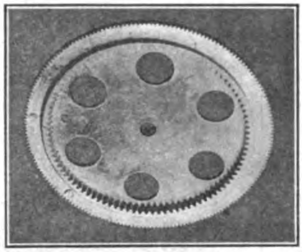

Fig. 9 Internal Gear

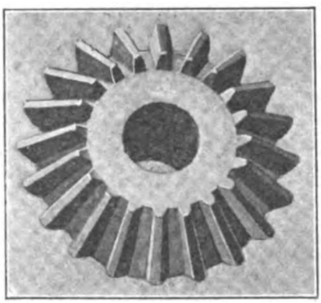

Fig. 10 External Gear

not escape before the casting sets. This is a case exactly parallel to that found in making iron castings. The shrinkage of the ordinary die casting is not as great as that of cast iron, and some of the tin alloys particularly shrink scarcely at all.

21 Another similarity to iron molding is found in the fact that the outside skin of the die casting is ordinarily stronger and harder than its interior. The hard outside skin is always desirable on a die casting, because the piece being cast to its finished size and no cutting being required, it is this outside skin which is first subjected to wear.

22 Exact figures on the strength of die castings might be quite misleading unless the exact composition and treatment of the castings were noted, so that general figures only can be given. They compare very favorably with cast iron in tensile strength, but are not nearly so strong in compression as that material. Their compressive strength is usually but little greater than the tensile, although it is somewhat, say one-third, greater. As the material is not as brittle as cast iron, it can be subjected to shocks which the iron would not

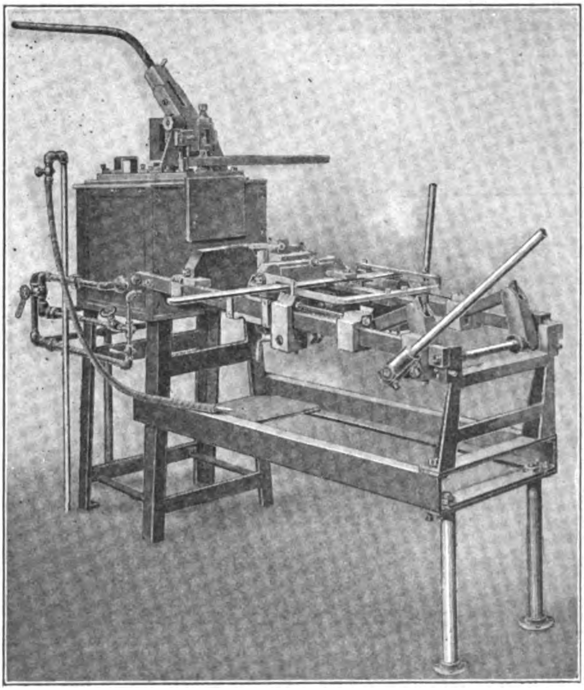

FIG. 11 SOSS DIE-CASTING MACHINE

withstand. Most die castings are much more ductile than cast iron. The greater ductility of the die castings is an advantage for threaded or tapped pieces. The castings do not chip out when tapped near an edge and a fine thread may be used. Some of the alloys are so ductile that the castings may be spun or riveted. This is often needed or is convenient for fastening two castings together or fastening a casting and some other piece.

23 Very little idea can be given of the cost of parts manufactured by the die-cast method. The tools or dies are costly or otherwise, according to their complexity or their simplicity. Practically all the die-casting manufacturers make the customer who ordered the castings pay for the dies. The parts are then charged for according to the time needed to cast them and the amount of metal used. As only the metal in the finished casting is charged for, there is no expense for scrap. The time for casting a complicated piece is little, if any, greater than for a simple one. From this it follows that the more complicated the casting, or the more difficult it would be to machine, the greater will be the saving effected by the use of die castings. The number of pieces to be made from a die is also pertinent, for hundreds of thousands of pieces can be made from some dies with no injury whatever to them. Other dies may need frequent repairs due to unavoidably weak points in their construction. Number wheels having internal or hooded gear teeth are good examples of parts which are profitably made by this process.

24 The set of number wheels and pinions shown in Fig. 8 will serve as a fair example for the comparison of costs by hand-casting machines and by automatic machines. The dies for this set of wheels and pinions for a hand machine would cost in the neighborhood of $450. The number-wheel castings would cost, in lots of 1000, about 10 cents each, and in lots of 10,000, about 8½ cents each. The pinion castings in lots of 1000 would be 4 cents each and in lots of 10,000 would be 3 cents each. The cost of the dies for an automatic machine for the same wheels and pinions would be about $2000. The number-wheel castings in lots of 10,000 would cost about 2½ cents each, and in lots of 25,000 or more about 2 cents each. The pinion castings would cost about 1½ cents in 10,000 lots and in 25,000 or more lots, about 1 cent each.

25 The necessary die for the internal and external gear shown in Figs. 9 and 10 would cost about $100 for a hand-casting machine, and the castings about 13 cents each in 10,000 lots. The dies for the same piece to be used in an automatic machine would cost about $450, and the castings would cost about 2 cents each in 10,000 lots, plus 8 to 9 cents each for metal. The bevel gear illustrated was made in a hand-operated machine of a zinc alloy, commonly known as hard metal. A die for this costs about $90, and the casting 7½ cents each in 1000 lots, and 6½ cents each in 10,000 lots.

26 Fig. 11 shows the Soss die-casting machine. This machine is offered for sale and enables a manufacturer to make his own die castings with a comparatively inexpensive equipment.

# GAS POWER SECTION

## PRELIMINARY REPORT OF LITERATURE COMMITTEE

## (XI)

### ARTICLES IN PERIODICALS[1]

AUSNUTZUNG VON GASWERKSNEBENPRODUKTEN FÜR KRAFTZWECKE, NEUERE ERFAHRUNGEN IN DER, Kutzbach. *Journal für Gas und Wasserversorgung, August 19, 1911.* 7 pp., 10 figs., 4 tables.

Results of the utilization of the gas by-products for power purposes.

BEARING PRESSURES IN GAS ENGINES, G. W. Lewis and A. G. Kessler. *Power, September 19, 1911.* 4 pp., 7 tables, 10 curves, *ace.*

Charts and tables showing average values of maximum bearing pressures in American stationary gas-engine practice.

CALORIMETER, THE SMITH RECORDING GAS. *The Gas Engine, August 1911.* 2 pp., 2 figs. *bfA.*

Instrument designed primarily to record heat value of producer gas; reads in terms of standard 60-deg. gas under 30 in. barometric pressure; readings automatically corrected to this standard, regardless of actual conditions under which they are taken.

DIESEL À BORD DES NAVIRES DE HAUTE MER, LE MOTEUR, M. A. Bochet. *Journal Société des Ingénieur Civils de France, July 1911.* 15 pp., 21 figs., 1 table, 1 curve. *A.*

The Diesel engine on board ships.

DIESEL ENGINE IN MARINE WORK, PROGRESS OF THE, J. Rendell Wilson. *International Marine Engineering, October 1911.* 7 pp., 9 figs.

Outlines progress made in England and in Europe.

DREHROST-GASERZEUGER, PRAKTISCHE ERFAHRUNGEN BEI INBETRIEBSETZUNG UND BEHANDLUNG DER, K. Munzel. *Stahl und Eisen, September 14, 1911.* 4 pp., 1 fig. *f.*

Practical experiences in starting and managing rotary-grate generators.

[1] Opinions expressed are those of the reviewer not of the Society. Articles are classified as *a* comparative; *b* descriptive; *c* experimental; *d* historical; *e* mathematical; *f* practical. A rating is occasionally given by the reviewer, as *A*, *B*, *C*. The first installment was given in The Journal for May 1910.

ENGINE AND DYNAMO FOR THE CALCUTTA MINT, COMBINED OIL. *The Engineer (London), September 8, 1911.* 1 p., 4 figs. *bfA.*

**Describes a 30-kw. 500-volt combined oil engine and dynamo.**

FLUGMOTOREN DER ÖSTERREICHISCHEN DAIMLER MOTOREN GESELLSCHAFT, DIE, Fr. W. Seckatz. *Dinglers Polytechnisches Journal, September 30, 1911.* 2 pp., 4 figs. *A.*

**Description and construction of aerial motor of the Austrian Daimler works.**

GAS ENGINES; THEIR DESIGN AND APPLICATION, E. N. Percy. *International Marine Engineering, September and October 1911.* 6 pp., 5 tables.

**Continued article on construction and considerations in design of gas engines.**

GAS TURBINE PROBLEM, THE, G. W. Malcolm. *Power, October 15, 1911.* ¾ pp., 1 fig. *ab.*

**Discusses Mr. Blaisdell's article in Power, September 5, 1911.**

KEROSENE-ENGINED CRAFT, BIG BRITISH, J. Rendell Wilson. *International Marine Engineering, August 1911.* 1½ pp., 2 figs.

**Describes vessel and engine built by John I. Thornycroft & Co., Ltd.**

KNIGHT GASOLINE ENGINE WITH SLIDING SLEEVE VALVES, THE. *Engineering News, August 10, 1911.* 1 p., 2 figs.

**General description of the new Knight engine.**

LOCOMOTIVE, PETROL. *The Engineer (London), September 8, 1911.* 1 p., 2 figs. *bfC.*

**Describes a 12-h.p. oil tractor engine shipped to India by Ironside, Son and Dyckerhoff, London**

MARINE ENGINE OF LARGE SIZE, A TWO-CYCLE. *The Gas Engine, August 1911.* 3 pp., 2 figs. *bfA.*

**Describes 2-cycle, 3600-h.p. Diesel type, Oechelhauser system, oil engine for 6500-ton cargo vessel of Hamburg-American line. Engine known as Junkers oil engine and consists of two sets of vertical tandem cylinders acting on one shaft.**

MARINE OIL ENGINES, SOME SCOTTISH. *The Engineer (London), September 22, 1911.* 2½ pp., 5 figs. *fA.*

**Describes the new 4-cycle Beardmore engine, Kelvin engine and Gleniffer engine.**

MOTEURS À PÉTROLE. *Revue de Mécanique, August 31, 1911.* 24 pp., 64 figs., 31 curves.

**Review of letters of patent, magazine article. Latest patents, design and detail construction of kerosene motors. Types: Koerting, Day, Lamplough, Lepape, Hewitt, Roberts, Hult, Rumpler, Wolseley, Darracq, Haviland, Buffalo, Thornycroft, Westinghouse, Daimler, Gnome.**

OIL ENGINE, A REVERSIBLE 300-H.P., 4-CYLINDER. *International Marine Engineering, August 1911.* 1 p., 1 fig.

**Describes 300-h.p. Diesel motor built by Messrs. Fried Krupp Ltd.**

PRODUCER GAS PLANT ON BARKENTINE ARCHER, A. H. Cox. *International Marine Engineering, June 1911.* 2 pp., 3 figs.

**General description of gas engine and producer built for Tacoma & Roche Harbor Lime Co., Roche Harbor, Wash.**

PUMPING PLANT, A GAS ENGINE. *Engineering News, July 6, 1911.* 1 p., 6 figs.

**Describes pumping plant for water supply of Haddonfield, N. J.**

SARGENT COMBINED GAS ENGINE AND AIR COMPRESSOR. *Power, October 10, 1911.* 2 pp., 3 figs. *b.*

**Description and details of engine and compressor.**

SECHSZYLINDRIGER VIERTAKTSCHIFFSMOTOR VON $100PS_e$, Dierfield. *Zeitschrift des Vereines deutscher Ingenieure, September 2, 1911.* 6½ pp., 30 figs. *bf.*

**Describes a 6-cylinder, 4-cycle, 100-e.h.p. yacht engine using alcohol for fuel.**

TEERÖLEN IN DIESELMOTOREN, UBER VERWERTUNG VON, Rath und Rossenbeck. *Dinglers Polytechnisches Journal, September 23, 1911.* 3 pp., 8 tables, 1 curve. *A.*

**The use of tar-oil for Diesel engines.**

TOILER-A DIESEL OIL-ENGINED VESSEL OF 2700 TONS, J. Rendell Wilson. *International Marine Engineering, July 1911.* 1 p., 1 fig.

**General description of vessel driven by two 180-b.h.p. reversible Diesel 4-cylinder oil engines and her trial trip.**

# GENERAL NOTES

## NATIONAL CONSERVATION CONGRESS

The third annual session of the National Conservation Congress was held in Kansas City, Mo., September 25–27. More than a thousand delegates from every part of the United States attended the sessions, the most prominent of whom were President Taft, Theodore Roosevelt, Gifford Pinchot, James R. Garfield, William Bryan, Secretary Fisher and Dr. H. W. Wiley. The special topic of discussion was the conservation of the soil, and in particular two points were emphasised. The first was the necessity of scientific farming to end the appalling soil robbery of the nineteenth century; the second was the need of considering the welfare of women and children on the farms, and so of making rural life attractive. Among the points touched on were the acidity of soils, the use of phosphorus, legume culture, and other aspects of the sickness and cure of soils. One of the interesting addresses of the convention was by Mrs. Harriet Wallace Ashby on The Farmer's Wife. She advocated the formation of clubs of farmers' wives, the improvement of rural schools, and the establishing of social neighborhood centers. Other speakers discussed the place of the rural church, agricultural training in schools, the parcels post, good roads and other methods for making farm life attractive, so that the young people should be content to stay at home instead of being eager to go to the cities. President Taft's message was the plan of the Government to coöperate with the state and the county authorities in placing a farm expert, so far as possible, in every county to study particularly the conditions of the soil and climate in that county and act as a counselor for the farmers.

## AMERICAN SOCIETY OF CIVIL ENGINEERS

At a meeting of the American Society of Civil Engineers in the Society house at 220 West 57th Street, New York, October 4. W. S. Kinnear read a paper on The Detroit River Tunnel. On October 18, the subject was The New York Tunnel Extension of the Pennsylvania Railroad: Station Construction, Road, Track, Yard Equipment, Electric Traction and Locomotives.

## AMERICAN ELECTRIC RAILWAY ASSOCIATION

The American Electric Railway Association held its annual meeting October 10 to 13, at Atlantic City, N. J. Among the addresses were: The Hudson and Manhattan Tunnels, William G. McAdoo; The Effect of Electric Railway Operation on Taxable City Property, G. H. Harries; Measures for the Welfare of Employees, D. T. Pierce; Electric Railway Securities, J. G. Cannon; The Interurban, C. L. Henry; The Toledo Street Railway Situation, A. E. Lang; Physical Valuation, O. T. Crosby. Various committees reported as follows:

on the Welfare of Employees, McGraw Dictionary, Compensation for Carrying United States Mail, Taxation Matters, Federal Relations, and Determining the Proper Basis for Rates and Fares.

Affiliated with the American Electric Railway Association are the American Electric Railway Accountants' Association, the American Electric Railway Enginering Association, the American Electric Railway Claim Agents' Association and the American Electric Railway Transportation and Traffic Association. Separate simultaneous meetings were held by these various branches, at which the following papers were read: Accounting System for a Small Electric Railway, E. D. Gault; Overhead Charges, M. E. Cooley; Statistics of Cost of Electric Operation on Steam Railways, A. B. Bierck; Trainmen, Their Selection and Method of Instruction in order to Obtain Complete and Intelligent Accident Reports, E. P. Walsh; The Prevention of Accidents: What can be done to increase the interest of employees of all departments in this work; The best means of promoting greater caution on the part of platform men, E. C. Carpenter; The Practical Value of the Index Bureau with Some Statistics and Illustrations, H. R. Goshorn; How can the Public be Educated in the Prevention of Accidents.

### NATIONAL COMMERCIAL GAS ASSOCIATION

The annual meeting of the National Commercial Gas Association was held in Denver, Colo., October 23 to 28, 1911. The papers read were: Illuminating Engineering and its Application to the Gas Industry, E. L. Elliott; Exhibition and Description of Model Glass Gas Works, A. F. Traver; The Modern Gas Fixture, C. Ummach; Some Notions of a Manufacturer, R. K. Clark; Increased Efficiency in Scientific Office Accounting, P. R. Jones; Practical Demonstration Work, Mrs. Anna Carroll; Manufacture of Gas Mantles from Artificial Fiber, S. Gulbrandsen; Ventilation of Fuel Gas Appliances, J. H. Walker; Pension and Profit Sharing, J. B. Douglas; Relative Cost and Efficiencies of Gas, Electric and Gasoline Lighting, W. M. Blinks. The entertainment provided was a special feature of the convention and included an all-day trip over the famous Moffat Road to the top of the Continental Divide, where a game dinner of bear meat, venison, grouse and mountain trout was served; a trip to the Garden of the Gods where the members and guests were served with a chuck-wagon dinner; a trip up South Cheyenne Cañon and visits to Seven Falls, Manitou Springs and Mt. Manitou.

### NATIONAL MACHINE TOOL BUILDERS' ASSOCIATION

The annual convention of the National Machine Tool Builders' Association was held at the Hotel Astor, New York, October 10 and 11, at which the following addresses were delivered: Task Work as a Basis of Proper Management, H. L. Gantt, Mem.Am.Soc.M.E.; Shop Hygiene as a Factor in Efficiency, W. Talbot; Standardization of Machine Tools for the Benefit of the User, L. P. Alford, Mem.Am.Soc.M.E.; and Heart to Heart Talks on Trade Conditions. On the opening evening the association was the guest of Machinery at an entertainment and organ solo in the grand ball room of the Hotel Astor. A buffet supper was also served. The following evening the American Machinist entertained the members at a theater party at the Hippodrome.

## PERSONALS

E. E. Alexander has assumed the duties of chief draftsman of the Taylor Iron and Steel Co., High Bridge, N. J. Mr. Alexander was until recently identified with the Cooke Works of the American Locomotive Co., Paterson, N. J.

Joseph E. Aue has become connected with the De La Vergne Machine Co. New York, in the capacity of chief engineer of the gas and oil engine department. He was formerly identified with the Snow Steam Pump Works, Buffalo, N. Y.

William W. Boyd has accepted a position with the E. & F. Fairbanks Co., St. Johnsbury, Vt. He was recently draftsman of the motive power department of the Pennsylvania Railroad, Altoona, Pa.

Harold V. Coes has resigned as consulting engineer and director of the Searchlight Gas Co. and also as mechanical engineer for the Liquid Carbonic Co., to accept a position as manager of the Chicago office of Lockwood, Greene & Co., Chicago, Ill.

H. V. Conrad, formerly consulting engineer with the Westinghouse Air Brake Co., Wilmerding, Pa., has become connected with the National Brake and Electric Company, Milwaukee, Wis.

Harry H. Cook, until recently chief engineer of the Coffin Valve Co., Boston, Mass., has accepted a position with the Chapman Valve Manufacturing Co., Indian Orchard, Mass.

William Elmer, formerly master mechanic of the Pennsylvania Railroad at Pittsburgh, Pa., has been appointed superintendent of motive power of the same company, with headquarters in Buffalo, N. Y.

George F. Gast has become connected with the Atlantic Gulf and Pacific Co., San Francisco, Cal. He was formerly associated with the construction department of the Minnesota and Ontario Power Co., International Falls, Minn.

W. W. Hodge, formerly connected with Dodge, Day & Zimmermann, Philadelphia, Pa., as field superintendent, has accepted a position with the American Steel and Wire Co., Worcester, Mass., as assistant superintendent of the electrical cable works.

O. D. Hogue, formerly manager of the power pump department of the Goulds Manufacturing Co., Boston, Mass., has been appointed vice-president and treasurer of the same company with headquarters in Chicago, Ill.

Gaetano Lanza, professor of theoretical and applied mechanics, in charge of the department of engineering of Massachusetts Institute of Technology, Boston, Mass., has been made professor emeritus.

Neal T. McKee has become identified with the Locomotive Superheater Co., New York. He was until recently associated with H. Clay McKee & Sons Co., Mt. Sterling, Ky.

Allen V. Moyer, formerly associated with the Lyons Boiler Works, De Pere, Wis., in the capacity of assistant secretary and mechanical engineer, has assumed the duties of secretary and treasurer of the American Welding Co., Carbondale, Pa.

Alfred Müllhaupt, Jr., has left the engineering department of the Buffalo Forge Co., Buffalo, N. Y., to take up sales work with the Westinghouse Electric and Manufacturing Co., East Pittsburgh, Pa.

William Newell has been appointed mechanical engineer of the Bureau of Factory Inspection of the New York State Department of Labor, in which capacity he will devote his attention to the prevention of industrial accidents. He was formerly assistant Superintendent of the liability department of the Fidelity and Casualty Co., New York.

Albin J. Nott has become identified with the Central Georgia Power Co., Macon, Ga., as designing draftsman. He was formerly switchboard man in charge of Pumping Station No. 6, Sewerage and Water Board, New Orleans, La.

Peter Schwamb has resigned from his position as professor of machine design and director of the mechanical laboratories at the Massachusetts Institute of Technology, Boston Mass.

Charles F. Scott, recently consulting engineer of the Westinghouse Electric and Manufacturing Co., Pittsburgh, Pa., has been appointed professor of electrical engineering, Sheffield Scientific School, Yale University, New Haven, Conn.

Jos. W. Seymour, formerly general superintendent of the W. A. Harris Steam Engine Co., Providence, R. I., has accepted a position with the Providence Engineering Works, of the same city.

W. H. Smead, formerly with the General Fire Extinguisher Co., Warren, O., has accepted a position with The Samuel Austin & Son Co., Cleveland, O., as superintendent of the heating and equipment department.

Rupert K. Stockwell has accepted a position with the Robins Conveying Belt Co., New York. He was until recently in the employ of the Tennessee Copper Co., Copperhill, Tenn.

L. P. Streeter has become associated with the Illinois Central Railroad, Chicago, Ill. in the capacity of air brake engineer. Mr. Streeter was formerly air brake inspector of the Southern Pacific Co., Los Angeles, Cal.

C. D. Terry, formerly superintendent of mill departments of the National Tube Co., Kewanee, Ill., has been appointed assistant to the general superintendent of the same company with headquarters in Pittsburgh, Pa.

W. H. Trask, Jr., has become connected with the United Hydro Electric Co., Idaho Springs, Colo. He was formerly assistant sales manager of the Central Colorado Power Co., Denver, Colo.

Frank S. Tucker, president of Tucker and Laxton, Charlotte, N. C., has become associated with the Westinghouse Electric and Manufacturing Co., Boston, Mass.

R. A. Wilson has resigned his position as expert gas engineer for the Snow Steam Pump Works, Buffalo, N. Y., to take up a similar line of work for the Carnegie Steel Co., with location at the Ohio Works, Youngstown, O.

# ACCESSIONS TO THE LIBRARY

## With Comments by the Librarian

This list includes only accessions to the library of this Society. Lists of accessions to the libraries of the A. I. E. E. and A. I. M. E. can be secured on request from Calvin W. Rice, Secretary, Am. Soc. M. E.

Bagasse Drying, E. W. Kerr. (Louisiana State University. Agricultural Experiment Station Bulletin no. 128). *Baton Rouge, 1911.*

Brussels Exhibition Fire with Some Suggestions as to Safeguards at Future Temporary Exhibitions. *London, 1911.*

Canal Record. Vol. 1; vol. 2, nos. 6, 9–26, 28–52; vol. 3, nos. 1–5, 9–14, 16–18, 21, 24, 26, 28-52; vol. 4, nos. 2–4, 7–52; vol. 5, no. 1. *Ancon, 1907–1911.* Gift of B. D. Pender.

Cambridge (Mass.) Water Board. Annual Report, 1911. *Cambridge, 1911.* Gift of the board.

Chicago School of Architecture. Year Book, 1911–1912. *Chicago, 1911.* Gift of the school.

Colorado Agricultural College. 32d Annual Register of Officers and Students. *Fort Collins, 1911.* Gift of the college.

Colorado School of Agriculture. 2d Annual Register of Officers and Students, 1911–1912. *Fort Collins, 1911.* Gift of State Agricultural College.

Composition of Raw Mixtures for Cement Making, S. B. Newberry. Ed. 3. (Bull. no. 8 Association of American Portland Cement Manufacturers.) *Philadelphia, 1905.* Gift of the association.

Dampflokomotiven der Gegenwart, Robert Garbe. *Berlin, 1907.*

David Ranken, Jr., School of Mechanical Trades Foundation Deed, Deed of Gift, Deed Referred to in Deed of Gift, Charter and By-Laws. 1910. *St. Louis, 1910.* Gift of the school.

———2d Annual Catalogue, 1911. *St. Louis, 1911.* Gift of the school.

Drahtseile, Josef Hrabák. *Berlin, 1902.*

Eiserne Brücken ein Lehr und Nachschlagebuch für Studierende und Konstrukteure, G. Schaper. Ed. 2. *Berlin, Ernst & Sohn, 1911.*

Elements of Electrical Transmission, O. J. Ferguson. *New York, Macmillan Co., 1911.*

The author is associate professor of electrical engineering in Union College, and the work is evidently designed for a textbook for college classes. It seems well planned, and embodies modern practice; is well illustrated and indexed.

Engineering Teacher and his Preparation, A. N. Talbot. (Reprinted from bulletin of the Society for the Promotion of Engineering Education, vol. 2, 1911.) Gift of the author.

Étude de la Stabilité de l'Aéroplane, G. de Bothezat. (Study of the stability of aeroplanes.) *Paris, 1911.* Gift of Dunod et E. Pinat.

This is a thesis for the doctorate degree in the École Polytechnique of Paris. The author discusses as a preliminary the forces acting on an aeroplane, the fundamentals in the construction of an aeroplane, and the action of the planes; the discussion of the stability is mathematical and is quite detailed.

Fire Precautions and the Coronation Celebrations, being a Report on the Special Fire-Preventive Work of the British Fire Prevention Committee for June 22, 23, 1911. *London, 1911.*

German Methods in Portland Cement Manufacture, Dry and Wet Processes, Otto Schott. *Philadelphia.* Gift of the Association of American Portland Cement Manufacturers.

Hilfsbuch für Wärme und Kälteschutz, I. Andersen. *Berlin, 1910.*

Multiplex Telephony and Telegraphy by means of Electric Waves Guided by Wires, Geo. O. Squier. Paper presented at Annual Convention, June 28, 1911, of American Institute of Electrical Engineers. Gift of the author.

National Machine Tool Builders' Association. Alphabetical and Segregated List.

Newberry College. Catalogue 1910–1911. *Columbia, 1911.* Gift of the college.

New York City Department of Docks and Ferries. Studies for Combined Waterfront and Terminal Industrial Development, C. Tomkins. *New York, 1911.* Gift of C. W. Staniford.

Power Plant Testing, J. A. Moyer. *New York, McGraw Hill Book Co., 1911.*

Report upon Price of Gas in Chicago for the Chicago Council Committee on Gas, Oil and Electric Light, Edward W. Bemis. *Chicago, 1911.* Gift of the author.

Report of the Fire at the Empire Palace Theatre, Edinburgh, May 9, 1911. (British Fire Prevention Committee, no. 157.) *London, 1911.*

Rohrleitungen. Gesellschaft für Hochdruck-Rohrleitungen. Vol. 1. *Berlin, 1909.*

Über Sandgebläse, H. P. A. Knacke. *Berlin, 1910.*

Schnellstahl und Schnellbetrieb im Werkzeugmaschinenbau, Fr. W. Hülle. *Berlin, 1909.*

Selbstkostenberechnung für Maschinenfabriken. J. Bruinier. *Berlin, 1908.*

Shipyard Practice as applied to Warship Construction, N. J. McDermaid. *London, Longmans, Green & Co., 1911.*

Standard Methods of Testing and Specifications for Cement. *Philadelphia, 1911.* Gift of Association of American Portland Cement Manufacturers.

Technische Untersuchungsmethoden zur Betriebskontrolle, J. Brand. Ed. 2. *Berlin, 1907.*

Tri-Borough Rapid Transit Railroad. (Bids for construction with municipal funds of portions. Submitted and opened October 27, 1910.) Gift of C. W. Rice.

United States War Department. Army List and Directory, August 20, September 20, 1911. *Washington, 1911.* Gift of the department.

University of Cincinnati. Reports of the Chairman and President, 1910. *Cincinnati.* Gift of the university.

University of Maine. Annual Report, 1909. *Orono, 1909.* Gift of the university.

University of Oklahoma. General Catalogue, 1910–1911. *Norman, 1911.* Gift of the university.

Ventilation of Electrical Machinery, W. H. F. Murdoch. *New York, 1911.*

This little work of 79 small pages summarizes in an elementary way what is known of the ventilation of generators. The author predicts that with the advance of artificial local cooling the cost of large generators may be reduced to one-half or one-third the present cost per kilowatt.

Western Australia Geological Survey. Bull. no. 41. *Perth, 1911.* Gift of Western Australia Geological Survey.

Western Railway Club. Official Proceedings, vol. 23. *Chicago, 1911.* Gift of the club.

Wood Pulp and its Uses, C. F. Cross, E. J. Bevan and R. W. Sindall. *New York, Van Nostrand Co., 1911.*

## GIFT OF MRS. CHARLES WALLACE HUNT

American Machinist. Vols. 5–12, 14–20, 22–28. *New York, 1882–1889, 1891–1897, 1899–1905.*

Dredge, James. Record of the transportation exhibits at the World's Columbian Exposition of 1893. *London–New York, 1894.*

Electrical Engineer. 1892–1894.

Electrical World. 1891–1894.

Engineer, The. Vols. 68–109, 1889–1910.

Engineering. Vols. 33–89, 1882–1910.

Engineering News. Vols. 25–36, 1891–1896.

Manufacturer and Builder. 1869.

Mechanics. 1884.

Railroad Gazette. 1891–1894.

Sanitary Engineer and Construction Record. Vol. 15, 1886–1887.

Scientific American. Vols. 3–8, 11–14, 55, nos. 13–26; vol. 56–57, 1847–1852, 1855–1859, 1886–1887.

Street Railway Journal. 1893, 1894.

United States Census Bureau. 12th Census. Vols. 1–2, 7–10, 1900.

Watts, I., Rankine, W. J. M. and others. Shipbuilding, Theoretical and Practical. Vols. 1–2. *London, 1886.*

Miscellaneous Periodicals, 2 vols.

## EXCHANGES

Institution of Civil Engineers. Minutes of Proceedings. Name Index, vols. 119–170. *London, 1910.*

Langley Memoir on Mechanical Flight. (Smithsonian Contributions to Knowledge. Vol. 27, no. 3.) *Washington, 1911.*

## UNITED ENGINEERING SOCIETY

American Year Book, 1910. *New York–London, 1911.* Gift of Engineers Club, New York.

Graphite as a Lubricant. Ed. 11. *Jersey City, 1909.* Gift of Joseph Dixon Crucible Co.

International Institute of Technical Bibliography. Year Book (Engineering Abstracts), 1910. *London, 1910.*

Rhodesia Chamber of Mines. 16th Annual Report 1910. *Cape Town, 1911.* Gift of the Rhodesia Chamber of Mines.

## GIFT OF G. H. CONDICT

American Institute of Electrical Engineers. Transactions, vols. 22, 23. *New York, 1904, 1905.*

Barber, T. W. Engineer's Sketch book of Mechanical Movements, etc. Ed. 3. *London, 1897.*

Camp, W. M. Notes on Track Construction and Maintenance. Ed. 2. *Chicago, 1904.*

Crosby, O. T. and Bell, Louis. Electric Railway in Theory and Practice. Ed. 2. *New York, 1893.*

Hiscox, G. D. Gas, Gasoline and Oil Vapor Engines. Ed. 2. *New York, 1898.*

——Mechanical Movements, Powers, Devices and Appliances. *New York, 1889.*

Hasluck, P. N. Automobile, Its Construction and Management. Translated from G. Lavergne's Manuel Theoretique et Pratique de L'Automobile sur Route. *Philadelphia, 1902.*

Jenkins, Rhys. Motor Cars and the Application of Mechanical Power to Road Vehicles. *London, 1892.*

Steinmetz, C. P. General Lectures on Electrical Engineering. *Schenectady, 1908.*

## GIFT OF UNIVERSAL VANADIUM COMPANY

Alloy Steels for Motor Car Construction, J. A. Mathews. *Pittsburgh.*

Case-Hardening Process, J. K. Smith. *Pittsburgh.*

Estimation of Vanadium in Ferro Alloys, Steels, Cupro-Vanadium, Brasses and Bronzes. *Pittsburgh.*

Static and Dynamic Properties of Steels. (Reprint of an article from Iron Age, July 2, 1908). *Pittsburgh.*

Vanadium: Its Application to Cast and Malleable Iron, with Results of Tests.

Vanadium: Its Service in Automobile Manufacture, J. K. Smith. *Pittsburgh.*

Vanadium Spring Steel (Type D). *Pittsburgh.*

Vanadium Steels. Their Classification and Heat Treatment with Directions for Application of Vanadium to Iron and Steel. *Pittsburgh, 1911.*

Vanadium Steels for the Automobile. *Pittsburgh, 1911.*

## TRADE CATALOGUES

Bell Electric Motor Company, *Garwood, N. J.* High efficiency, single-phase motors, 16 pp.

Bristol Co. *Waterbury, Conn.* Condensed catalogue no. 160 of Bristol instruments for pressure, temperature, time speed, etc., 64 pp.

Coatesville Boiler Works, *Coatesville, Pa.* Boilers, tanks, stacks, and steel-plate construction, 24 pp.

William Gainschow Co., *Chicago, Ill.* Catalogue no. 25 of cut and planed gears, cut-steel machine racks, gear patterns, etc., 228 pp.

Goldschmidt Thermit Co., *New York.* Reactions, 3d Quarter, 1911, devoted to alumino-thermics and the use of thermit in welding, 60 pp.

Ingersoll-Rand Co., *New York.* Class PB duplex power driven air compressor, 24 pp.

Manufacture Française d'Armes, *St. Étienne, France.* Catalogue of sporting goods and firearms, 940 pp.

Model Heating Co., *Philadelphia, Pa.* The model heating system, 23 pp.

H. Mueller Mfg. Co., *Decatur, Ill.* Catalogue of water, gas and plumbing brass goods and tools, 1100 pp.

Pulsometer Steam Pump Co., *New York.* The pulsometer; its operation, construction, application, 27 pp.

Turbo-Blower Co., *New York.* Description of the turbo-blower, 8 pp.

# EMPLOYMENT BULLETIN

The Society has always considered it a special obligation and pleasant duty to be the medium of securing better positions for its members. The Secretary gives this his personal attention and is most anxious to receive requests both for positions and for men available. Notices are not repeated except upon special request. Copy for notices in this Bulletin should be received before the 12th of the month. The list of men available is made up of members of the Society and these are on file, with the names of other good men not members of the Society, who are capable of filling responsible positions. Information will be sent upon application.

#### POSITIONS AVAILABLE

0122 Chief engineer with large established plant. Location Middle States. Must be good executive, competent to design and construct all manner of steel structures, familiar with the handling of materials, competent to solve electrically either D. C. or A. C. mechanical problems.

0123 Member with long experience desires to organize manufacturing company for large and successful specialty requiring total capital of $15,000 and necessitating only small working force.

0124 Member desires to associate with party willing to invest $5,000 in manufacturing a new electrical instrument now in great demand, patented and introduced successfully this past year.

#### MEN AVAILABLE

300 Mechanical engineer desires position as manager or operating engineer; for 12 years with large industrial plant as operating engineer. Best of references.

301 Mechanical and electrical engineer, Cornell graduate; ten years' practical experience in steam and hydraulic power-plant construction, gas work, building construction, including reinforced concrete, factory superintendence and maintenance. Desires position with consulting or contracting firm or as executive engineer in manufacturing concern.

302 Member; mechanical engineer and draftsman; extensive experience in general drafting-room work, power-plant design, mill engineering, inspecting, charge of men and office work, etc. Executive position preferred, but not essential. Best of references.

303 Member; now employed, with 17 years' experience in design and construction of machinery and buildings, manufacturing, systematizing and accounting, graduate Massachusetts Institute of Technology in mechanical

engineering, post-graduate course in electrical engineering, desires permanent position in New York City, administrative or executive capacity.

304 Member; experienced in construction, management, manufacturing, organization and independent research work. desires to become identified in responsible capacity with manufacturing or industrial concern of prominence. Concise record of experience and references on file at A.S.M.E.

305 Stevens graduate, mechanical engineer, Junior member; six years' general experience in steam and electrical engineering work, especially from commercial end, desires position as sales engineer or as assistant in firm of consulting or industrial engineers. Best references from present employers. Age 27.

306 Electrical engineer, 18 years' experience in Corliss engine and steam turbine power plants; motor driving in industrial plants, operation, maintenance and construction of general electrical work in executive capacity in large industrial plants. Salary $2400.

307 Thoroughly competent chief engineer, who can produce results, desires to make a change in his position; 17 years' practical experience on large steam and gas engines, boilers and power-plant equipment. Thirty-eight years of age, married. Can furnish the best of references. Middle West preferred.

308 Mechanical and electrical engineer, college graduate, seven years' experience in power-plant design, erection and general plant engineering, including estimates, drafting and supervision; accustomed to handling men, both in engineering office and field, purchasing equipment, drawing contracts, appraising properties, maintenance and operation of equipment; experience covers steam and hydraulic power, electrical machinery and equipment, electric lighting plants, surveys, buildings, furnaces, heating systems, hydraulic equipment and machine design. Desires position either in above lines, in sales engineering, or with contractor. At present employed.

309 Technical graduate experienced in drafting room and in office work, desires position in connecion with power and industrial plant installations.

310 Cornell mechanical and electrical engineer; 17 years' experience in electric railway, power and industrial plant design, cost accounting, manufacturing, office administration, etc., good draftsman and systematizer, competent as works manager, superintendent, auditor, purchasing agent, and efficiency engineer.

311 Member with wide experience as superintendent, familiar with modern machine-shop practice, expert on tools and methods for increasing production and reducing costs.

312 Works manager, superintendent or efficiency engineer, with 20 years' experience in similar capacity with some of the best known concerns in the country. Can furnish good references.

313 Member with 25 years' experience in designing special tools and general machine work of all kinds, hydraulic, steam, coal-handling, stokers and furnace work, will be pleased to give part time for outside work.

314 Mechanical engineer, wide experience in sale of power plant equipment, will be available November 1. New York territory preferred.

315 Member, over 20 years' experience in design, superintendence and management in shop and field, desires position preferably near Philadelphia.

316 Technical graduate with 18 years' experience in shop, drafting room, office and teaching in mechanical engineering, the last including executive work, would like to change. Desires to become connected with consulting engineer or with engineering department in college or university.

## CHANGES IN MEMBERSHIP

### CHANGES IN ADDRESS

ALBRIGHT, H. Fleetwood (1903), Genl. Supt., West. Elec. Co., Hawthorne Sta., Chicago, Ill.

ALEXANDER, Edward E. (Associate, 1908), Ch. Draftsman, Taylor Iron & Steel Co., High Bridge, N. J.

ALSBERG, Julius (Junior, 1905), Asst. to John Bogart, 141 Broadway, and *for mail*, 56 W. 95th St., New York, N. Y.

AUE, Joseph E. (1899), Ch. Engr. Gas and Oil Eng. Dept., De La Vergne Mch. Co., foot E. 138th St., New York, N. Y.

BAILEY, Alex. D. (Junior, 1910), Asst. to Ch. Engr., Commonwealth Edison Co., Chicago, and *for mail*, 21 Elmwood Ave.. La Grange, Ill.

BAILEY, William J. (Junior, 1910), United Coal Co., Pa. Bldg., and *for mail*, 5831 Springfield Ave., Philadelphia, Pa.

BANKS, Thomas Dent (Junior, 1910), Asst. Engr., Dept. Pub. Service, and *for mail*, 215 W. 11th Ave., Columbus, O.

BARR, John H. (1889), Cons. Engr., Union Typewriter Co., 293 Broadway, New York, N. Y.

BEHREND, Ernst Richard (1900), Pres. and Genl. Mgr., Hammermill Paper Co., Erie, Pa.

BENTLEY, O. D. H. (1910), Mgr. Turbine Dept., B. F. Sturtevant Co., Hyde Park, Mass.

BERRYMAN, Wilson G. (Junior, 1905), Engr., Combustion Utilities Corp., 60 Wall St., New York, and *for mail*, 36 Murray St., Flushing, N. Y.

BOYD, William Wallace (Junior, 1910), Engrg. Dept., E. & T. Fairbanks & Co., and *for mail*, Box 78, St. Johnsbury, Vt.

BROOKS, Louis C. (Junior, 1901), Elec. Engr. Industrial Control Dept., Genl. Elec. Co., and *for mail*, Route 49, Schnectady, N. Y.

CHENEY, Walter L. (1883), Sales Mgr., Lucas Mch. Tool Co., Cleveland, O., and Meriden, Conn.

COES, Harold V. O. (Junior, 1907), Mgr. Chicago Office, Lockwood Greene & Co., First Natl. Bank Bldg., Chicago, Ill.

CONRAD, Hugh Vincent (1887; 1891), Natl. Brake & Elec. Co., Milwaukee, Wis.

COOK, Harry Hall (Junior, 1910), Engr., Chapman Valve Mfg. Co., Indian Orchard, and *for mail*, 44 Massachusetts Ave., Springfield, Mass.

CORNELIUS, Henry Robert (1888), Sales Mgr., Mesta Mch. Co., and Darlington Rd., Pittsburgh, Pa.

COWLES, William Barnum (1881), R. Hoe & Co., 504 Grand St., New York, N. Y.

CRAMP, Edwin S. (1888), Vice-President, 1896-1898; 829 Park Ave., New York, N. Y.

CROGHAN, John T. (Associate, 1909), Stone & Webster Engrg. Corp., West Boylston, Mass.

CUNNINGHAM, George H. (Junior, 1910), 301 Hilda Ave, Missoula. Mont.

DALLIS, Park Andrew (1911), Mill Arch. and Engr., 913 Candler Bldg., Atlanta, Ga.

DODDS, William B. (Junior, 1907), Instr. Mech. Engrg., Harvard Univ., 111 Pierce Hall, Cambridge, Mass.

DORNER, Frederick Harry (Junior, 1907), Mech. Engr., Bayley Mfg. Co., and *for mail*, 716 Prospect Ave., Milwaukee, Wis.

EILERS, Karl Emrich (1890; 1904), Am. Smelting & Refining Co., 165 Broadway, and *for mail*, 435 Riverside Drive, New York, N. Y.

ELMER, Wm. (Junior, 1896), Supt. M. P., Pa. R. R., 622 Brisbane Bldg., Buffalo, N. Y.

FERGUSON, Geo. R. (1890), 179 Washington St., Brooklyn, N. Y.

FLANDERS, Ralph E. (Associate, 1908), Engr., The Fellows Gear Shaper Co., and *for mail*, 41 Pleasant St., Springfield, Vt.

FOSTER, Horatio A. (1895), Elec. Engr., 229 S. Broadway, Yonkers, N. Y.

FOWLER, Geo. L. (1886), Cons. Mech. Engr., 83 Fulton St., New York, N. Y.

FRY, Lawford H. (1905), Tech. Rep. in Europe, Baldwin Loco. Wks., 34 Victoria St., London, S. W., England.

FULLER, Floid M. (Junior, 1907), 509 Fidelity Bldg., and Y. M. C. A., Duluth, Minn.

GARDNER, Thomas M. (1903), Anna, Ill.

GAST, George Fred (Junior, 1910), Atlantic Gulf & Pacific Co., and *for mail*, 1239 Fairfax Ave., San Francisco, Cal.

GODDARD, Arthur L. (1903), Supt. of Shops, Univ. of Wis., and *for mail*, 1717 Monroe St., Madison, Wis.

GREENE, Augustine E. (1909), Mill Engr., 847 Main St., and 20 Imlay St., Hartford, Conn.

HADFIELD, Sir Robert Abbott, F. R. S. (1907), Chairman and Managing Dir., Hadfield Co., Sheffield, and *for mail*, 3 Green St., also 28 Hertford St., Mayfair, W., London, England.

HAMILTON, James (1898), Pat. Lawyer, 31 Nassau St., New York, N. Y., and *for mail*, 80 Beech St., East Orange, N. J.

HARGRAVE, Russell William (Junior, 1899), Gisholt Mch. Co., Madison, and *for mail*, P. O. box 223, Appleton, Wis.

HATMAN, Julius G. (Junior, 1911), Asst. Supt., The Wyandotte County Gas Co., and *for mail*, 607-A, Orville Ave., Kansas City, Kan.

HENDERSON, Richard (1906), Capt., U. S. N., Ret., P. O. Box 285, Salisbury, N. C.

HITCHCOCK, Fred'k Matthew (1899; 1907), Exec. Engr., Dexter Folding Co., Pearl River, N. Y.

HODGE, Wm. W. (Junior, 1909), Asst. Supt. Elec. Cable Wks., Am. Steel & Wire Co., and *for mail*, 3 Berkman St.. Worcester, Mass.

HOFMEYER, George August (Associate, 1905), Bldg. Supt., Gimbel Bros., Broadway and 33d St., and *for mail*, 250 W. 22d St., New York, N. Y.

HOGUE, Oliver D. (1909), V. P. and Treas., The Goulds Mfg. Co. of Ill., cor. Ohio and Franklin Sts., and The Pattington, 660 Graceland Ave., Chicago, Ill.

HOLMES, Urban Tigner (1910), Commander U. S. N., U. S. S. Louisiana, care of Postmaster, New York, N. Y.

HUMPHREYS, Alex C. (1884), Manager, 1907–1910; Vice-President, 1910-1911; Life Member; Pres., Stevens Inst. of Tech., Hoboken, N. J., Pres. Buffalo Gas Co., and *for mail*, Pres., Humphreys & Miller, Inc., 165 Broadway, New York, N. Y.

HUNT, Leigh A. (1906), Pres., Hunt Engrg. Co., 911 Commerce Bldg., Kansas City, Mo.

JURGENSEN, Jess Christian (Associate, 1905), United Piece Dye Wks., Lodi, N. J.

KELMAN, John H. (1904), 194 Lefferts Pl., Brooklyn, N. Y.

LAFORE, John Armand (1904), Second V. P., Lathbury-D'Olier Co., Morris Bldg., and *for mail*, Shady Hill, Logan P. O., Philadelphia, Pa.

LAIRD, Wilbur G. (Associate, 1906), with Henry L. Doherty, 60 Wall St., New York, N. Y.

LANGE, Heinrich Bartels (Junior, 1910), Am. Optical Co., and *for mail*, 4 Walnut St., Southbridge, Mass.

LANZA, Cav. Gaetano (1882), Prof. Emeritus Theor. and Applied Mech., Mass. Inst. of Tech., Boston, Mass., and Engr., Baldwin Loco. Wks., 500 N. Broad St., and *for mail*, The Montevista, 63d and Oxford Sts., Philadelphia, Pa.

LELAND, Sanford Daniels (1900), Pres. and Genl. Mgr., Mfg. Equip. & Engrg. Co., 209 Washington St., Boston, and *for mail*, 6 Arlington Rd., Wellesley Hills, Mass.

LUDY, Llewellyn V. (1905), Acting Prof. Steam and Gas Engrg., Univ. of Wis., Madison, Wis.

McKEE, Neal Trimble (Junior, 1907), Loco. Superheater Co., 30 Church St., New York, N. Y.

MacLAREN, Malcolm Neill (1899), Nordberg Mfg. Co., 42 Broadway, New York, N. Y.

MERRILL, Albert S. (Junior, 1903), 122 N. 3d St., Easton, Pa.

MITCHELL, Guy Edward (1903), Mgr. Pittsfield Plant, Alden Sampson Mfg. Co., Pittsfield, and *for mail*, 60 Dudley St., Medford, Mass.

MONTGOMERY, H. M. (1889), Chicago Mgr., Alberger Condenser Co., 137 S. LaSalle St., Chicago, and 1221 Davis St., Evanston, Ill.

MOYER, Allen V. (Junior, 1909), Secy. and Treas., Am. Welding Co., and *for mail*, Lock Box 902, Carbondale, Pa.

MÜLLHAUPT, Alfred, Jr. (Junior, 1911), Sales Wk., Westinghouse Elec. & Mfg. Co., East Pittsburgh, and *for mail*, 208 Gray Bldg., Wilkinsburg, Pa.

MURRAY, Charles R. (Associate, 1889), Supt., Barnhart Bros. & Spindler, 168–172 W. Monroe St., Chicago, and 1714 Asbury Ave., Evanston, Ill.

NOTT, Albin James (Junior, 1910), Designing Draftsman, Central Ga. Power Co., and *for mail*, 6 Nevarro Flats, Macon, Ga.

OSTERGREN, Oscar Patric (1910), Mech. and Cons. Engr., 431 Throop Ave., Brooklyn, N. Y.

PALMER, Arthur E. (Junior, 1909), Sales Engr., 710 New England Bldg., Cleveland, and *for mail*, 105 Carlyon Rd., East Cleveland, O.

PARKER, Levin S. (1908), Atlas Dredging Co., 1629 Whitehall Bldg., New York, N. Y.

PLACE, Clyde R. (Associate, 1907), Mech. Engr., 70 E. 45th St., New York, N. Y., and River Edge, N. J.

POTTS, S. Warren (1909), Mech. Engr., R. Hoe & Co., 504 Grand St., New York, and *for mail*, 34 Shepherd Ave., Brooklyn, N. Y.

RAY, Frederick (Junior, 1903), Ch. Engr., Alberger Pump Co., 140 Cedar St., New York, N. Y., and Hemlock Rd., Short Hills, N. J.

RICHARDS, Chas. Dexter (Junior, 1904), Asst. Engr. of Tests, Solvay Process Co., and *for mail*, 268 Meadowbrook Ave., Detroit, Mich.

ROBESON, Anthony Maurice (1895), care of A. Moir, 1 London Wall Bldgs., London, E. C., England.

RUMSEY, Spencer S. (1900; 1907), Engr. of Constr., Oliver Iron Min. Co., 713 Wolvin Bldg., and 217 S. 19th Ave., E. Duluth, Minn.

RUPP, M. E. (Junior, 1909), Mech. Engr., Stanley G. Flagg & Co., 1421 Chestnut St., Philadelphia, Pa., and 303 E. 4th St., New York, N. Y.

SAWFORD, Frank (1909), 687 George St., Sydney, N. S., Canada.

SCOTT, Charles Felton (1911), Prof. Elec. Engrg., S. S. S., Yale Univ., and *for mail*, 284 Orange St., New Haven, Conn.

SEYMOUR, Jos. W. (Junior, 1891), Providence Engrg. Wks., Providence, and *for mail*, 29 Arnold Ave., Edgewood, R. I.

SHEPARD, Geo. H. (1903), Emerson Co., 30 Church St., New York, N. Y., and *for mail*, 1206 Harrison St., Syracuse, N. Y.

SHERWOOD, Mather W. (1909), Mech. Engr., Chicago Pneu. Tool Co., and *for mail*, 1406 Liberty St., Franklin, Pa.

SOWDEN, Parkin T. (Junior, 1908), Mech. Engr., Stand. Silver Co., Ltd., 33 Hayter St., and 32 Palmerston Gardens, Toronto, Ont., Canada.

SPONSEL, C. W. (1902), 22 Huntington St., Hartford, Conn.

STOCKWELL, Rupert Kennedy (Junior, 1910), Engr., The Robins Conveying Belt Co., 13 Park Row, New York, N. Y.

STREETER, Lafayette P. (1902; Associate, 1903), Air Brake Engr., Ill. Central. R. R., and *for mail*, P. O. Box 69, Chicago, Ill.

TADDIKEN, J. F., Jr. (Junior, 1907), Am. Beet Sugar Co., Oxnard, Cal.

TERRY, Charles D. (1902; 1908), Asst. to Genl. Supt., Natl. Tube Co., 1706 Frick Bldg., Pittsburgh, and *for mail*, 1123 South Ave., Wilkinsburg, Pa.

THOMAS, Carl C. (1908), Prof. Steam and Gas Engrg., Univ. of Wis., Madison, Wis., and *for mail*, Münchnerstr. 8[II] Dresden, Germany.

THURSTON, Edward D., Jr. (Junior, 1909), Instr. Dept. Mech. Engrg., Columbia Univ. and *for mail*, 511 W. 113th St., New York, N. Y.

TRASK, Walter H., Jr. (Junior, 1908), Engr., The United Hydro Elec. Co., Idaho Springs, Colo.

TRAUTSCHOLD, Reginald (Junior, 1904), 90 Upper Mountain Ave., Montclair, N. J.

TRUELL, Karl O. (Associate, 1906), Sydney Cement Co., Sydney, N. S., Canada.

TUCKER, Frank Stevenson (1905), Westinghouse Elec. & Mfg. Co., and *for mail*, P. O. Box 3303, Boston, Mass.

ULBRICHT, T. Carlile (Junior, 1908), Instr. Dept. of Power Engrg., Sibley College, Cornell Univ., and *for mail*, 128 Dryden Rd., Ithaca, N. Y.

WEBBER, William Oliver (1881), Cons. Engr., 7 Wellington Terrace, Brookline, Mass.

WEBSTER, Lawrence Burns (Junior, 1910), Mech. Engr., Am. Gas & Elec. Co., 30 Church St., New York, N. Y., and *for mail*, 926 S. Washington St., Marion, Ind.

WEGG, David S., Jr. (Junior, 1909), Telluride Asso., Ithaca, N. Y., and 16 E. Ontario St., Chicago, Ill.

WETMORE, Charles P. (1901), 588 Astor St., Milwaukee, Wis.

WILSON, Robert Alexander (Junior, 1910), Carnegie Steel Co., Ohio Wks., Youngstown, O.

YEOMANS, Lucien I. (1910), Production Engr. Dept. 213, Sears, Roebuck & Co., and 416 E. 48th Pl., Chicago, Ill.

## NEW MEMBERS

ASPINALL, John A. F. (Honorary, 1911), Gledhill, Mossley Hill Drive, Liverpool, England.

BLAIR, William Richard (1911), Wks. Mgr., Landis Mch. Co., St. Louis, Mo.

FRANCIS, Isaac Hathaway, Jr. (1911), Cons. Engr., 1508 Commonwealth Trust Bldg., Philadelphia, Pa.

MURPHY, Thomas Robert Hoysted (Junior, 1911), Industrial Engr. and Draftsman, Jos. H. Wallace & Co., 5 Beekman St., New York, N. Y., and *for mail*, P. O. Box 185, Espanola, Ont., Canada.

VICTOREEN, Ernest Vitalis (1910), Supt. Shops, Tenn. Coal, Iron & R. R. Co., Ensley, and *for mail*, 2233 Arlington Ave., Birmingham, Ala.

## PROMOTIONS

COLE, Arthur W. (1904; 1911), Asst. Prof. Mech. Engrg., Purdue Univ., Lafayette, and *for mail*, 224 Waldron St., West Lafayette, Ind.

FOX, Royal E., Jr. (1901; 1911), V. P., The Engr. Co., Rm. 1180, 50 Church St., and Irving Arms, 222 Riverside Drive, New York, N. Y.

MATTHEWS, Fred Elwood (1904; 1911), Asst. Mgr. Cold Storage Insulation Dept., H. W. Johns-Manville Co., 100 William St., New York, N. Y.

## DEATHS

GOBEILLE, Jos. Léon, September 12, 1911.
McKINNEY, William S., August 30, 1911.
TURNER, John, September 12, 1911.

# COMING MEETINGS

## November–December

**Advance notices of annual and semi-annual meetings of engineering societies are regularly published under this heading and secretaries or members of societies whose meetings are of interest to engineers are invited to send such notices for publication. They should be in the editor's hands by the 15th of the month preceding the meeting. When the titles of papers read at monthly meetings are furnished they will also be published.**

AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE
December 27, annual meeting, Washington, D. C. Secy., L. O. Howard, Smithsonian Institution.

AMERICAN CHEMICAL SOCIETY
December 27–30, annual meeting, Washington, D. C. Secy., C. L. Parsons, Durham, N. H.

AMERICAN INSTITUTE OF CHEMICAL ENGINEERS
December 20–22, annual meeting, Washington, D. C. Secy., J. C. Olsen, Polytechnic Institute, Brooklyn, N. Y.

AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS
November 10, monthly meeting, 29 W. 39th St., New York. Secy., R. W. Pope.

AMERICAN PUBLIC HEALTH ASSOCIATION
December 4–9, annual meeting, Havana, Cuba. Secy., W. C. Woodward, Washington, D. C.

AMERICAN RAILWAY ASSOCIATION
November 15, semi-annual meeting, Chicago, Ill. Secy., W. F. Allen, 75 Church St., New York.

AMERICAN ROADMASTER'S ASSOCIATION
November 14–17, annual convention, Rochester, N. Y. Secy., E. L. Powers, 150 Nassau St., New York.

AMERICAN SOCIETY FOR JUDICIAL SETTLEMENT OF INTERNATIONAL DISPUTES
November 7-8, Conference, Cincinnati, O. Secy., T. Marburg, Baltimore, Md.

AMERICAN SOCIETY FOR MUNICIPAL IMPROVEMENTS
December 11–13, annual meeting, Waldorf-Astoria, New York. Secy., A. P. Folwell, 239 W. 39th St.

AMERICAN SOCIETY OF AGRICULTURAL ENGINEERS
December 27–30, annual meeting, St. Paul, Minn. Secy., J. B. Davidson, Ames, Iowa.

AMERICAN SOCIETY OF CIVIL ENGINEERS
November 1 and 15, bi-monthly meetings, 220 W. 57th St., New York. Secy., C. W. Hunt.

THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS
Monthly Meetings: New York, November 14; Boston, November 15; New Haven, November 15. Secy., Calvin W. Rice, 29 W. 39th St., New York.

ASSOCIATION OF RAILWAY ELECTRICAL ENGINEERS
November 6–10, annual convention, Chicago, Ill., Secy., J. A. Andreucetti, C. & N. W. Ry.

ENGINEERS CLUB OF ST. LOUIS
December 6, annual business meeting, 3817 Olive St., St. Louis, Mo. Secy., W. W. Horner.

NATIONAL ASSOCIATION OF BRASS MANUFACTURERS
December 13–14, annual meeting, New York. Secy., W. M. Webster, 64 W. Randolph St., Chicago, Ill.

NATIONAL FOUNDER'S ASSOCIATION
November 15–16, annual convention, New York. Secy., F. W. Hutchings, 915 Hammond Building, Detroit, Mich.

NATIONAL GAS AND GASOLINE ENGINE TRADES ASSOCIATION
December 5–8, annual meeting, Hotel Hollenden, Cleveland, O. Secy., A. Stritmatter, 224 E. 7th Ave., Cincinnati.

NATIONAL IRRIGATION CONGRESS
December 5–9, Chicago, Ill. Secy., Arthur Hooker, 830 Commercial National Bank Bldg., Chicago, Ill.

NATIONAL SOCIETY FOR THE PROMOTION OF INDUSTRIAL EDUCATION
November 2–4, annual meeting, Cincinnati, O. Secy., E. H. Reisner, 20 W. 44th St., New York.

OHIO SOCIETY OF MECHANICAL, ELECTRICAL AND STEAM ENGINEERS
November 17–18, annual meeting, Canton, O. Secy., F. E. Sanborn, Ohio State University, Columbus.

SOCIETY OF NAVAL ARCHITECTS AND MARINE ENGINEERS
November 16–17, annual meeting, New York. Secy., W. J. Baxter, 29 W. 39th St.

## MEETINGS IN THE ENGINEERING SOCIETIES BUILDING

| Date | Society | Secretary | Time |
|---|---|---|---|
| November | | | |
| 2 | Blue Room Engineering Society | W. D. Sprague | 8.00 p.m. |
| 9 | Illuminating Engineering Society | P. S. Millar | 8.00 p.m. |
| 9 | Institute of Operating Engineers | H. Collins | 8.00 p.m. |
| 10 | American Institute of Electrical Engineers | R. W. Pope | 8.00 p.m. |
| 14 | American Society of Mechanical Engineers | C. W. Rice | 8.00 p.m. |
| 16 | American Society of Engineer Draftsmen | H. L. Sloan | 8.00 p.m. |
| 16–17 | Society of Naval Architects and Marine Engineers | W. J. Baxter | All day. |
| 17 | New York Railroad Club | H. D. Vought | 8.15 p.m. |
| 21 | New York Telephone Society | T. H. Lawrence | 8.00 p.m. |
| 22 | Municipal Engineers of New York | C. D. Pollock | 8.00 p.m. |

| Date | Society | Secretary | Time |
|---|---|---|---|
| December | | | |
| 5-8 | American Society of Mechanical Engineers | C. W. Rice | All day. |
| 7 | Blue Room Engineering Society | W. D. Sprague | 8.15 p.m. |
| 8 | American Institute of Electrical Engineers | F.L.Hutchinson (Acting Secy.) | 8.15 p.m. |
| 14 | Illuminating Engineering Society | P. S. Millar | 8.00 p.m. |
| 15 | New York Railroad Club | H. D. Vought | 8.15 p.m. |
| 19 | New York Telephone Society | T. H. Lawrence | 8.15 p.m. |
| 27 | Municipal Engineers of New York | C. D. Pollock | 8.15 p.m. |

## OFFICERS AND COUNCIL

*President*

E. D. MEIER

*Vice-Presidents*

Terms expire 1911
CHARLES WHITING BAKER
W. F. M. GOSS
ALEX. C. HUMPHREYS

Terms expire 1912
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Terms expire 1912
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Terms expire 1913
D. F. CRAWFORD
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ROBERT M. DIXON

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F. J. MILLER (4)

Note—Numbers in parentheses indicate number of years the member has yet to serve.

## SOCIETY REPRESENTATIVES

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W. F. M. GOSS (2)
H. R. TOWNE (3)
J. A. BASHEAR (4)

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*Conservation Commisson*

G. F. SWAIN
C. T. MAIN
J. R. FREEMAN

*A. A. A. S.*

A. C. HUMPHREYS
H. G. REIST

*I. A. for T. M.*

CHARLES KIRCHHOFF

*Engineering Education*

A. C. HUMPHREYS
F. W. TAYLOR

## SPECIAL COMMITTEES

*Refrigeration*

D. S. JACOBUS
A. P. TRAUTWEIN
G. T. VOORHEES
P. De C. BALL
E. F. MILLER

*Power Tests*

D. S. JACOBUS, *Chmn.*
E. T. ADAMS
G. H. BARRUS
L. P. BRECKENRIDGE
W. KENT
C. E. LUCKE
E. F. MILLER
A. WEST
A. C. WOOD

*Conservation*

G. F. SWAIN, *Chmn.*
C. W. BAKER
L. D. BURLINGAME
M. L. HOLMAN
CALVIN W. RICE

*Student Branches*

F. R. HUTTON, *Chmn.*

*Sub-Committee on Steam of Research Commmittee*

R. H. RICE, *Chmn.*
J. F. M. PATITZ
C. J. BACON
E. J. BERG
W. D. ENNIS
L. S. MARKS

*Flanges*

G. H. STOTT, *Chmn.*
A. C. ASHTON
W. SCHWANHAUSSER
J. P. SPARROW
W. M. McFARLAND

*Constitution and By-Laws*

J. M. SMITH, *Temp. Chmn.*
G. M. BASFORD
F. R. HUTTON
D. S. JACOBUS
H. G. STOTT

*Power House Piping*

H. G. STOTT, *Chmn.*
I. E. MOULTROP
H. P. NORTON
J. P. WHITTLESEY
F. R. HUTTON

*Involute Gears*

W. LEWIS, *Chmn.*
H. BILGRIM
E. R. FELLOWS
C. R. GABRIEL
G. LANZA

*Engineering Standards*

HENRY HESS, *Chmn.*
H. W. SPANGLER
CHAS. DAY
J. H. BARR

*Standardization of Catalogues*

WM. KENT, *Chmn.*
M. L. COOKE
W. B. SNOW
J. R. BIBBINS

*Pipe Threads*

E. M. HERR, *Chmn.*
W. J. BALDWIN
G. M. BOND
S. G. FLAGG, JR.

*Society History*

J. E. SWEET
H. H. SUPLEE
F. R. HUTTON

*Tellers of Election*

W. T. DONNELLY
G. A. ORROK
T. STEBBINS

*Nominating*

R. C. CARPENTER
New York, *Chmn.*
R. H. FERNALD
Cleveland, O.
E. G. SPILSBURY
New York
A. M. HUNT
San Francisco, Cal.
C. J. H. WOODBURY
Boston, Mass.

*Committee to Formulate Standard Specifications for the Construction of Steam Boilers and other Pressure Vessels and for Care of Same in Service*

J. A. STEVENS, *Chmn.*
E. F. MILLER
C. L. HUSTON
C. H. MEINHOLTZ
R. C. CARPENTER
W. H. BOEHM
R. HAMMOND

NOTE—Numbers in parentheses indicate number of years the member has yet to serve.

## SPECIAL COMMITTEES

(*Continued*)

### *Administration*

J. M. DODGE, *Chmn.*
H. A. HEY, *Secy.*
D. M. BATES
H. A. EVANS
W. LEWIS
W. L. LYALL
W. B. TARDY
H. R. TOWNE
H. H. VAUGHAN

## MEETINGS OF THE SOCIETY

### *The Committee on Meetings*

L. R. POMEROY (1), *Chmn.*
C. E. LUCKE (2)
C. J. H. WOODBURY (5)
H. De B. PARSONS (3)
W. E. HALL (4)

### *Meetings of the Society in Boston*

I. N. HOLLIS, *Chmn.*
I. E. MOULTROP, *Secy.*
R. H. RICE
E. F. MILLER
R. E. CURTIS

### *Meetings of the Society in New York*

W. RAUTENSTRAUCH, *Chmn*
F. A. WALDRON. *Secy.*
R. V. WRIGHT
F. H. COLVIN
E. VAN WINKLE

### *Meetings of the Society in St. Louis*

E. L. OHLE, *Chmn.*
F. E. BAUSCH, *Secy.*
J. HUNTER
M. L. HOLMAN
R. H. TAIT

### *Meetings of the Society in San Francisco*

A. M. HUNT, *Chmn.*
T. W. RANSOM, *Secy.*
E. C. JONES
T. MORRIN
W. F. DURAND

### *Meetings of the Society in Philadelphia*

T. C. McBRIDE, *Chmn.*
D. R. YARNALL, *Secy.*
W. C. KERR
A. C. JACKSON
J. E. GIBSON
J. C. PARKER

### *Meetings of the Society in New Haven*

E. S. COOLEY, *Chmn.*
E. H. LOCKWOOD, *Secy.*
H. B. SARGENT
L. P. BRECKENRIDGE
F. L. BIGELOW

## SUB-COMMITTEES ON

### *Textiles*

CHARLES T. PLUNKETT, *Chmn.*, Adams, Mass.

DANIEL M. BATES, Wilmington, Del.
JOHN ECCLES, Taftville, Conn.
EDW. W. FRANCE, Philadelphia, Pa.
EDWARD F. GREENE, Boston, Mass.
FRANKLIN W. HOBBS, Boston, Mass.
C. R. MAKEPEACE, Providence, R. I.
C. H. MANNING, Manchester, N. H.
HENRY F. MANSFIELD, Utica, N. Y.

EDWARD W. THOMAS, *Secy*, Lowell, Mass.

Note—Numbers in parentheses indicate the number of years the member has yet to serve.

## MEETINGS OF THE SOCIETY

*(Continued)*

### *Cement*

W. R. DUNN, *Chmn.*
F. W. KELLEY, *Secy.*
J. G. BERGQUIST
W. F. COWHAM
J. W. FULLER, Jr.
L. L. GRIFFITHS
E. M. HAGAR
LEIGH HUNT
MORRIS KIND
F. H. LEWIS
R. K. MEADE
EJNAR POSSELT
H. J. SEAMAN
A. C. TAGGE
H. STRUCKMANN
P. H. WILSON

### *Machine Shop Practice*

F. E. ROGERS, *Chmn.*
L. D. BURLINGAME
W. L. CLARK
W. A. DIEFENDORF
A. L. DeLEEUW
F. L. EBERHARDT
F. A. ERRINGTON
A. A. FULLER
H. D. GORDON
H. K. HATHAWAY
E. J. KEARNEY
Wm. LODGE

## OFFICERS OF AFFILIATED SOCIETY

### *Providence Association of Mechanical Engineers*

T. M. PHETTEPLACE, *Pres.*
W. H. PAINE, *Vice-Pres.*
J. A. BROOKS, *Secy.*
A. H. WHATLEY, *Treas.*

## OFFICERS OF THE GAS POWER SECTION

*Chairman*
R. H. FERNALD

*Secretary*
GEO. A. ORROK

*Gas Power Executive Committee*

F. H. STILLMAN (5), *Chmn.*
G. I. ROCKWOOD (1)
C. J. DAVIDSON (1)
E. D. DREYFUS (1)
F. R. HUTTON (2)
H. H. SUPLEE (3)
F. R. LOW (4)

*Gas Power Committee on Meetings*

WM. T. MAGRUDER, *Chmn.*
W. H. BALUVELT
E. D. DREYFUS
A. H. GOLDINGHAM
NISBET LATTA
H. B. MACFARLAND

*Gas Power Literature Committee*

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H. S. ISHAM
W. F. MONAGHAN
A. W. H. GRIEPE
W. S. MORRISON
H. G. WOLFE
N. J. YOUNG
S. O. SANDELL
S. I. OESTERREICHER
J. MAIBAUM

*Gas Power Installations Committee*

L. B. LENT, *Chmn.*
A. BEMENT
C. B. REARICK

*Gas Power Plant Operations Committee*

I. E. MOULTROP, *Chmn.*
J. D. ANDREW
C. J. DAVIDSON
C. N. DUFFY
H. J. K. FREYN
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*Gas Power Membership Committee*

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A. E. JOHNSON
F. S. KING
A. F. STILLMAN
G. M. S. TAIT
GEORGE W. WHYTE
S. S. WYER

## OFFICERS OF STUDENT BRANCHES

| INSTITUTION | DATE AUTHORIZED BY COUNCIL | HONORARY CHAIRMAN | PRESIDENT | CORRESPONDING SECRETARY |
|---|---|---|---|---|
| Stevens Inst. of Tech. | Dec. 4, 1908 | Alex. C. Humphreys | A. E. Bauhan | A. D. Karr |
| Cornell University | Dec. 4, 1908 | R. C. Carpenter | F. E. Yoakem | D. S. Wegg, Jr. |
| Armour Inst. of Tech. | Mar. 9, 1909 | G. F. Gebhardt | C. E. Beck | F. H. Griffiths |
| LelandStanfordJr.Univ. | Mar. 9, 1909 | W. F. Durand | C. H. Shattuck | C. W. Scholefield |
| Brooklyn Poly. Inst. | Mar. 9, 1909 | W. D. Ennis | A. L. Palmer | R. C. Ennis |
| Purdue University | Mar. 9, 1909 | L. V. Ludy | L. Jones | H. E. Sproull |
| University of Kansas | Mar. 9, 1909 | P. F. Walker | V. H. Hilford | L. L. Browne |
| New York University | Nov. 9, 1909 | C. E. Houghton | Harry Anderson | Andrew Hamilton |
| Univ. of Illinois | Nov. 9, 1909 | W. F. M. Goss | F. J. Schlink | E. J. Hasselquist |
| Penna. State College | Nov. 9, 1909 | J. P. Jackson | J. A. Kinney | H. S. Rodgers |
| Columbia University | Nov. 9, 1909 | Chas. E. Lucke | N. E. Hendrickson | J. L. Haynes |
| Mass. Inst. of Tech. | Nov. 9, 1909 | Gaetano Lanza | J. A. Noyes | R. M. Ferry |
| Univ. of Cincinnati | Nov. 9, 1909 | J. T. Faig | C. J. Malone | J. H. Schneider |
| Univ. of Wisconsin | Nov. 9, 1909 | H. J. B. Thorkelson | F. B. Sheriff | L. F. Garlock |
| Univ. of Missouri | Dec. 7, 1909 | H. Wade Hibbard | G. D. Mitchell | P. A. Tanner |
| Univ. of Nebraska | Dec. 7, 1909 | C. R. Richards | W. O. Forman | C. A. Bennett |
| Univ. of Maine | Feb. 8, 1910 | Arthur C. Jewett | A. H. Blaisdell | W. B. Emerson |
| Univ. of Arkansas | Apr. 12, 1910 | B. N. Wilson | W. Q. Williams | H. W. Barton |
| Yale University | Oct. 11, 1910 | L. P. Breckenridge | F. M. Jones | W. St. C. Childs |
| Rensselaer Poly. Inst. | Dec. 9, 1910 | A. M. Greene, Jr. | G. K. Palsgrove | H. J. Parthesius |
| State Univ. of Ky. | Jan. 10, 1911 | F. P. Anderson | J. W. Cary | J. T. Lowe |
| Ohio State University | Jan. 10, 1911 | E. A. Hitchcock | H. T. Lang | W. J. Assel |
| Washington University | Mar. 10, 1911 | | | F. E. Glasgow |
| Lehigh University | June 2, 1911 | | | |

# THE JOURNAL

OF

# THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS

VOL. 33 — DECEMBER 1911 — NUMBER 12

## THE ANNUAL MEETING

The 32d Annual Meeting of the Society will open in the Engineering Societies Building, New York, on Tuesday, December 5, 1911.

The program as announced includes a large number of papers of professional interest, with sessions on such diversified subjects as the performance and strength of steam boilers, machine shop and foundry practice, cement manufacture, problems in the textile industry, and a gas power session at which a discussion of oil engines will be a feature.

### ENTERTAINMENT FEATURES

At the conclusion of the address by the President and of the report of the tellers, on Tuesday evening, a reception will be tendered to the membership and their guests in the Society rooms, by the President and President-Elect and their ladies. As the opening gathering of the convention this event offers opportunity for a furtherance of acquaintanceship among the membership and for the promotion of good-fellowship in the Society. Chamber music will be rendered and a collation will be served.

On Wednesday afternoon, December 6, the Ladies' Committee, composed of ladies resident in or near New York, will give a reception in the rooms of the Society to the membership and their guests, at which they hope to welcome a large number of their friends, both among the members and visiting ladies. The Ladies' Committee expect to make further provision for the entertainment of visiting ladies during the convention and will organize trips to various points of interest about the city.

The New York membership will entertain the Society and their guests in the grand ballroom of the Hotel Astor on Thursday evening, December 7. Dancing will commence at nine o'clock and refreshments will be served throughout the evening. The occasion is expected to be one of unusual enjoyment and the Committee on Entertainment has the plans for the affair well in hand. Boxes will be provided for those who do not care to participate in the dancing.

## ADDRESS BY DR. R. S. WOODWARD

On Wednesday evening, December 6, Dr. Robert Simpson Woodward, president of the Carnegie Institution of Washington, will deliver an address on Geo-Dynamics, or the Mechanics of the Formation of Worlds, which will be one of the important features of the convention. Dr. Woodward, who is a Past-President of the American Mathematical Society, of the New York Academy of Sciences, and of the American Association for the Advancement of Science, and a member of the National Academy of Sciences, is an authority on this subject, and will give an address of great interest and value.

## EXCURSIONS

The White Star Line has invited the Society to be its guest and to inspect the S. S. Olympic on Thursday afternoon, December 7, from 1.30 to 2.30 o'clock. Both members and ladies will be welcomed on this occasion. This will be the first visit of the Olympic to America since her recent accident and repairs are being hastened so that the Society may not be disappointed in its plans to visit this great passenger vessel.

Technical excursions are being arranged for Thursday and Friday afternoons, December 7 and 8, and will include visits to the Brooklyn Navy Yard, the Edison Laboratory, Bush Terminal, E. W. Bliss Company, Hotel Astor plant, and the Ward bread bakeries. Information regarding these and other points of interest about the city may be secured from the Bureau of Information in the foyer.

The Society is cordially invited to visit the American Museum of Safety, located on the sixth floor of the Engineering Societies' Building, and to inspect its models and photographs of safety devices to protect the lives of workmen and the public. Someone will be in attendance to explain the various devices to those interested.

### HEADQUARTERS

The headquarters of the convention will be established in the foyer on the first floor of the Engineering Societies Building, and members and guests are requested to register immediately upon their arrival and receive a badge and program. Railroad certificates should be presented at that time for validation. A writing room will be provided on the first floor opposite the entrance, fully equipped for the use of members. There is also a telephone exchange with several booths on the first floor adjoining the elevators, providing ample facilities for quick service.

### MEMBERS REGISTER

The printed Members Register will contain the names of those registered before Wednesday evening and will be distributed at the morning session on Thursday.

### RAILROAD TRANSPORTATION

Arrangements for hotel, transportation and Pullman car accommodations should be made personally.

For members and guests attending the Annual Meeting in New York, December 5–8, 1911, the special rate of a fare and three-fifths for the round trip, on the certificate plan, is granted when the regular fare is 75 cents and upwards, from territory specified below.

*a* Buy your ticket at full fare for the going journey, between December 1 and 7 inclusive, and get a certificate, *not a receipt*, securing these at least half an hour before the departure of the train.

*b* Certificates are not kept at all stations. If your station agent has not certificates and through tickets, he will tell you the nearest station where they can be obtained. Buy a local ticket to that point and there get your certificate and through ticket.

*c* On arrival at the meeting, present your certificate to the registration desk at the Headquarters. A fee of 25 cents will be collected for each certificate validated. No certificate can be validated after December 8.

*d* An agent of the Trunk Line Association will validate certificates, Dec. 6, 7, 8. No refund of fare will be made on account of failure to have certificate validated.

*e* One-hundred certificates and round trip tickets must be presented for validation before the plan is operative. This makes it important to show the return portion of your round trip ticket at Headquarters.

*f* If certificate is validated, a return ticket to destination can be purchased, up to Dec. 12, on the same route over which the purchaser came, at three-fifths the rate.

This special rate is granted only for the following:

Trunk Line Association:

All of New York east of a line running from Buffalo to Salamanca, all of Pennsylvania east of the Ohio River, all of New Jersey, Delaware and Maryland; also that portion of West Virginia and Virginia north of a line running through Huntington, Charleston, White Sulphur Springs, Charlottesville, and Washington, D. C.

## PROGRAM

### TUESDAY, DECEMBER 5

*Opening Session, 8.30 p.m.*

Presidential Address: The Engineer in The Future, Col. E. D. Meier.
Report of Tellers of Election of Officers.
Introduction of President-Elect.
President's reception in the rooms of the Society. All members and guests invited. Music and refreshments.

### WEDNESDAY, DECEMBER 6

*Business Meeting, 10.00 a.m.*

Annual business meeting. Reports of Council, tellers of election of membership, standing and special committees. Amendment to Constitution under C 57 relating to the financing of geographical and professional sections. Announcement of sub-committees of the Committee on Meetings. New business.

*Professional Session*

The Turret Equatorial Telescope, James Hartness, member of Council.
Expense Burden: Its Incidence and Distribution, Sterling H. Bunnell.
Standard Cross-Sections, H. de B. Parsons.

*Professional Session, 2 p.m.*

Tests of Large Boilers at the Detroit Edison Company, D. S. Jacobus.
Strain Measurements of Some Steam Boilers under Hydrostatic Pressures, James E. Howard.
Herringbone Gears, P. C. Day.

*Simultaneous Session, Cement Manufacture*

This session will be in charge of the Sub-Committee on Cement Manufacture. A number of papers on important phases of the subject will be presented.

*Reception, 4.00 to 6.00 p.m.*

Reception by the Ladies' Committee to the members and ladies, in the rooms of the Society. Music and refreshments.

*Lecture, 8.00 p.m.*

Address: GEO-DYNAMICS, OR THE MECHANICS OF THE FORMATION OF WORLDS, Dr. Robert Simpson Woodward, President of the Carnegie Institution, Washington, D. C.

## THURSDAY, DECEMBER 7

*Professional Session, 10.00 a.m.*

THE CORE ROOM: ITS EQUIPMENT AND MANAGEMENT, Henry M. Lane.
TESTS OF A SAND-BLASTING MACHINE, Wm. T. Magruder.
(Contributed by Sub-Committee on Machine Shop Practice)
DIE CASTINGS, Amasa Trowbridge.
VARIABLE-SPEED POWER TRANSMISSION, G. H. Barrus and C. M. Manly.
(Illustrated with working models)

*Simultaneous Session, Gas Power Session*

OIL ENGINES, H. R. Setz.
TEST OF AN 85-H.P. OIL ENGINE, Forrest M. Towl.
DESIGN CONSTANTS FOR SMALL GASOLENE ENGINES, Wm. D. Ennis.
1000-KW. NATURAL GAS ENGINE: TESTS, CONSTRUCTION AND WORKING COSTS, E. D. Dreyfus and V. J. Hulquist.

*Excursions, 1.30 p.m.*

Inspection of the White Star S. S. Olympic, 1.30 to 2.30 p.m.

Technical excursions to points of engineering interest, to be arranged by the Committee.

*Reunion, 9.00 p.m.*

Reunion of the membership in Hotel Astor. Dancing and Refreshments.

## FRIDAY, DECEMBER 8

*Professional Session, 10.00 a.m.*

THE DEVELOPMENT OF THE TEXTILE INDUSTRIES OF THE UNITED STATES, Frank W. Reynolds.
(Contributed by Sub-Committee on Textiles)

Rational Psychrometric Formulae: Their Relation to the Problems of Meteorology and of Air Conditioning, W. H. Carrier.

Air-Conditioning Apparatus, W. H. Carrier and F. L. Busey.

Experiences with the Pitot Tube on High and Low Air Velocities, Frank H. Kneeland.

*Technical Excursions, 2.00 p.m.*

Visits to various points of engineering interest, including the Brooklyn Navy Yard, Edison Laboratory, Bush Terminal, E. W. Bliss Company, Hotel Astor plant, and the Ward bread bakeries.

## Organization of Committees

### COMMITTEE ON MEETINGS

L. R. Pomeroy, *Chairman*

C. E. Lucke
H. deB. Parsons
W. E. Hall
C. J. H. Woodbury

### MEETINGS OF THE SOCIETY IN THE NEW YORK

Walter Rautenstrauch, *Chairman*
F. A. Waldron, *Secy. and Treas.*

F. H. Colvin
Edw. Van Winkle
R. V. Wright

### COMMITTEE ON WAYS AND MEANS

Frederick A. Waldron, *Chairman*

Geo. M. Basford
Walter L. Clark
Wm. T. Donnelly
Harrington Emerson
J. W. Lieb, Jr.
Walter M. McFarland
Chas. A. Moore

### COMMITTEE ON PRESIDENT'S RECEPTION

George J. Foran, *Chairman*.

R. S. Allyn
R. P. Bolton
H. R. Cobleigh
S. D. Collett
Maurice Coster
W. N. Dickinson
Lester G. French
Willis E. Hall
H. A. Hey
W. D. Hoxie
W. H. Kenyon
Chas. Kirchhoff
J. W. Lieb, Jr.
E. W. Marshall
F. J. Miller
Alfred Noble
F. E. Rogers
W. Schwanhausser
Theo. Stebbins
W. R. Warner
I. H. Woolson
R. V. Wright

### COMMITTEE ON REUNION

F. A. Scheffler, *Chairman*

C. W. Aiken
L. P. Alford
A. R. Baylis
L. G. French
H. L. Gantt
H. O. Pond
E. J. Prindle
F. E. Rogers
E. W. Rutherford
J. C. Schaeffler
E. A. Sperry
Theo. Stebbins
J. W. Thomas
F. A. Waldron

## COMMITTEE ON EXCURSIONS

Walter Rautenstrauch, *Chairman*

## ACQUAINTANCESHIP COMMITTEE

Roy V. Wright, *Chairman*

### Tuesday

*Afternoon*

C. J. Morrison, *Sub-Chairman*
Lawrence Addicks
F. E. Eberhardt
R. E. Fox, Jr.
H. L. Gantt
J. D. Maguire
E. J. Prindle
F. E. Rogers

*Evening*

L. A. Shepard, *Sub-Chairman*
H. R. Cobleigh
W. C. Douglas
C. I. Earll
H. S. Hayward, Jr.
F. R. Hutton
M. C. Maxwell
C. W. Obert
C. F. Scott

### Wednesday

*Morning*

J. A. Kinkead, *Sub-Chairman*
L. D. Burlingame
W. R. Dunn
M. P. Fillingham
T. M. Keith
H. P. Merriam
F. J. Miller
Fitz-William Sargent

*Afternoon*

F. H. Stillman, *Sub-Chairman*
H. H. Barnes, Jr.
H. D. Gordon
P. C. Idell
J. P. Ilsley
A. C. Jackson
H. F. J. Porter
W. S. Timmis

*Thursday Morning*

J. J. McKee, *Sub-Chairman*
W. W. Christie
A. Falkenau
J. W. Lieb, Jr.
W. M. McFarland
C. H. Parson
H. B. Prout
E. A. Stillman
L. A. Whitcomb

*Friday Morning*

Hosea Webster, *Sub-Chairman*
A. F. Ganz
F. A. Haughton
J. W. Nelson
N. B. Payne
W. W. Ricker
J. M. B. Scheele
M. M. Upson
I. H. Woolson

## LADIES' RECEPTION COMMITTEE

Mrs. Jesse M. Smith, *Chairman*

Mrs. L. P. Alford
Mrs. Robert S. Allyn
Mrs. C. Kemble Baldwin
Mrs. Frank H. Ball
Mrs. G. H. Barbour
Mrs. Arthur R. Baylis
Mrs. Chas. H. Bigelow
Mrs. Wm. H. Boehm
Mrs. L. B. Bonnett
Mrs. S. H. Bunnell
Mrs. F. T. Chapman
Mrs. W. W. Christie
Mrs. Edward Ciardi
Mrs. J. V. V. Colwell
Mrs. C. H. Corbett
Mrs. C. A. Dawley
Mrs. George Dinkel
Mrs. Harrington Emerson
Mrs. Wm. D. Ennis
Mrs. F. A. Errington
Mrs. Chas. H. E'sstrand
Mrs. Geo. L. Fowler
Mrs. R. E. Fox, Jr.
Mrs. Nelson E. Funk
Mrs. F. deR. Furman
Mrs. H. L. Gantt
Mrs. Albert F. Ganz
Mrs. A. H. Goldingham
Mrs. F. A. Halsey
Mrs. G. A. Harris
Mrs. David L. Hough
Mrs. W. D. Hoxie
Mrs. Wm. F. Hunt
Mrs. Harry C. Hutchins
Mrs. F. R. Hutton
Mrs. D. S. Jacobus

Mrs. Wm. H. Kenyon
Mrs. G. L. Knight
Mrs. Nixon Lee
Mrs. S. H. Libby
Mrs. John W. Lieb, Jr.
Mrs. F. R. Low
Mrs. W. W. Macon
Miss Clara E. Meier
Miss M. Alice Meier
Mrs. Wm. H. McKiever
Mrs. B. M. Mitchell
Mrs. Samuel L. Moore
Mrs. C. W. Obert
Mrs. Chas. H. Parson
Mrs. Nathan B. Payne
Mrs. H. O. Pond
Mrs. W. R. Porter
Mrs. Sidney A. Reeve
Mrs. Calvin W. Rice
Mrs. J. M. Robinson
Mrs. A. B. See
Mrs. Augustus Smith
Mrs. A. Parker Smith
Mrs. Theodore Stebbins
Mrs. P. V. Stephens
Mrs. H. H. Suplee
Mrs. W. S. Timmis
Mrs. H. G. Torrey
Mrs. Gustave R. Tuska
Mrs. Maxwell M. Upson
Mrs. C. R. Wight
Mrs. Jas. Edw. Wilson
Mrs. Ira H. Woolson
Mrs. Roy V. Wright

## COMING MEETINGS

### ST. LOUIS MEETING, DECEMBER 15

The Society will join with the St. Louis Sections of the American Institute of Electrical Engineers and of the American Society of Civil Engineers, and with the American Society of Engineering Contractors, in a dinner to be given under the auspices of the Engineers Club, on December 15 in the club rooms.

### BOSTON MEETING, DECEMBER 20

A meeting of the Boston Section of the American Institute of Electrical Engineers will be held in Boston, on December 20, in which the members of the Society and of the Boston Society of Civil Engineers will coöperate. A paper will be presented by W. L. R. Emmett, Mem.Am.Soc.M.E., engineer of the lighting department, General Electric Company, Schenectady, N. Y., on the Electric Propulsion of Ships.

## CURRENT AFFAIRS OF THE SOCIETY

The activities of the Society can best be judged from the reports of the Standing Committees to the Council, to be presented at the Annual Meeting.

The work of the Committee on Meetings and of the Publication Committee has been so fully referred to in The Journal from month to month, in connection with the development of plans for the meetings and with the publication of the annual volume of Transactions and of the Journal itself, that they need not here be dealt with at length. The appointment of the sub-committees by the Committee on Meetings, to be announced at the Annual Meeting, will mark one of the most important forward movements that the Society has ever undertaken. Plans are also under way in connection with The Journal for its development beyond the point of containing simply the proceedings of the Society, making it a periodical on mechanical engineering.

The Public Relations Committee reports its work in connection with the proposed bill for licensing engineers, before the New York Legislature. The bill was opposed on the ground that if one State should pass such a law, other States would be likely to follow with bills lacking uniformity in their requirements, thus imposing a burden on the profession.

During the year the Research Committee has compiled lists of all laboratories available for engineering investigation, in the hope of unifying the work undertaken and of collating the results. It is proposed to form a sub-committee on Safety-Valve Investigation.

The House Committee has had the care of the Society rooms continuously in hand, and the collection of pictures of Past-Presidents and Honorary Members has been enlarged, forming a notable collection.

The Membership Committee has as usual performed faithfully its arduous task of reviewing the applications for membership, over 200 having been added to the Society during the year. To the Committee's efforts is largely due its high standard of membership.

The report of the Finance Committee, appearing in the current issue of The Journal, indicates the substantial success of the Society in financial matters.

Committee activity in this Society has never before been so promising as now, showing a live interest in its affairs on the part of increasingly large number of members. Besides the Standing Committees there are sixteen sub-committees and the various committees on meetings in the different cities; and to these will soon be added the sub-committees of the Committee on Meetings about to be formed. Of the special committees, that recently appointed to formulate standard specifications for the construction of steam boilers and other pressure vessels and for care of same in service, is undertaking an unusually broad work. It is intended to prepare a code which will be submitted to engineers throughout the world, thus making it international in its scope and authoritative.

## AUTOBIOGRAPHY OF JOHN FRITZ

Many members and friends of the Society will be interested to learn of the publication of a de luxe edition of the Autobiography of John Fritz, the noted steel manufacturer, Honorary Member and Past-President of the Society. This edition, which will be limited to 200 copies, will be uniform in size with the Transactions of the Society, bound in dark green full Persian morocco, and will contain a photogravure portrait of the author and many other illustrations.

Mr. Fritz dedicates the account of his life and achievements to the "loyal, able, brave and fearless men who so faithfully stood by me throughout my career. To them all, in whatever capacity employed, I am ever grateful, and I should like to call each one by name and to thank them personally, from the depth of my heart, for their most valuable assistance and for the uniform kindness they have ever shown me. They deserve the plaudits of the country for the innumerable blessings they have conferred in performing the great amount of mental and physical labor necessary in accomplishing the marvelous changes and wonderful results that have marked the development of the iron and steel business from my first connection with it some seventy years ago."

In the preface to the book, Mr. Fritz says that the book has been written wholly to satisfy the persistent urging of a number of old friends, who insisted on his writing out for them, in his own words, an account of his life struggles; and that the publication of the autobiography before his death is owing to the fact that, against his wishes, these good friends would not wait for it, but insisted on having it now. He warns his readers not to expect fine language nor eloquent periods, but only the honest record of the hard-working life of one who loves his country and his fellowmen and who has tried to serve them both.

The volume is expected to be ready for distribution about December 20.

### LETTERS OF ACKNOWLEDGMENT

The following letters of acknowledgment have been received relating to the Engrossed Resolutions of Thanks sent to The Institution of Mechanical Engineers, and to the recent election to Honorary Membership in the Society of John A. F. Aspinall, Past-President of the Institution:

*Storey's Gate, St. James's Park, Westminster, S. W.*
*October 5, 1911*

My dear Sir:

I have to convey to you as President of The American Society of Mechanical Engineers, both on my own behalf as well as for my colleagues on the Council, and the Members generally of The Institution of Mechanical Engineers, our most cordial thanks for the beautifully engrossed Resolution which your Society has been so kind to send to our Institution.

At the same time I desire to assure you that we all most thoroughly endorse the satisfaction which you have expressed as to the cordial and harmonious relations of our two Societies. I can assure you of the great value we attach to this appreciation of the benefits which attend the interchange of professional ideas and the accompanying pleasant social side of such Meetings as those held in Birmingham and London in 1910.

I may add that in order to ensure that these sentiments may be shared by all our members, wherever they may have their homes, it is intended to publish a copy of the engrossed Resolution in an early volume of our Proceedings.

I am, dear Sir,
Yours faithfully,
E. B. ELLINGTON, *President*

*Gledhill, Mossley Hill Drive, Liverpool*
*October 8, 1911*

My dear Sir:

It was with very great pleasure that I received your letter of September 26th announcing to me that your Council had unanimously elected me an Honorary Member of The American Society of Mechanical Engineers.

I beg that you will convey to your Council my warmest thanks and my great appreciation of the honour which they have done to me.

It is one more evidence of the kindly feeling which exists between the two great English speaking Societies of Mechanical Engineering.

I am satisfied that my colleagues on the Council of The Institution of Mechanical Engineers will be as much gratified as I am at the action which your

Council have taken, and I can assure you that I accept the honour with the fullest knowledge of its value.

Yours faithfully,
JOHN A. F. ASPINALL

*Storey's Gate, St. James's Park, Westminster, S. W.*
*October 25, 1911*

Dear Mr. Rice:

I am sure that you will like to know that when I read your letter of the 26th September to the Council at their recent Meeting, they appreciated the action of the Council of The American Society of Mechanical Engineers in electing Mr. Aspinall an Honorary Member of the Society. They welcomed the news as a well merited distinction for their Past-President.

I am,
Yours very truly
EDGAR WORTHINGTON

## VISIT OF SIR WILLIAM H. WHITE

An important event during the past month has been the visit of Sir William H. White, Honorary Member of the Society, to the United States, to receive the John Fritz Medal awarded by the John Fritz Medal Board composed of representatives of the four national societies of civil, mining, mechanical and electrical engineering.

Sir William H. White is popularly associated in the minds of the American public with the design of the Mauretania, which makes the trip from Queenstown to New York in four days and ten hours, an unequalled record. Apprenticed at the age of fourteen to the master shipwright at the royal dockyards at Devonport, England, where he gained both practical knowledge of construction and a technical training from the school attached to the yards, he entered at the age of nineteen the Royal School of Naval Architecture in London, standing first in the competitive examination for admission. Immediately after his graduation, he became a member of the staff of the Admiralty, and for several years was largely engaged in the construction of the types of warships then regarded as the most advanced. He left the Admiralty to become the head of the warship department of one of the largest shipbuilding firms in England, and was the designer of warships for several of the largest navies of the world. Our own navy is directly indebted to him for plans from which the cruisers Charleston and Baltimore, the real beginning of our modern navy, were built. He resigned this work at personal sacrifice to become Director of Naval Construction in the British Navy, where he served for thirty years. During that time 174 ships were built from his designs.

Sir William H. White has been an Honorary Member of the Society for more than ten years. He last visited the Society at the Spring Meeting held in Atlantic City in 1910, when he came as an emissary from The Institution of Mechanical Engineers, to complete the plans for the meeting of the Society with the Institution, held in July of that year in England.

Members of the Council who were entertained by Sir William H. White during the meeting in England, gave a dinner in his honor, as well as to Lady White and Miss White who accompanied Sir William on his visit, on Monday evening, November 20, at the St. Regis. A number of the hosts came from a considerable distance in order to be present, and covers were set for about thirty. Charles Whiting Baker, chairman of the committee of arrangements, acted as toastmaster, and called upon George Westinghouse, Past-President of the Society, to offer to Sir William the toast, "He has brought England and America one day nearer together." E. D. Meier, President, offered a toast to Lady White, and Miss White was called upon by Ambrose Swasey, Past-President, to respond to the toast of "the White Rose of England."

CALVIN W. RICE, *Secretary*

## REPORTS OF MEETINGS

### JOHN FRITZ MEDAL AWARD

The John Fritz Medal, founded in 1902 to perpetuate the memory of the steel pioneer whose name it bears, and which is annually awarded by a Board made up of four representatives from each of the national societies, the American Society of Civil Engineers, the American Institute of Mining Engineers, The American Society of Mechanical Engineers, and the American Institute of Electrical Engineers, was on November 17, 1911, formally bestowed for notable achievements in naval architecture, on Sir William H. White, Hon. Mem.Am.Soc.M.E., former chief constructor of the British Navy, and the designer of the Mauretania. This is the eighth award of the Medal, John Fritz, Lord Kelvin, George Westinghouse, Alexander Graham Bell, Thomas Alva Edison, Charles T. Porter and Alfred Noble having been, in the order named, the former recipients.

The occasion of the presentation was the annual dinner of the Society of Naval Architects and Marine Engineers, held in the grand ballroom of the Waldorf-Astoria. Stevenson Taylor, president of the society, acted as toastmaster and the award of the Medal was made by Onward Bates, Past-President of the American Society of Civil Engineers, Chairman of the Board of Award. Sir William H. White in accepting the medal, expressed his appreciation of the honor which it conveyed, and spoke particularly of his admiration for John Fritz who was present at the gathering. Sir William told of his own career and in closing said that the memory of the occasion would always remain with him.

The evening concluded with a reception to Mr. Fritz, now in his ninetieth year. Secretary of the Navy Meyer was the principal speaker at the dinner.

### SAN FRANCISCO MEETING, NOVEMBER 2

A meeting of the Society in San Francisco was held on November 2, members of the American Society of Civil Engineers, the American Institute of Electrical Engineers, the Pacific Coast Gas Association, the Mining and Metallurgical Society of America, the American Institute of Mining Engineers, the American Chemical Society, and the Technical Society of the Pacific Coast, coöperating. The topic considered was the projected Engineering Congress in 1915 and the following resolution was adopted:

*Resolved:* That a meeting of delegates from the various American engineering societies shall be held in San Francisco on January 15, 1912, for the purpose of formulating plans for holding an International Engineering Congress in conjunction with the Panama-Pacific Exposition in San Francisco during the year 1915; that each society represented at this meeting be invited to send three delegates to this conference; and that the chairman and secretary of this meeting be authorized in their discretion to invite other American engineering or technical societies not represented at this meeting, to participate.

## ST. LOUIS MEETING, NOVEMBER 11

The members of the Society in St. Louis held a business meeting preceded by an informal dinner at the Mercantile Club, St. Louis, on November 11. At this meeting the availability of prospective applicants was discussed and other routine matters considered.

## NEW YORK MEETING, NOVEMBER 14

A well-attended and interesting meeting of the Society on the subject of Welding, was held in the Engineering Societies Building on November 14. Papers on the subject were presented by H. R. Cobleigh, Mem.Am.Soc.M.E., International Steam Pump Company, New York, who gave a general account of the processes employed and the progress which had been made with them, with considerable stress also on the flame process; by G. E. Pelissier, Assoc.Am.Soc. M.E., Goldschmidt Thermit Company, New York; and C. B. Auel, assistant manager of works of the Westinghouse Electric and Manufacturing Company, the former treating the thermit process and the latter electric welding.

In the discussion, electric resistance, electric arc, thermit, oxy-acetylene and oxy-hydrogen welding were dealt with, the fields of application, costs of work, how difficult work may be accomplished, and the advantage of special features of apparatus, being taken up under each of these divisions. The papers and discussions were well illustrated with lantern slides, Mr. Pelissier presenting a series of moving pictures which showed the process under consideration very clearly.

Those who discussed the paper were: W. H. Brown, Mem.Am.Soc. M.E., of Cleveland, Ohio; W. H. Spire, Electric Welding Products Company; J. D. Mooney, The American Machinist, New York; Henry Cave, Autogenous Welding Equipment Company, Springfield, Mass.; W. R. Noxon, Davis-Bournonville Company, New York; W. H. Levin, International Oxygen Company; W. J. Fritz, Linde Company; F. A. Saylor, Walter McCloud Company, Cincinnati, Ohio; J. F. Springer, New York; Hugo Lieber, Blau Gas Company of America, New York; E. B. Katte, Mem. Am.Soc.M.E., chief engineer of electric traction, New York Central and Hudson River Railroad; C. B. Auel, East Pittsburgh, Pa.; Mr. Merrihew; T. S. Tenney, New York; Harry Harbison, Simmons Pipe Bending Works, Newark, N. J.; C. J. Nyquist, Davis-Bournonville Company, New York.

NEW HAVEN MEETING, NOVEMBER 15

The members of the Society in New Haven held a meeting in the Mason Laboratory of Mechanical Engineering on November 15, with afternoon and evening sessions. E. S. Cooley, Mem. Am.Soc.M.E., of the Connecticut Company, New Haven, acted as chairman of the afternoon session and conducted a brief business meeting. Papers were presented on the Cost of Power. These included, A Suction Producer Gas Plant in a Lumber Mill, by A. W. Honywill, Jr., which was discussed by E. S. Cooley, J. H. Norris, Frank B. Perry, Geo. A. Orrok and F. L. Bigelow; The Cost of Power from a 125-h.p. Hornsby-Akroyd Oil Engine, F. P. Pfleghar and E. H. Lockwood, discussed by W. S. Hudson, Geo. A. Orrok, H. L. Isbell, and Messrs. Krah and Risteen; The Present Status of the Small Steam Turbine, W. J. A. London, discussed by F. R. Low, W. S. Huson, J. H. Norris, L. P. Breckenridge and E. S. Cooley.

The afternoon session adjourned at five o'clock for inspection of the laboratory, and dinner was served in the Yale Dining Club.

At the evening session, L. P. Breckenridge, Mem.Am.Soc.M. E., professor of Mechanical Engineering, Yale University, presided, and introduced Col. E. D. Meier, President of the Society, who gave an address of welcome. He was followed by Chas. F. Scott, Mem.Am. Soc.M.E., New Haven, Conn., who gave an illustrated lecture on the Hartford Electric Light Company: its Power Plant, Distribution System and Public Service. More than 100 were in attendance at the meeting.

## BOSTON MEETING, NOVEMBER 16

A meeting of the Society was held in Boston on November 16, the Boston Society of Civil Engineers and the Boston section of the American Institute of Electrical Engineers cöoperating. Charles L. Norton, associate professor of physics at the Massachusetts Institute of Technology, Mem.Am.Soc.M.E., presented a paper on the subject of Some Refractory Substitutes for Wood, which told of the fire loss in this country due to the use of a large amount of rapid burning material in buildings, and outlined the various attempts made by different scientists to produce some satisfactory substitute. Professor Norton's own invention was described and full size samples of various manufactured articles were submitted. Lantern slides were used in describing the process of manufacture.

The paper was discussed by F. E. Cabot of the Boston Board of Fire Underwriters; W. L. Puffer, consulting engineer, Boston; F. F. Jonsberg, contractor and builder; G. K. Manson, consulting engineer with New England Telegraph and Telephone Company, Boston, Mass.; F. A. Waldron, Mem.Am.Soc.M.E., New York; Chas. T. Main, Mem.Am.Soc.M.E., Boston. Written discussion was contributed by L. H. Kunhardt, vice-president and engineer of the Boston Manufacturers' Mutual Fire Insurance Company; H. O. Lacount, Mem. Am.Soc.M.E., engineer of the Associated Factory Mutual Fire Insurance Companies; C. J. H. Woodbury, Mem.Am.Soc.M.E., consulting engineer, Boston; E. V. French, vice-president and engineer of the Arkwright Mutual Fire Insurance Company.

## STUDENT BRANCHES

### ARMOUR INSTITUTE OF TECHNOLOGY

The Student Branch of the Armour Institute of Technology met on November 1, 1911, and was addressed by A. J. Frith, Mem.Am.Soc.M.E., on the Diesel Engine. Professor Frith described the action of the engine in detail, with the aid of cards and diagrams. The construction of both the German and American types of engines were taken up, and the most important features influencing their design were explained. A number of interesting points of a practical nature were brought out during the discussion.

### COLUMBIA UNIVERSITY

A meeting of the Columbia Student Branch was held October 27, 1911, when the subject of Mechanical Engineering as Applied to the Manufacture of Shredded Wheat was presented by C. H. Wilson.

### MASSACHUSETTS INSTITUTE OF TECHNOLOGY

On Thursday evening, November 2, Mr. Weingar of the Studebaker Corporation gave an illustrated lecture before the Mechanical Engineering Society of the Massachusetts Institute of Technology, upon Automobile Construction at the E. M. F. Factories. The lecture was illustrated by moving pictures. The points covered were, the sulphur and carbon test on the iron and steel purchased, tensile and torsion tests, molding, pouring, welding, case-hardening, drop forging of several different parts, special jigs, multiple machinery, such as the drilling of 17 holes simultaneously, blanking out of the body, cylinder boring, and the assembly of the motor and the car. At the close of the lecture a vote of thanks was extended to Mr. Weingar.

### OHIO STATE UNIVERSITY

On October 23, 1911, the Ohio State University Branch held a meeting at which J. T. Hay, chief chemist of the Stark Rolling Mill Company, Canton, O., spoke on the Effects of Improper Methods in the Manufacture of Iron and Steel. A discussion followed in which Professor Orton, E. A. Hitchcock, Mem.Am.Soc.M.E., F. E. Sanborn, Jun. Am.Soc.M.E., and others took part.

### POLYTECHNIC INSTITUTE OF BROOKLYN

At a meeting of the Polytechnic Student Branch on November 4, thirteen new members were admitted. The speaker of the evening was Mr. Ordway of the Yaryan Company, who gave a very interesting address on Multiple Effect Evaporation.

### STEVENS INSTITUTE OF TECHNOLOGY

At a meeting of the Stevens Engineering Society on October 19, addresses were delivered by Calvin W. Rice, Secretary, and Charles Whiting Baker, Vice-President of the Society. Mr. Rice after extending the greetings of the Society, spoke of the exceptional advantages offered by membership in a student branch, and expressed the hope that the student members would avail themselves of the privilege of visiting the rooms of the Society. Mr. Baker took as his subject, Reading for Engineers, and said that despite the rather confusing wealth of technical literature such reading should not be entirely neglected. Mr. Baker advised above all a certain amount of non-technical reading, that the engineer may not become a mere computing machine.

At a meeting on October 26, G. L. Clouser presented a paper on Industrial Management, with Special Reference to the Development of Labor. The paper made a comparison of the various systems of employment as to their advantages and disadvantages; and included a consideration of the worker and his surroundings and the requisites for an efficient executive organization. An interesting discussion followed in which many took part.

### UNIVERSITY OF KANSAS

A meeting of the University of Kansas Student Branch was held on October 26, with the following papers: The Arrangement and Equipment of the Allis-Chalmers Plant at West Allis by V. H. Hilford; The Plants of A. O. Smith in Milwaukee and the Thomas B. Jeffery Company in Kenosha by C. G. Martinson; Aluminum Castings by Mr. Ackerman; The Gyroscope Compass by Mr. Newby; Aerial Navigation by Mr. Nosfinger.

The annual inspection trip made this year by members of the society included the plants of The Indiana Steel Company, at Gary; the Standard Oil refinery at Whiting; the Commonwealth Edison Company, and Western Electric Company, in Chicago; Allis-Chalmers, A. O. Smith, Vilter, and light and power plants in Milwaukee; and the Thomas B. Jeffery Company in Kenosha, Wis.

At the meeting on November 2, the subjects presented were, The Distribution of Rainfall in Various Sections of the United States, by C. I. Corp, Jun.Am.Soc.M.E; The Fisk and Quarry Street Stations of the Commonwealth Edison Company in Chicago, by Mr. Conley; Revue de Mécanique, by L. E. Knerr; and The Power Plant of the Curtis Publishing Company in New York by Mr. Bevlin.

### UNIVERSITY OF MISSOURI

At a meeting of The University of Missouri Student Branch on November 6, 1911, two papers were read, one on the Manufacture of Dynamite by S. Thomas, and another on the Manufacture of Plate Glass by F. I. Kemp.

## MEETING OF THE COUNCIL

A meeting of the Council was held on November 20, at which the following were present: E. D. Meier, President, presiding; S. G. Flagg, Jr., Jesse M. Smith, H. G. Reist, E. B. Katte, H. L. Gantt, James Hartness, George M. Brill, I. E. Moultrop, F. W. Taylor, Chas. Whiting Baker, F. R. Hutton, Alex. C. Humphreys, R. M. Dixon, and Calvin W. Rice, Secretary.

The Secretary read the amendment to the Constitution proposed by the Committee on Meetings of the Society in New York, authorizing an assessment of $3 per capita on the membership resident in New York and vicinity.

*Voted:* That in the opinion of the Council it is unwise at the present time so to amend the Constitution as to make any fixed increase in the dues of any section of the membership.

*Voted:* That when the matter is brought up at the business session of the Annual Meeting, December 6, 1911, the amendment offered by the committee be amended by substitution as follows:

> The expenses of all meetings of the Society and of any group or section thereof, shall be provided for in accordance with such By-Laws and Rules as the Council may from time to time adopt; provided, however, that nothing in this section shall be construed to authorize the Council to make any increase in the annual dues of members in any grade.

*Voted:* That the report of the special committee appointed by the Council on the plan for financing professional and geographical sections be accepted and placed on file.

The report of the Committee on Constitution and By-Laws was presented by Jesse M. Smith.

*Voted:* To accept the annual report of the Finance Committee, together with schedule of appropriations for the coming year.

*Voted:* That the thanks of the Council be given to R. M. Dixon and W. H. Marshall for the work accomplished in raising the money for the land debt of the Society.

*Voted:* That the adjustment of any subscriptions to certificates in excess of the issue be referred with power to the Finance Committee.

*Resolved:* That the Council desires to express its high appreciation of the work of the Publication Committee in maintaining the high character of the Society's publications, and adding so largely to the Society's income during the past year.

*Voted:* That the reports of the Standing Committees as required annually under the By-Laws be sent in galley proof to every member of the Council for their information and approval.

*Voted:* That the report of the Committee on Power House Piping, dated April 24, printed in The Journal, June 1911, for presentation at the Spring Meeting in Pittsburgh, be received and ordered printed and that the Committee be discharged with thanks.

*Voted:* That the report of the Special Committee on ballots for election in the Society be referred to the Committee on Constitution and By-Laws.

*Voted:* To appoint the following committee to arrange details of a reception to the delegates to the Twelfth International Congress of Navigation to be held in June 1912: Chas. Whiting Baker, W. M. McFarland, G. B. Massey, George W. Melville, H. de B. Parsons, Stevenson Taylor, with power to select a delegate to the Congress, to which the Society is entitled by virtue of its membership in the Permanent International Association of Navigation Congresses.

*Voted:* That the Secretary be appointed Honorary Vice-President to represent the Society on the local committee of arrangements for the Sixth Congress of the International Association for Testing Materials, to be held in September 1912 and to serve temporarily as representative to the Congress.

*Voted:* In response to the invitation of the American Museum of Safety, that L. D. Burlingame be appointed Honorary Vice-President to represent the Society on the local committee arranging for the International Congress for the Prevention of Accidents and Industrial Hygiene, to be held in Milan in 1912.

*Voted:* To confirm the appointment of Carl Angstrom as Honorary Vice-President at the 50th anniversary of the foundation of the Svenska Taknologforeningen and 250th anniversary of the birth of the Swedish engineer and inventor, Christopher Polhem, held in Stockholm, Sweden, November 18, 1911.

*Voted:* That the Society issue the autobiography of John Fritz, Honorary Member and Past-President, and that the Secretary be authorized to work out the details.

*Voted:* That the design of student pin which has been approved for several of the student branches of the Society, be approved for all educational institutions with the appropriate changes in initials and colors to suit individual cases.

*Voted:* To confirm the action of the Executive Committee recommending for ballot the list of applicants approved and submitted by the Membership Committee under date of September 18, 1911.

The Secretary read letters of appreciation from The Institution of Mechanical Engineers concerning the resolutions of thanks which had been presented to them, and the conferring of Honorary Membership on Mr. J. A. F. Aspinall, their Past-President, from whom a letter was also read.

*Voted:* That these be published in The Journal.

The Secretary spoke of the work which Mr. Max Toltz had been doing in St. Paul toward enlarging the membership of the Society in that city, and on motion, the Secretary was requested to transmit to Mr. Toltz a vote of appreciation and thanks.

The following resignations were accepted: Edw. M. Blake, J. Lawrence Lyon, E. H. Bedell, H. B. Binsse, S. A. Ellenbogen, W. A. Drysdale, W. F. Hibbert, Cortlandt E. Palmer, W. M. Stone, C. T. Church, C. H. Quereau, R. W. Berliner, H. E. Smith, E. W. Davenport, A. Y. Hoy, W. F. Kneif, F. J. Loomis, W. C. McBain, R. E. Titcomb.

The Secretary reported the following deaths: J. L. Gobeille, H. J. Johnson, John Turner, R. H. Thomas, L. R. Hopton, Edgar W. Mix, W. S. McKinney, C. D. Haskins, T. B. Davis, O. A. Stranaham.

*Voted:* To approve the following amendment to By-Law 20:

**B20 The Council shall institute a monthly publication to be called "The Journal" which shall be under the management of the Secretary, who shall act under the general supervision of the Publication Committee, subject to approval by the Council as to the policy thereof and the expenditures therefor. The annual subscription price of The Journal to each member is two dollars and is included in the annual dues of such member.**

*Voted:* To request the Publication Committee to advise at the next Council meeting what societies shall be regarded as "sister societies" to whom The Journal will be sold at the $2 rate.

The minutes of the Council meeting of September 15, 1911, were read and approved.

*Voted:* In response to the invitation of the National Waterways Commission, H. G. Stott be appointed an Honorary Vice-President to represent the Society at the hearings to be held in Washington, D. C., beginning Tuesday, November 21.

The meeting adjourned.

## REPORT OF THE FINANCE COMMITTEE

Appended will be found the certified report of the examination of the accounts of the Society, made by Messrs. Peirce, Struss & Company, for the fiscal year of the Society, ending September 30, 1911.

The total receipts of the Society were $97,580.67 and the expenditures were $95,081.74, not including $600 returned to Reserve Fund account.

The appropriations made at the beginning of the year contemplated a total expenditure amounting to $88,390 based on an estimated income of $88,500, $1900 of the appropriations being from reserve. But because of the increased earnings of the Society, due to the progressiveness of the management of The Journal and the earnings accruing therefrom, and because of the increased amount of sales and the earnings accruing therefrom, your Finance Committee recommended to the Council that it increase the appropriations primarily made, to a total of $94,390.83.

The mortgage indebtedness, which at the beginning of the year was $81,000, has been met by the sale of 4 per cent Certificates of Indebtedness. The total subscriptions amount to $84,700 of which $75,100 has been paid. With the issuance of these Certificates of Indebtedness it becomes obligatory on the Society to devote all initiation fees to their redemption, and it has been the understanding that the initiation fees devoted to this purpose are approximately $6000 a year. It therefore seems to your Committee of the utmost importance for the Society that steps be taken to insure this and that a special committee on Increase of Membership, composed of well-qualified men, should be appointed for the express purpose of using all reasonable means for the adding to the membership of properly qualified engineers who are not now members of the Society.

Your Finance Committee recommends that $1898.93 be appropriated towards cancelling the amounts advanced by the Society on the Engineering Building, and that enough be taken from Reserve Fund, namely $2117.98, to wipe out this account, and that payments to the Land Fund as hereafter paid be credited to Reserve Fund.

For the year ending September 30, 1912, it is estimated that the income of the Society will be $100,000 as follows:

| | |
|---|---|
| Dues | $56,350 |
| Sales | 7,600 |
| Interest and discount | 775 |
| Advertising | 35,000 |
| Miscellaneous | 275 |
| Total | $100,000 |

and it recommends that the following appropriations be made:

| | |
|---|---|
| Finance Committee | $26,875 |
| Membership Committee | 2,100 |
| Increase in Membership | 800 |
| House Committee | 1,425 |
| Library Committee | 4,500 |
| Meetings Committee | 5,100 |
| Council | 4,200 |
| Publication Committee | 42,300 |
| Research Committee | 100 |
| Committee on Power Tests | 50 |
| Public Relations Committee | 50 |
| Sales Expenditures | 3,500 |
| Reserve Fund | 600 |
| Total | $ 91,600 |

which, in the opinion of your Committee, should not be exceeded on an estimated income of $100,000.

It is also recommended by your Finance Committee that all unexpended appropriation balances be returned to unappropriated revenue, and that the expenditures made which exceed specific appropriations be approved.

Respectfully yours,

R. M. Dixon, *Chairman*
G. J. Roberts
W. H. Marshall
H. L. Doherty
W. L. Saunders
*Finance Committee*

PEIRCE, STRUSS & CO.
CERTIFIED PUBLIC ACCOUNTANTS

*October 25, 1911*

MR. R. M. DIXON,
CHAIRMAN FINANCE COMMITTEE
Dear Sir:

In accordance with your instructions, we have audited the books and accounts of The American Society of Mechanical Engineers for the year ended September 30, 1911.

The results of this examination are presented in three exhibits, attached hereto, as follows:

*Exhibit A* Balance Sheet, September 30, 1911
*Exhibit B* Income and Expenses for the year ended September 30, 1911
*Exhibit C* Receipts and Disbursements for year ended September 30, 1911

We beg to present, attached hereto, our Certificate to the aforesaid exhibits.

Respectfully submitted,
PEIRCE STRUSS & CO.
*Certified Public Accountants*

PEIRCE, STRUSS & CO.
CERTIFIED PUBLIC ACCOUNTANTS

*October 25, 1911*

MR. R. M. DIXON,
CHAIRMAN FINANCE COMMITTEE
Dear Sir:

Having audited the books and accounts of The American Society of Mechanical Engineers for the year ended September 30, 1911, we hereby certify that the accompanying Balance Sheet is a true exhibit of its financial condition as of September 30, 1911, and that the attached statements of Income and Expenses, and Cash Receipts and Disbursements are correct.

PEIRCE, STRUSS & CO.
*Certified Public Accountants*

## EXHIBIT A

BALANCE SHEET, SEPTEMBER 30, 1911

ASSETS

| | | |
|---|---|---|
| Equity in Societies Building (25 to 33 West 39th Street) | $353 346.62 | |
| Equity one-third cost of land (25 to 33 West 39th Street) | 180 000.00 | |
| | | $533 346.62 |
| Library Books | 13 000.00 | |
| Furniture and Fixtures | 5 000.00 | |
| | | 18 000.00 |

| | | |
|---|---|---|
| New York City 3½% Bonds 1954 | | |
| Par $35,000.00 | 30 925.00 | |
| Cash in Bank representing Trust Funds | 11 085.78 | |
| | | 42 010.78 |
| Stores including plates and finished publications | | 12 165.10 |
| Cash in bank for general purposes | 19 745.32 | |
| Petty Cash on hand | 250.00 | |
| | | 19 995.32 |
| Accounts Receivable | | |
| Membership Dues | 8 992.00 | |
| Initiation Fees | 475.00 | |
| Sale of publications, advertising, etc. | 9 354.81 | |
| | | 18 821.81 |
| Advances account land subscription fund. | | 4 016.91 |
| Unexpended Appropriation | | 690.91 |
| Advance payments | | 1 687.29 |
| Total Assets | | $650 734.74 |

LIABILITIES

| | | |
|---|---|---|
| United Engineering Society | | $41 000.00 |
| Certificate of Indebtedness applied to Mortgage | | 40 000.00 |
| Certificate of Indebtedness unapplied to Mortgage | | 7 100.00 |
| Funds | | |
| Life Membership Fund | $35 151.07 | |
| Library Development Fund | 4 902.71 | |
| Weeks Legacy Fund | 1 957.00 | |
| | | 42 010.78 |
| Current Accounts Payable | | 4 538.40 |
| Dues paid in advance | 961.51 | |
| Initiation fees paid in advance | 80.00 | |
| | | 1 041.51 |
| Initiation fees uncollected | | 475.00 |
| Unappropriated Revenue | | 4 489.84 |
| Reserve (Initiation fees) | | 32 206.97 |
| Surplus in property and accounts receivable | | 477 872.24 |
| Total Liabilities | | $650 734.74 |

# EXHIBIT B

## Income and Expenses for the Year Ended September 30, 1911

### INCOME

| | | |
|---|---|---|
| Membership Dues | $56 526.29 | |
| Sales gross receipts | 8 761.30 | |
| Advertising | 30 932.64 | |
| Iuterest and Discount | 1 357.11 | |
| Miscellaneous | 3.33 | |
| | | $97 580.67 |

### EXPENSES

| | | |
|---|---|---|
| Finance Committee Office Administration including Salaries | $21 853.00 | |
| Finance, United Engineering Society Assessments | 3 375.00 | |
| Finance, Miscellaneous | 346.06 | |
| Finance, Interest | 3 240.00 | |
| Finance, London Book | 289.91 | |
| Finance, Stores Expense | 1 713.18 | |
| | | 30 817.15 |
| Membership Committee | | 2 137.84 |
| Increase of Membership Committee | | 490.96 |
| House Committee | | 994.70 |
| Library Committee | | 3 698.40 |
| Committee on Meetings | | |
| Annual Meeting | 2 700.84 | |
| Monthly Meetings | 3 382.37 | |
| Spring Meeting | 2 317.55 | |
| Student Meetings | 72.36 | |
| Gas Power Meetings | 121.79 | |
| Meetings Programs | 15.56 | |
| Classification | 109.84 | |
| | | 8 720.31 |
| Power Test Committee | | .59 |
| Amount Forward | | $46 859.95 |
| Publication Committee | | |
| Advertising Section, The Journal | 14 956.77 | |
| Journal, except Advertising | 15 739.51 | |
| Revises | 513.89 | |
| Transactions Volume 32 | 8 615.65 | |
| Year Book | 2 874.38 | |
| Transactions Volume 31 | 954.18 | |
| | | 43 654.38 |

| | | |
|---|---|---|
| Research Committee | 28.87 | |
| Public Relations Committee | 21.08 | |
| Sales Expenditures | 4 517.46 | |
| Reserves Fund | 600.00 | |
| Total | | 95 681.74 |
| Excess of Income over Expenses | | 1 898.93 |
| | | $97 580.67 |

# EXHIBIT C

### Receipts and Disbursements for Year Ended September 30, 1911

#### RECEIPTS

| | | |
|---|---|---|
| Membership Dues | $54 775.00 | |
| Initiation Fees | 5 490.00 | |
| Membership Dues and Initiation Fees paid in advance | 1 194.84 | |
| Sales of publications, badges, advertising, etc. | 37 626.80 | |
| Subscription to Land Fund | 5 900.00 | |
| Interest | 2 112.54 | |
| Certificates of Indebtedness | 47 106.33 | |
| | 154 205.51 | |
| Cash in Banks and on hand, September 30, 1910 | 15 218.32 | |
| | | $169 423.83 |

#### DISBURSEMENTS

| | | |
|---|---|---|
| Disbursements for general purposes | $98 342.73 | |
| Payments on the mortgage with funds received from sale of Certificate of Indebtedness | 40 000.00 | |
| Cash in Banks and on hand, September 30, 1911 | 31 081.10 | |
| | | $169 423.83 |

# NECROLOGY

## JOSEPH LEON GOBEILLE

Joseph Leon Gobeille, identified throughout most of his business career with the Gobeille Pattern Company, Cleveland, Ohio, was born in Poughkeepsie, N. Y., July 2, 1855. He obtained his mechanical training at Cooper Union, New York, and at the Rensselaer Polytechnic Institute, Troy, N. Y. At eighteen years of age he entered the pattern shop of N. S. Vedder in Troy, leaving there five years later to take charge of the department of design and ornamentation with the Cleveland Stove Company, Cleveland, Ohio. In 1881 he established the firm of Gobeille & Brothers in the same city, retaining for himself the designing and drafting. In 1884 he bought out this concern and organized the Gobeille Pattern Works which he developed to large proportions. While he specialized in stove patterns, his shop turned out some of the largest and most intricate work called for by the leading foundries of the country. He invented and constructed ingenious and useful woodworking machinery and his pattern shop was provided with valuable and rare machine tools.

Leaving Cleveland in 1905 after a financial reverse, he was connected for a short time with the Abram Cox Stove Company, Philadelphia, Pa. Later he went to Niagara Falls, N. Y., and organized the Gobeille-Harris Pattern Company, of which he retained control until attacked by the illness which caused his death on September 27, 1911.

Mr. Gobeille was a past-president of the Cleveland Engineers Club and contributed papers at various times to meetings of foundrymen and stove manufacturers associations. He will also be remembered as a writer of short stories and a lover of rare books.

## HENRY JAMES JOHNSON

Henry James Johnson was born in Providence, R. I., July 7, 1842. He was educated in the Providence public schools and in 1861 was graduated from Brown University with the degree of C.E. From 1863 to 1891 he was employed by the Providence Steam Engine Company, first as draftsman and later as designing engineer. He designed and superintended the construction of the Nagle pumping engine, the Burdict bolt and nut forging machines, steam capstans for the United States Navy, the improved Greene automatic drop cut-off engine, stationary and marine boilers, and others, upon several of which he secured patents. In 1891 he became designing engineer for Plumb, Burdict and Barnard, Buffalo, N. Y., bolt manufacturers. Two years later he again became connected with the Providence Steam Engine Company in the capacity of consulting engineer, and from 1898 to the date of his death was consulting engineer for Filer and Stowell Engineering Company's eastern office.

## JOHN TURNER

John Turner was born May 8, 1846 at Cornwall, England, and six years later moved with his family to this country, settling in Michigan where his father became a mine contractor. He received his early education in the schools of Dover, N. J., and in 1863 entered the machine shop of Hewes & Phillips, Newark, N. J., where he served his apprenticeship and later became erecting engineer. In this capacity he was associated with the Watts Campbell Company, Newark, after which he became superintendent of shops for Boone & Perez, Brooklyn, N.Y. From 1874 to 1885 he acted as chief engineer at the State Asylum, Morris Plains, N. J., leaving there to take charge in the same capacity of the Peerless Steam Power Company. In 1887 he became chief engineer of the College of Physicians and Surgeons, New York, and in 1890 superintendent of central station construction for the General Electric Company, having entire charge of the construction of the underground system for the Cincinnati Edison Station and the Cleveland General Electric Company. In 1894 he became supervising engineer on the construction of the American Surety Building and later became its chief engineer for a period of three years. Subsequently he was associated with Sanderson & Porter, contracting and consulting engineers, for whom he built the electric light and railway plants at Far Rockaway, and the lighting plants at Tuxedo and Peekskill, N. Y. In 1901 he became superintendent and chief engineer of the American Bank Note Company, and from 1907 to the time of his death on September 12, 1911, acted in the same capacity at the Bishop Building.

# THE TURRET EQUATORIAL TELESCOPE

## A NEW ASTRONOMICAL OBSERVATORY

By James Hartness


## ABSTRACT

This paper describes a new type of astronomical observatory which was designed to protect the observer from the cold to which he is exposed in most of the observatories now in use. It accomplishes this purpose by the use of a revolving turret for the polar axis of the instrument, making the instrument and building integral. By this change in scheme of mounting it has been possible to avoid the use of the large reflecting mirrors employed in all previous designs where the comfort of the observer has been the controlling motive.

The problem in making an observatory of this kind is to maintain an equal temperature within and without the telescope tube, in order to avoid establishing disturbing air currents, and of course it is necessary to receive the beam of light coming from any object above the horizon.

In all previous work at least one relatively large plain reflector has been used to change the direction of the beam of light from that in which it comes from the celestial object to the fixed direction requisite for the eyepiece. In the present instrument the eyepiece has a slight motion, and therefore does not possess the ideal feature for comfort of the observer that is possessed by the previous instruments, but by sacrificing a trifle in this respect it has been possible to avoid the use of a large mirror. The point at which the direction of the cone of light is changed is about one-quarter of the distance from the ocular to the objective; this gives an area of about one-sixteenth of mirrors located near the objective. This is so small that it is possible to use a prism instead of a mirror, although even with a mirror it would be a distinct gain.

The paper includes a description of the means for heating and ventilating, and also touches on the delicate subject of patent rights for scientific instruments and the adverse effect to science of the present policy of allowing such things to go unprotected by patent rights.

# THE TURRET EQUATORIAL TELESCOPE

## A NEW ASTRONOMICAL OBSERVATORY

By James Hartness, Springfield, Vt.

Member of the Society

The subject of this paper cannot be properly considered without acknowledgment of indebtedness to at least three of our members, each one preëminent in one or more branches of astronomical science. Notwithstanding their great variety of interests, these men have found time to write long letters of advice and criticism in response to questions or on submission of drawings suggesting the various steps in the evolution of the present scheme. Years ago the writer thought he was favored in this respect, but later observation has proven that the same earnest, personal consideration is given to anyone. It was from these men that the microbe of work in the astronomical field was taken, and it is a pleasure to acknowledge indebtedness to our Honorary Member John A. Brashear, and to Past-Presidents Worcester R. Warner and Ambrose Swasey, for advice and criticism of the optical and general features of the various schemes out of which this new observatory has evolved. Indebtedness is also acknowledged to James B. McDowell and other members of the staff of John A. Brashear Co., Ltd., and to Alvin Clarke Son Corporation for painstaking care in answering questions and giving advice regarding the optical parts.

The new observatory grew out of an attempt to make an observatory in which the observer could work in comfort, independent of the outside temperature. To accomplish this end without serious handicap to good seeing and instrumental precision involved a departure from previous forms.

2 For the purpose of defining the relation of the new observatory to preceding types it is necessary to refer to diagrammatic illustrations, Figs. 1A, 2A and 3A. These sketches are purely schematic and are not true to important details.

3 Fig. 2A for the purpose of this paper will be referred to as the Standard Observatory, since it represents a type most highly developed by reason of the greater number of instruments of this kind

The American Society of Mechanical Engineers, 29 West 39th Street, New York. All papers are subject to revision.

that have been made. This instrument is not only the most efficient optically, but is probably the most reliable in point of mechanical precision when compared with any other instruments designed for covering the whole heavens and for general purposes. It has, however, the one serious handicap of requiring within the building a temperature equal to that of the outside air. It is for the purpose of overcoming this handicap that the instrument to be described was designed.

4 Fig. 1A is known as the Equatorial Coudé, or Elbow Equatorial. This instrument was designed to shelter the observer in comfortable

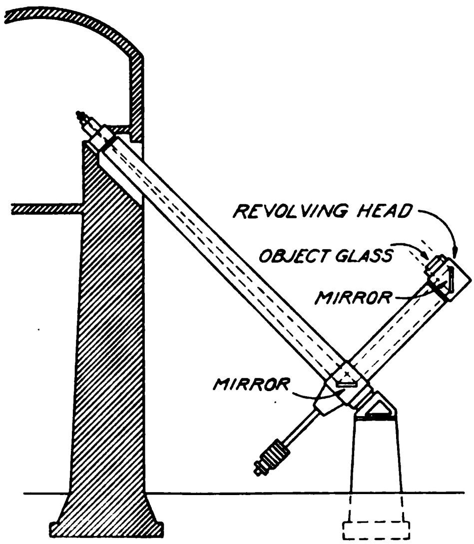



Fig. 1A Diagrammatic Sketch of the Equatorial Coudé
Object glass, 23 in. in diameter with 25:1 focal length; largest diameter of larger mirror, 32 in.; largest diameter of mirror at elbow, 23 in.

quarters. It is of French origin and a number of these are in use in Paris and elsewhere.

5 Fig. 3A is a schematic sketch of the new instrument which we propose to designate as the Turret Equatorial.

6 All of these instruments are refractors, using an object glass for collecting the rays of light and delivering them to a focal point within reach of the eyepiece.

7 In the standard equatorial the optical parts consist merely of the object glass and the ocular; for this reason it has the highest efficiency of any instrument for this purpose.

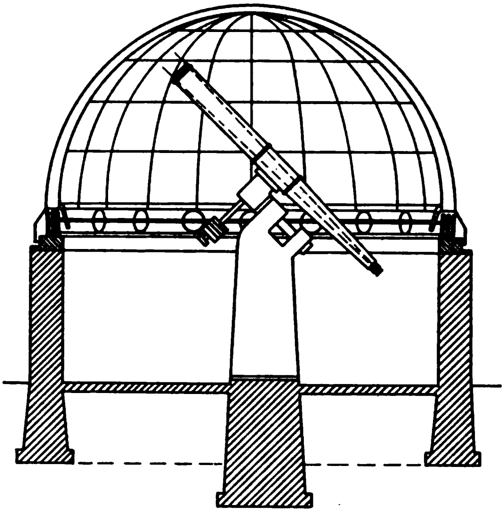


FIG. 2A STANDARD EQUATORIAL
Object glass, 10 in. in diameter with 15:1 focal length.

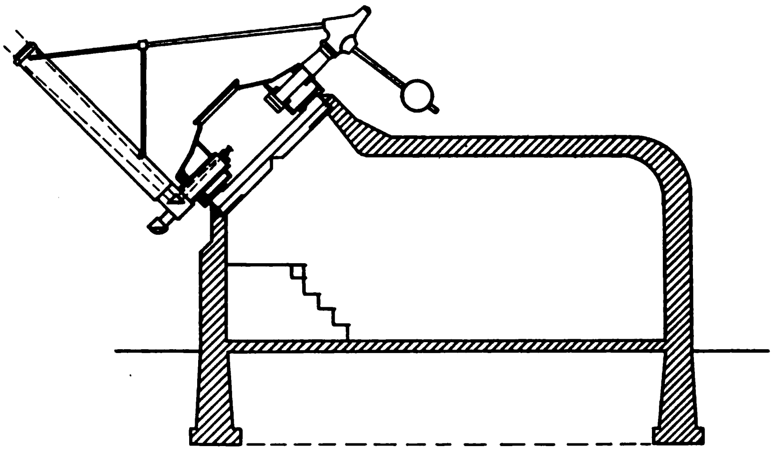


FIG. 3A TURRET EQUATORIAL
Object glass, 10 in. in diameter with 15:1 focal length, 2¾-in. prism at bend, which is approximately ¼ the distance from eyepiece to objective. Actual size of beam of light is 2½ in. at this point, or $\frac{1}{16}$ the area of objective.

8 The equatorial coudé purchases its comfort for the observer at the expense of a more or less serious optical loss, for between the object glass and the eyepiece two diagonal plane mirrors are interposed. In this instrument the beam of light comes to the eye at about the same angle as from a microscope on a table. The mirror at the object glass, of course, must be large enough to deliver the full bundle of rays, and since it stands at an angle of 45 deg., its major diameter must exceed the diameter of the object glass by about 40 per cent. This is also true of the diagonal plane at the elbow, although the diameter of the cone of rays is about 0.6 the diameter of the object glass. Notwithstanding this handicap, the equatorial coudé has doubtless been considered the best instrument which could be used by an observer comfortably housed.

9 There is another instrument, not shown in the sketches, somewhat similar to the equatorial coudé. It is called the broken equatorial coudé, and is joined at the bend in the elbow, avoiding the necessity of the large mirror at the objective. It has been excluded from this description because it does not cover the whole heavens. Its building obscures the circumpolar stars and that part of the heavens that happens to be north of the building.

10 Mention should also be made of the Tower telescope at Mount Wilson, Cal., designed for solar work. In this the beam of light is delivered downward by means of two reflectors through the object glass also located at the top of the tower. Reference might also be made to the various horizontal telescopes that have been used. But these instruments have thus far been used for only a limited part of the range covered by the standard equatorial.

11 In addition to the standard equatorial and equatorial coudé, both of which should be classed as refractors, special mention should be made of the common reflector as it is now mounted at Harvard University. This instrument delivers the beam of light to the observer, who may be seated at a desk, just as in the equatorial coudé observatory. It is, however, a reflector, and should perhaps be kept in a class by itself. It also uses two auxiliary mirrors to deliver into the eyepiece, and furthermore, like the broken equatorial, its working range is limited by the obscuring of part of the heavens by its own structure.

12 In all of the instruments designed for the comfort of the observer it has been necessary to introduce one or more reflectors, and barring the common reflector at Harvard and the broken equatorial, these auxiliary reflectors have been located near the objective.

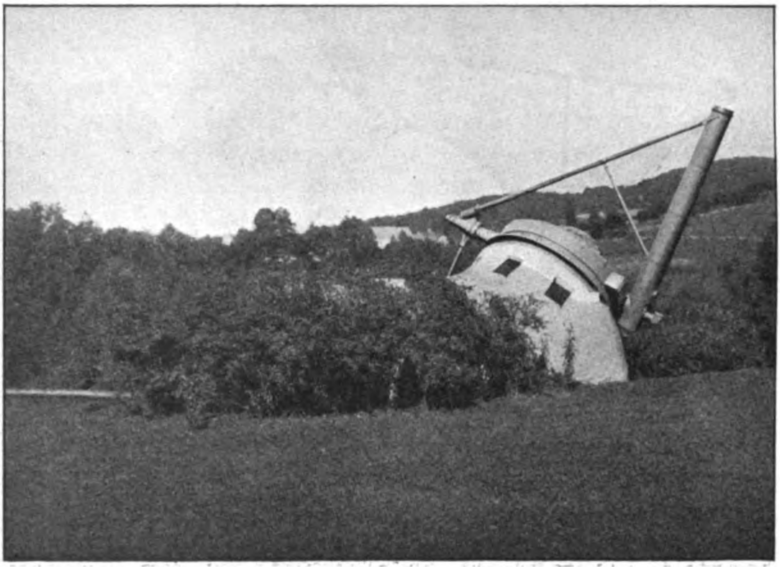


Fig. A View from a Point Southeast of the Observatory
Note the various positions of the turret on its axis and the positions of the tube in Figs. A–G

Fig. B View from a Point about Northeast of the Observatory

FIG. C VIEW SHOWING WEST SIDE AND SOUTH END

FIG. D WINTER VIEW TAKEN JUST AFTER COMPLETION OF GRADING, SHOWING NORTH END AND EAST SIDE

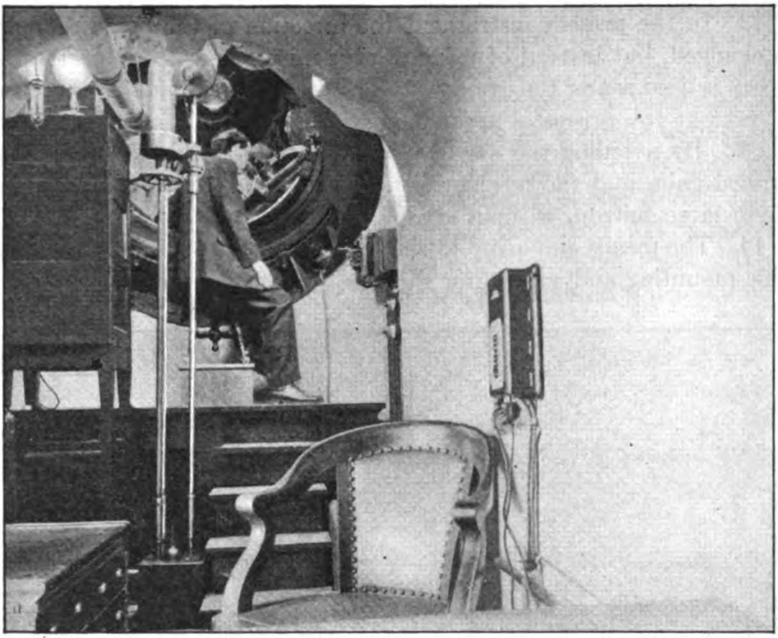


FIG. E INTERIOR OF OBSERVING ROOM

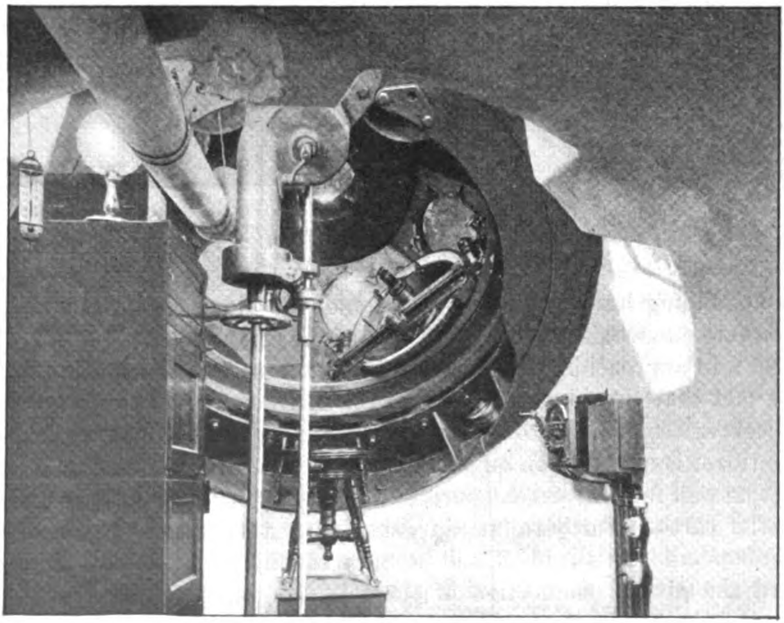


FIG. F ENLARGED VIEW OF INTERIOR OF DOME

13 In the present instrument the direction of the beam of light is changed, but instead of using a large mirror near the objective, a prism is used nearer the eyepiece. The area of the bundle of the cone of rays at the prisms is approximately $\frac{1}{16}$ of the area of the object glass. By avoiding the use of large mirrors there is, of course, the optical gain, and the mechanical difficulties encountered in holding these large mirrors without flexure are also obviated.

14 The means employed to shelter the observer and provide suitable mounting and control for this telescope may be briefly described

Fig. G Turret Equatorial Observatory and Residence to which it is connected by Underground Passageway

as a building having a turret-like dome, this dome being mounted to rotate on an axis parallel to the axis of the earth.

15 In approaching this problem it is perhaps well to bear in mind the fact that the distances between the instrument and the celestial objects are so great as to be practically infinite; hence, in saying that the turret is mounted on an axis parallel to the earth's axis, it will be just as well for our present purpose to consider it located at the axis of the earth. Furthermore, in considering the joint between the telescope and the turret, it will be more readily understood if we regard the pivotal connection of the telescope tube to the dome as located directly in the middle of the turret instead of at one side.

16 Regarding the mechanical precision of the present instrument, it is very natural for us to question the reliability of a turret in serving the place of an arbor for the main polar axis. This axis not only provides a control of the motion of the telescope as it follows a star in offsetting the earth's motion, but it also must combine with it some means for knowing with considerable precision a reasonably exact reading of the hour position or right ascension of the object. These two things make it necessary to provide the turret with a perfectly planed surface on its under side and a truly circular track. It also requires in the building a stable mounting for rolls on which the turret rests.

17 There are two sets of rolls: one set on which the flat face of the turret rests must keep the axis of the turret parallel with the axis of the earth. The circular part of the turret bears on the other set of rolls. The office of the second set is to hold the axis of the turret in a fixed position relative to the building to facilitate convenience in measurement of the angular position of the telescope as to hour position or right ascension.

18 If we can assure ourselves of the reliability of the turret for axial control and means for measuring the angular position of the tube around this axis, the author thinks we should be ready to accept the present scheme on account of its making possible the comfortable housing of the observer.

19 In mechanism for obtaining the greatest precision of axial control of a rotating object, machine designers invariably prefer an arbor of relatively small diameter mounted in two bearings, with the distance between the bearings of at least half a dozen diameters. Small diameters also furnish a most reliable center control around which to measure angular position.

20 In the present case as in nearly every problem of machine design, there are, however, other elements to be considered. The best solution is to determine what compromise to make. Even the almost ideal mounting of the standard telescope, such as exemplified in the great Yerkes refractor, an instrument which undoubtedly measures the highest attainment along these lines, seems handicapped by a delicacy of poise which is not the most favorable for stability of control.

21 It is entirely beyond and outside the object of this paper to discuss these various instruments, but it seems necessary, in order to set forth the object of the present instrument, to call attention to those that have preceded it, and in doing so to set forth the apparent

advantages and disadvantages as they appear to a novice, giving a view which, while it may not be correct, has at least the advantage of being a fresh one.

22 The refracting telescope having standard equatorial mounting is not only the best, optically considered, but it is undoubtedly superior to all others when made in the smaller sizes and for use in pleasant weather. The mechanical difficulties, however, increase very fast with the size of the telescope, and there are, of course, many latitudes and altitudes at which these instruments are used where the observer must be exposed to very cold weather.

23 The mechanical handicaps of the larger telescopes are due to the overhanging tube and counterweights. Not even the highest excellence in workmanship in making these machines nor the skill in their use seems to offset this instability. To the beginner, at least, it would appear that a breath of air or a change of adjustment would be sufficient to cause a quiver.

24 Referring now to the use of large mirrors, such as are used in the equatorial coudé and others, we have already mentioned the mechanical difficulties encountered in controlling the position of these mirrors without distortion. In the tower telescopes for solar work exceedingly thick mirrors have been used, and in the other telescopes devices have been employed by which the mirrors have been equally supported by many contact points; but notwithstanding this, no scheme seems to prevent fully the bending of the mirror and distortion of the image. The problem is especially difficult because these mirrors must be held in so many different positions. It would be a comparatively simple matter if there were no change of position. Furthermore, there is a temperature disturbance which is greater in a mirror than in a refractor. For this reason it is necessary to maintain an even temperature through the mirror.

25 In addition to the distortion of the image by lack of mechanical control of the mirror, there is the serious objection of absorption by even the most perfect reflectors. This absorption reduces the total light that reaches the eyepiece, and since the object in using telescopes of larger light-gathering power is to get more light, the use of a mirror is equivalent to a reduction of the diameter of the objective.

26 Furthermore, this cannot be offset by mere increase in size, for the loss in definition due to atmospheric disturbance increases with the diameter of the telescope, resulting in a net loss in definition. Therefore the price paid for comfort is not only the amount which must be expended for the large object glasses and still larger reflec-

tors to go with them, but also an actual loss in definition. This loss of definition, of course, is greatest in the low altitudes and least in the rarefied air of the best mountain top observatory sites.

27 In all equatorial telescopes provision must be made for changing the angular direction of the telescope to and from the pole; in other words, north and south. The axis on which the telescope turns for this position of declination must stand, of course, at right angles to the polar axis.

28 In the standard equatorial the arbor which furnishes the polar axis is provided with an opening transverse to it, which serves as a bearing for the arbor that is affixed to the side of the telescope tube and it is on the precision of this axis that the instrument depends for its true position in declination. It is undoubtedly due to the attachment of this secondary axis to the primary axis that this standard equatorial has the appearance of instability. It is, however, nicely counterbalanced, and the great precision of control is due to the excellence of workmanship and manipulation of a very high order. Nevertheless, it would seem desirable to provide some suitable control for the tube itself on this as well as on the primary axis.

29 In the new instrument the telescope is not pivoted at the middle, but at a point near the focus, and it is at this point that the prism is introduced and the rays are delivered into the turret through the hollow declination axis.

30 The scheme of counterweight resembles in some respects the old-fashioned well sweep. This counterweight is fulcrumed at the opposite side of the turret and reaches over to a point near the head of the telescope, supporting it without adding the weight to the telescope head, thus relieving a part of the weight of the declination axis and also all torsional strain.

31 This well sweep acts also as a brace in one direction. Its duty changes from that of a counterweight to one wholly of a brace. For instance, when the turret has been turned so that the declination axis is at the lowest part, and the tube has been pointed directly to the pole, then the counterweight is inoperative as a counterweight for the tube, but the arm becomes a brace. Therefore this scheme changes from one that is wholly a counterpoise to one that holds the telescope in position by a diagonal brace, and, of course, there are positions in which there is an equal service of each in the change from one extreme to the other. The brace always operates to stiffen the instrument against the action of the wind in certain positions

and the exact form may be varied to get the best results. The one shown in the illustrations was made to use available material.

32 The means for controlling the declination position of the telescope is a wormwheel in which two worms engage. All of this is clearly shown in the drawings Figs. 17 to 20.

33 It will be seen, then, that the observer sits inside the dome and receives the light coming from any celestial object above the horizon, and although it is necessary for him to change the position of the chair about 1 ft. east and west and 3 or 4 in. vertically, such a change does not constitute any serious inconvenience.

34 The beam of light comes into the observatory in a horizontal position when the telescope is pointed along the meridian, and it changes from the horizontal position to one in which the observer looks down towards the north at an angle of about 45 deg. at this latitude. The control of the dome, both for its quick motion for changing from one position to another, and also for providing movement to offset the rotation of the earth, is all effected by levers within convenient reach of the observer.

35 The rotation of the dome, instead of being effected by a wormwheel or gearing directly connected to the dome, is through the means used for driving four of the supporting rolls. These rolls take bearing on the circular track. They are hardened and ground to the proper diameter to get the desired relation of speeds. All of the other rolls are merely idlers for maintaining the fixity of axis of dome, and all rolls are mounted in ball bearings to reduce the total power required in turning the dome. Ball bearings keep the resistance more nearly uniform than could be maintained with plain bearings.

36 The motor which furnishes the power was originally located within the building, but on account of its noise it was placed in a separate box outside of the building.

37 As shown in Fig. G this observatory is located a short distance from the observer's residence. It is connected by an underground passageway which not only serves as a shelter in going to and from the observatory, but also as a means for carrying telephone and electric wires, hot and cold water, and the hot water for heating.

38 It is located on the brow of a terrace on which the residence stands, at a level a trifle lower, so that the tunnel rises in going from the lower room in the observatory to the residence, about 9 ft. in the 240 ft. of length. This difference in level, although it makes necessary the use of a small centrifugal pump to induce the hot water to circulate in the observatory, serves as an aid in ventilation.

39 The location of the observatory on the brow of a hill or terrace, makes it possible to get a fresh air inlet from the lower part of the lower room by running an air duct out through the side of the bank to the open air. In cold weather the air rushes through this air duct into the observatory, through the ventilators in the top of the door into the tunnel, and thence out of the tunnel either at the place where the tunnel joins the residence, or through the house. In summer, when it is hot outside, the current of air flows in the opposite direction. At such a time the door to the residence at the head of the tunnel is kept closed and another door is opened to the outside air. This takes the fresh air from the outside, which travels down through the tunnel by gravity, giving up some of its heat to the tunnel walls and reaching the lower room of the observatory at a fairly comfortable temperature. Then, by the aid of a small portable fan this air from the lower part of the room of the observatory is blown through an air duct into the dome.

40 In this connection, perhaps, it would be well to state that the dome is lagged with wood on the inside and the windows are all double, that is, there is one set of windows in the wooden lagging on the inside, and another in the metal dome outside. This air space is desirable in winter as well as in summer.

41 Regarding the form of the building, this may be almost anything from a large spherical dome to one having a hip roof. The one feature essential to this scheme is the proper neck for supporting the turret. This neck should be substantially the same as that shown in the present illustrations. The author selected the present form, partly to make it the least conspicuous from his residence, and perhaps it was influenced by the earlier form of the scheme in which it was intended to use a reflector instead of a refractor.

42 Closely connected with this subject is, of course, the cost, which must be based on the way such things are produced. If more instruments of this kind are to be made at different times and in various places, there is no hope of getting them produced at a low figure. There seems to be only one way of insuring the success of an instrument of this kind. Every machine builder knows it, and yet the mere mention seems to establish an antagonistic attitude at once in the mind of the average man.

43 It has not been considered ethical to take out patents on scientific instruments, and although the writer has not the courage of a reformer to wage battle against this sentiment, yet when it is such common knowledge that machinery cannot be successfully and eco-

nomically built without the concentration of the energies of a number of men for a given purpose, and since this cannot be accomplished without patent protection, it has been thought best to apply for patents on the new features of the present instrument. Although this will be done without dedicating it outright to the public, it is needless to say that no barrier will be allowed to prevent these instruments being built by any one until some business arrangement is made for the exclusive manufacture of some one size by some builder, and even then, others may be permitted to build other sizes; but all such permission will be given only by letter and not in a broadcast way that would in any way handicap the main purpose of making these machines available at a low cost to anyone who may desire them. It goes without saying that with patents there is always the thought of the exclusive right and profit of the patentee and manufacturer, but regarding this point it is well-known that the low cost of such things, as well as the best workmanship and results, can be obtained only by concentrating all of the work in one plant.

44 The writer does not contemplate manufacturing these instruments. More may be built experimentally, but not for the market. If others wish to build instruments of this kind, permission will doubtless be freely given, but with certain restrictions; but all this must be arranged in each case by correspondence.

45 If patent is granted no charge of any kind will be made for license to build until some arrangement has been made for manufacture on an efficient scale, and then only such restrictions as in the opinion of the patentee will be for the best interests of the science.

46 In closing, the writer begs to call attention to the fact that the great advancement in the world's knowledge, due to the work of the astronomers, has been carried on by the men who have braved the mosquitoes in summer and observed long hours in the most unfavorable temperatures. These men have been recruited from those who have taken up the work as an avocation and for every man of this number there have undoubtedly been ten or a hundred who have grown faint-hearted at the mere thought of the exposure incident to observing and at the high cost of the large instruments. With means of this kind made generally available it is thought that there will be more men in this work, and that from the greater number perhaps even greater work may be accomplished in the future.

## DATA REGARDING THE TURRET EQUATORIAL

Object glass, 10 in. in diameter, and 150 in. in focal length.
Inside dimensions of building, 6 ft. by 18 ft.
Outside diameter of dome, 7 ft., 4 in.
Weight of dome casting, about 1½ tons.
Total weight of dome with counterweight, tube, etc., about 2 tons.
Weight of ring-casting on which the dome is mounted, 1½ tons.
The optical parts were furnished by The John A. Brashear Co., Ltd. All of the other work was home-made, except the two large castings which were cast and turned in Fitchburg, Mass.
The hour circle consists of a flat ring having approximate dimensions of 52 in. outside, 48 in. inside, and ¾ in. thickness.
The inner diameter is graduated down to divisions of 1 minute. These divisions are about 0.1 in. apart. Vernier edges were provided for division of the minutes into seconds, but thus far a crude substitute has been used in preference. It consists of a rotating dial driven by gearing which also turns the dome. Its connection is such that the dial makes 1 r.p.m. With the 60 graduations on dial, the division of time into seconds is very readable.
In use the hour circle may be set to the even minute of position, leaving the plus or minus of seconds to be allowed for at the zenith point by the time piece.
The declination wormwheel is 24 in. in diameter, and is provided with two worms located on opposite sides. These are rotatively connected by means of a cross shaft and spiral gears.
In order to prevent conflict of action an eccentric bearing is provided for accurately gaging the depth of engagement of each worm. A separate means for turning each a very slight amount is also provided.
Graduations for minutes of degrees are carried by hubs on worm shafts.
The proximity of the two eyepieces led to the disuse of the finder, but if it is needed in future work, there are a variety of schemes for overcoming this difficulty.
Attention should be called to the rigidity of the eyepiece and the opportunity afforded for attaching photographic and spectroscopic apparatus. This feature is to be found in other telescopes designed for comfort, but as this instrument seems to partake more of the good seeing qualities of the standard telescope, it does not seem out of place to call attention to this advantage it has over the standard in which the delicacy of the poise is disturbed by added weight and adjustment of counterbalances.

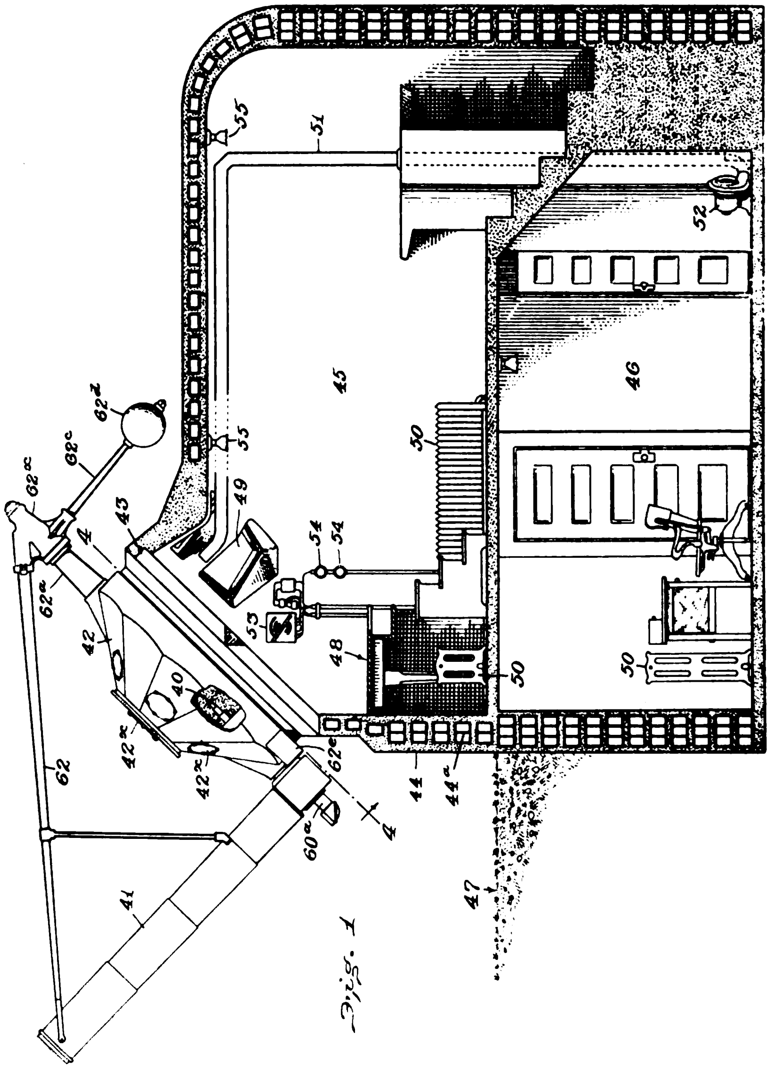



Fig 1. [Side] Elevation of the Telescope and Dome and a Longitudinal Vertical Section of the Building which forms the House for the Observer

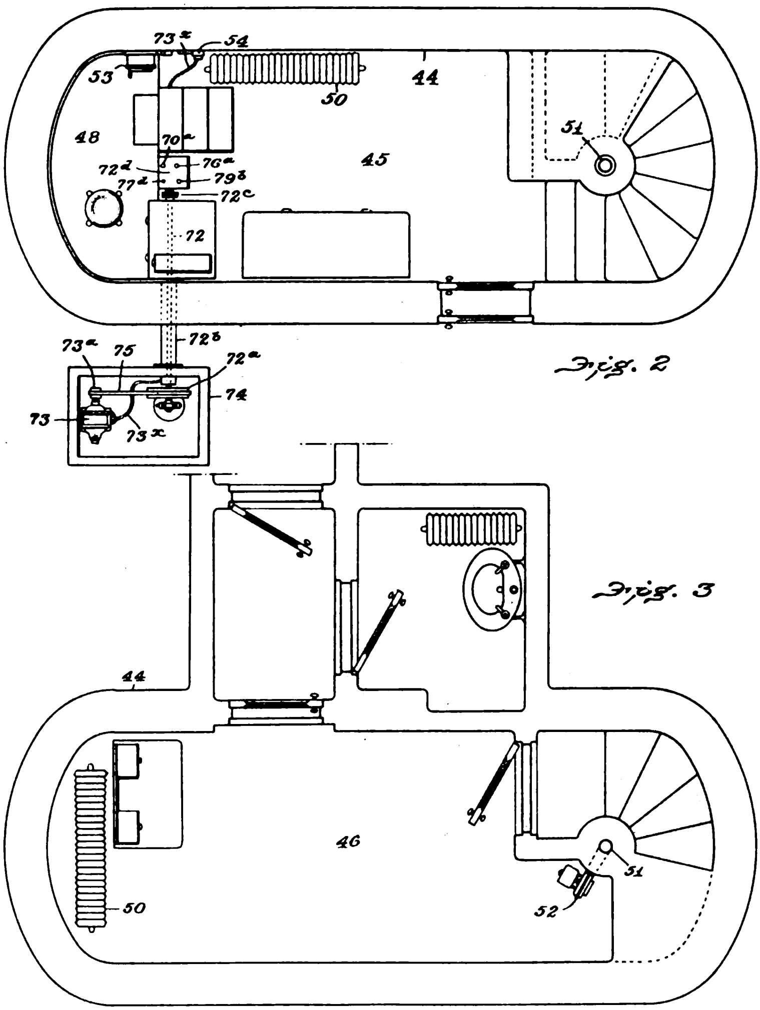
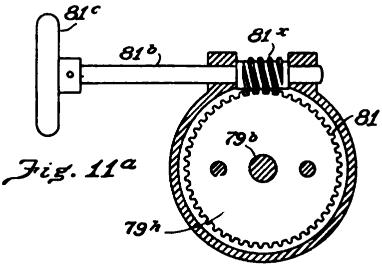



Fig. 2 Floor Plan of the Upper Compartment of Observing Room and the Box outside the Building in which the Motor is located

Fig. 3 Floor Plan of Lower Compartment and Subway Entrance



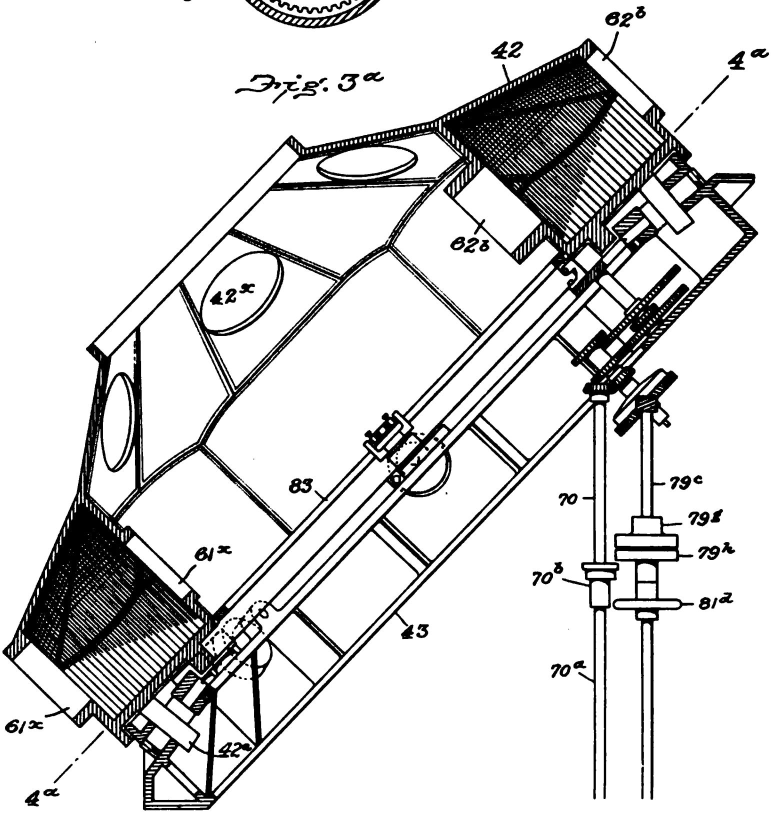




Fig. 3a Longitudinal Vertical Section through the Turret
Fig. 11a Original Form of Differential Motion for manually varying the Advance of Dome as it is turned by Motor to follow a Star
This has been superseded by Fig. 11, but may be reinstated again.

*Fig. 4a*

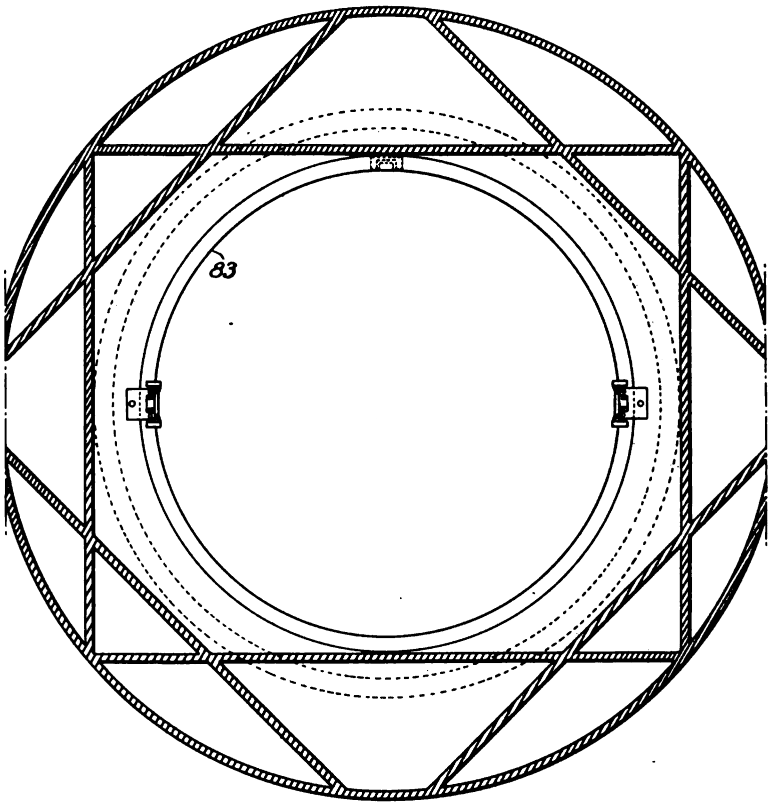



FIG. 4a CROSS-SECTION THROUGH TURRET ON THE PLANE INDICATED BY LINE 4a4a IN FIG. 3a

It clearly illustrates the scheme of ribbing which was chosen to resist warping or change of plane of under side of turret. It also shows its stability to resist any tendency to lose its true circular form of track, 42*f* in Fig. 4. The entire precision depends on the reliability of this plane and circular face of turret. This may be considered the most essential element in the whole structure.

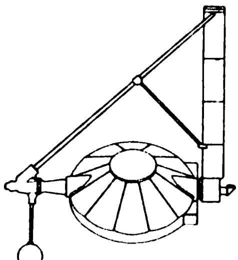


Fig. 5

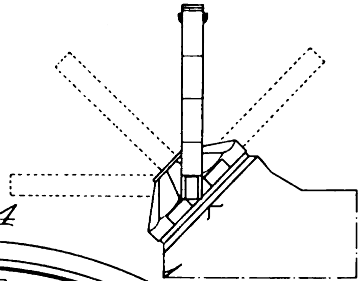


Fig. 6

Fig. 4

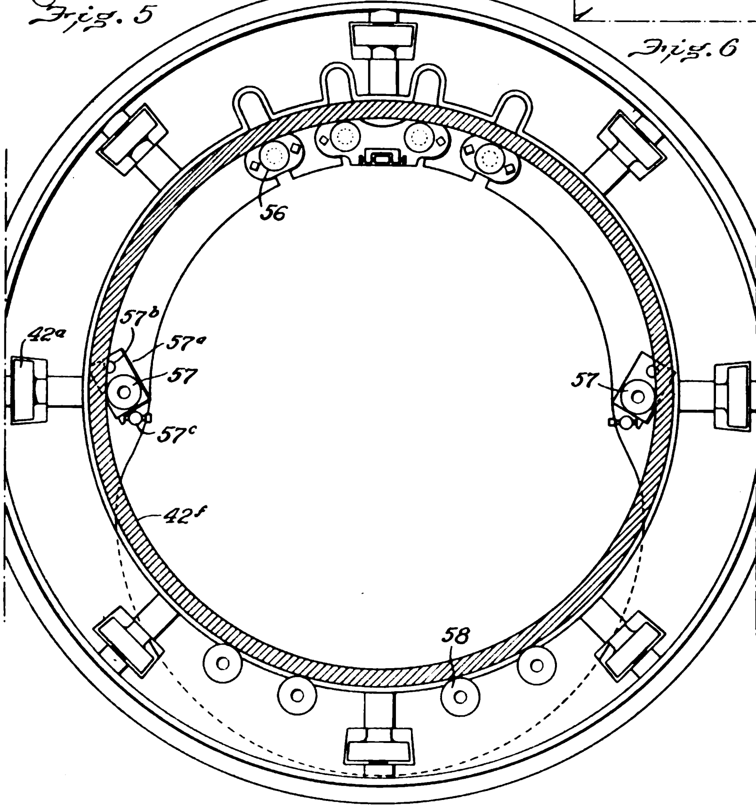



Fig. 4 Section through the Turret indicated by Line 4—4, Fig. 1

The eight conical rolls 42*a* furnish a support to plane the face of the turret. Their office is to keep the axis of the turret truly parallel with the axis of the earth; that is, they prevent the turret from tilting. The four rolls at the top, marked 56, are the driver rolls. The circular track of turret is shown in section 42*f*. The turret hangs on these driving rolls held in position laterally by side rolls 57.

The four rolls marked 58 at the bottom of the figure are to relieve the burden on driving rolls 56 when the instrument is not in use.

Figs. 5 and 6 North and West Elevations of the Telescope and Dome showing Telescope pointed to Zenith; also by dotted Lines, Various Other Positions of the Telescope relative to the Dome

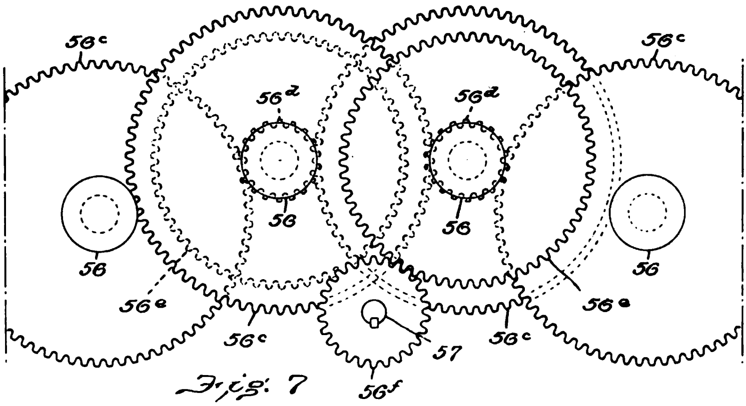



Fig. 7

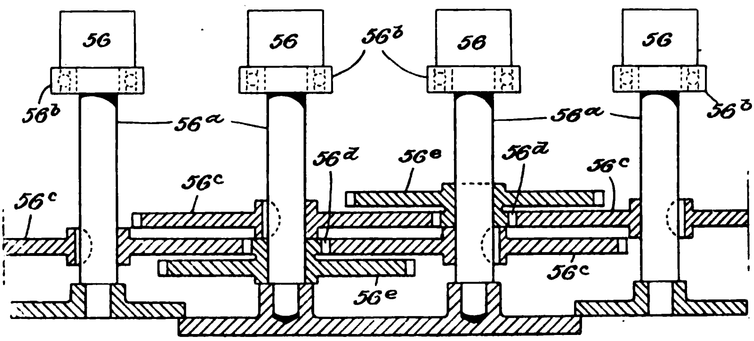



Fig. 8

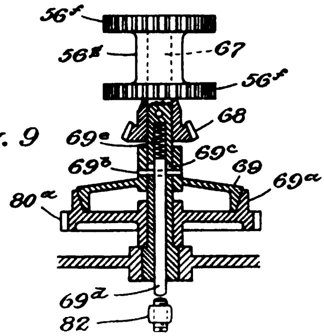



Fig. 9

FIGS. 7 AND 8 PLAN AND ELEVATION OF DRIVING ROLLS AND THEIR GEARS
FIG. 9 CLUTCH MECHANISM FOR THE SLOW MOTION OF DOME (SEE FIG. 10)

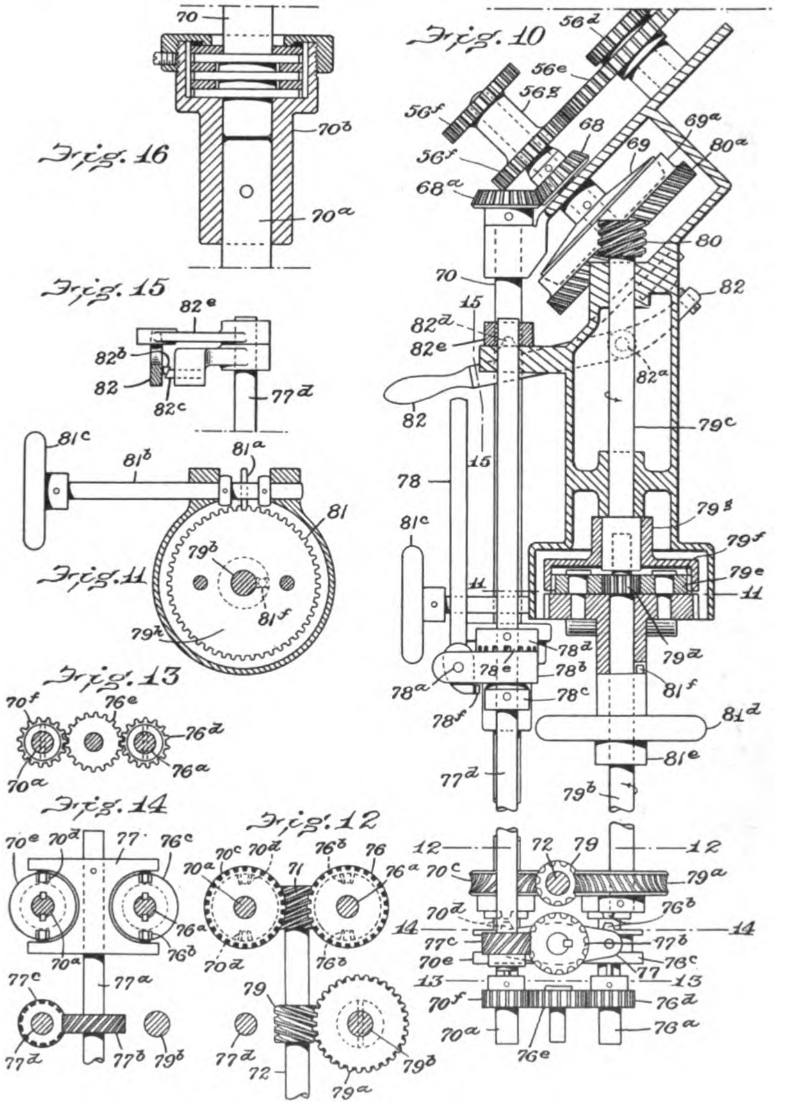



FIG. 10 DIAGRAM SHOWING TRANSMISSION GEARING AND CLUTCHES THAT GIVE THE MOTIONS TO THE TURRET. IT EXTENDS FROM THE TOP TO THE BOTTOM OF THE PAGE

The fast motion forward and back is under control of lever 78 and the slow motion is controlled by lever 82. These levers interlock to prevent conflicting engagement. The slow-motion clutch is shown as a friction clutch at 69 and 69*a*, and the fast motion clutches are of the positive, or toothed-clutch type and are shown rather obscurely at 70*d* and 76*b*. These gears with their clutches are located in a gear box on the floor of the observing room (Fig. 2). The shafts 70 and 70*a* which transmit the motion from this box to the upper group of gearing are unfortunately obscured in this view by the lever control shaft, 77*d*. They may be more clearly seen in Fig. 3a.

FIG. 16 SLIP BOX OR SAFETY COUPLING BETWEEN THE TWO SHAFTS 70 AND 70*a*

It is wholly unnecessary, for the driving rolls slip when any undue resistance is encountered.

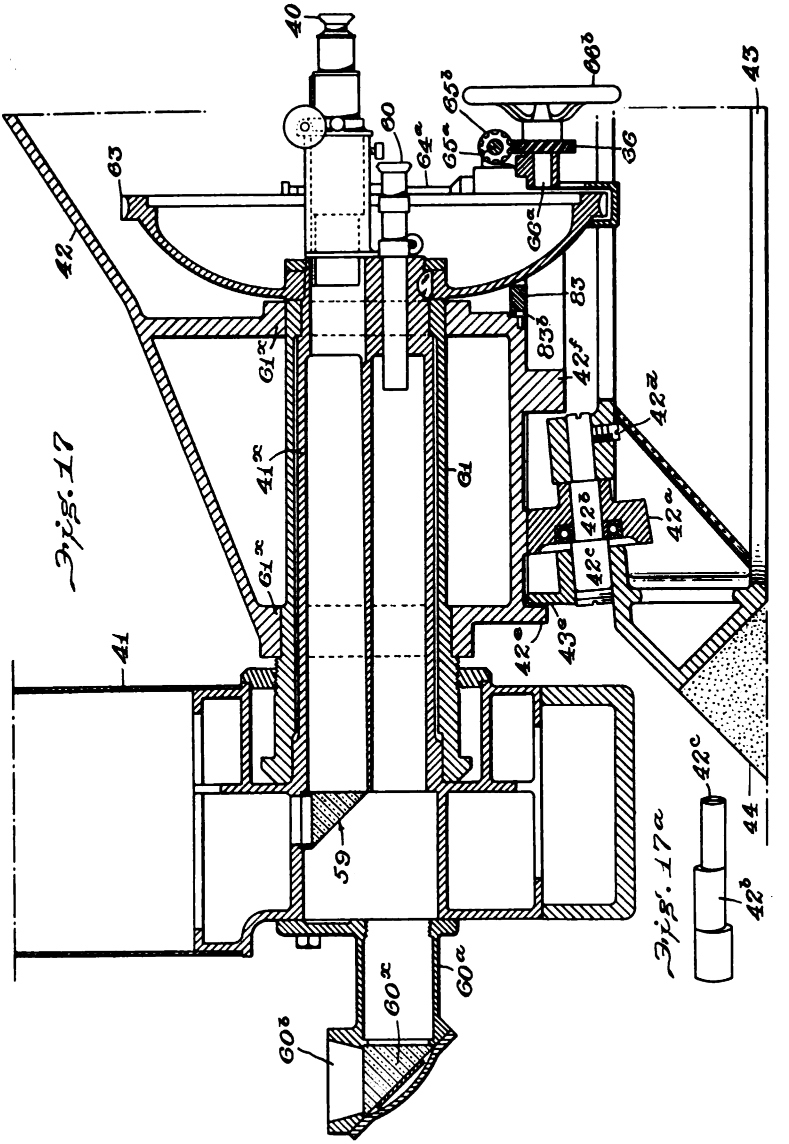
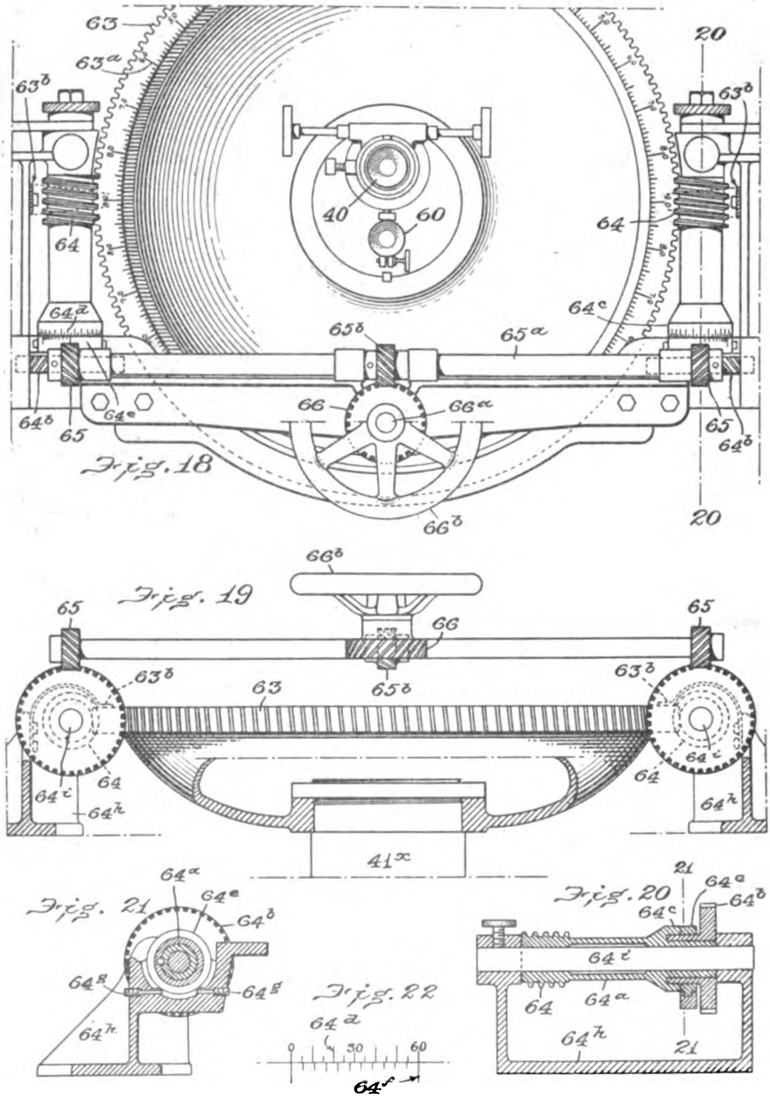


FIG. 17 SECTIONAL PORTION OF THE TURRET THROUGH THE DECLINATION AXIS, SHOWING ALSO SECTION OF THE LOWER PART OF FOUNDATION RING WITH ONE OF THE CONICAL SUPPORTING ROLLS IN SECTION

The part of the foundation ring shown is the same as the lowest part shown in **Fig. 3a**. In Fig. 17 the end of the telescope tube is represented by 41. It is attached to the head declination arbor 41*x*. This arbor turns in bushing 61 which is forced into turret seats at 61*x* and 61*x*.

The cone-shaped beam of light from the object glass comes down through tube 41, passes through prism 59 which changes its direction 90 deg., delivering it to the focal point near ocular 40. The light for the finder enters through opening 60*b* directly into prism 60*x*, thence through an object glass (not shown) which is located in the inner opening of 60*a*. From this object glass it converges to focal point near the finder eyepiece 60.




**FIGS. 18 TO 22 VARIOUS VIEWS OF DECLINATION WORMWHEEL AND ITS CONTROL BY DOUBLE WORMS**
The form of the wheel and its connection to the arbor is not ideal, but may be very much improved in any later work.

Fig. 28

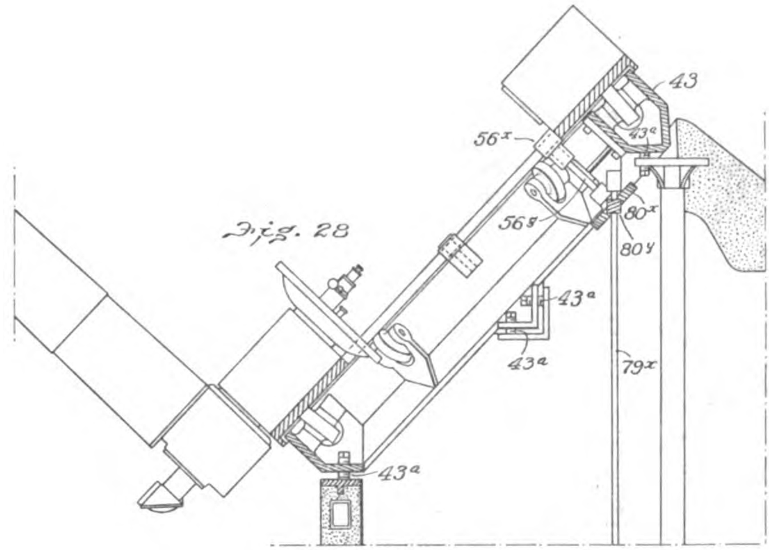



Fig. 23

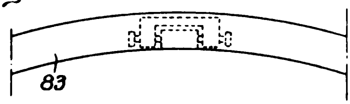



Fig. 24

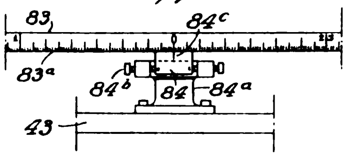



Fig. 25

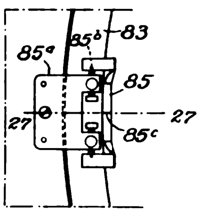



Fig. 26

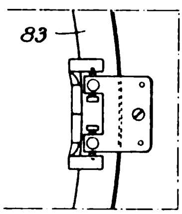



Fig. 27

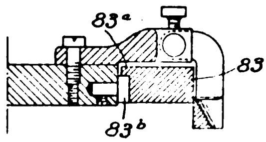
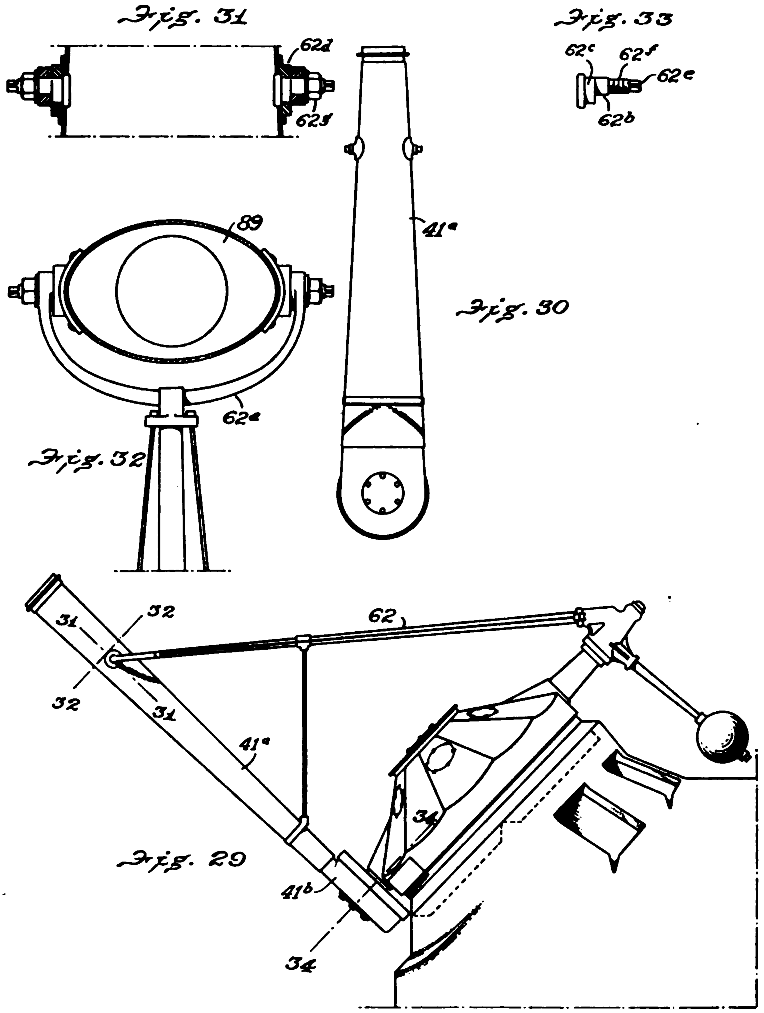


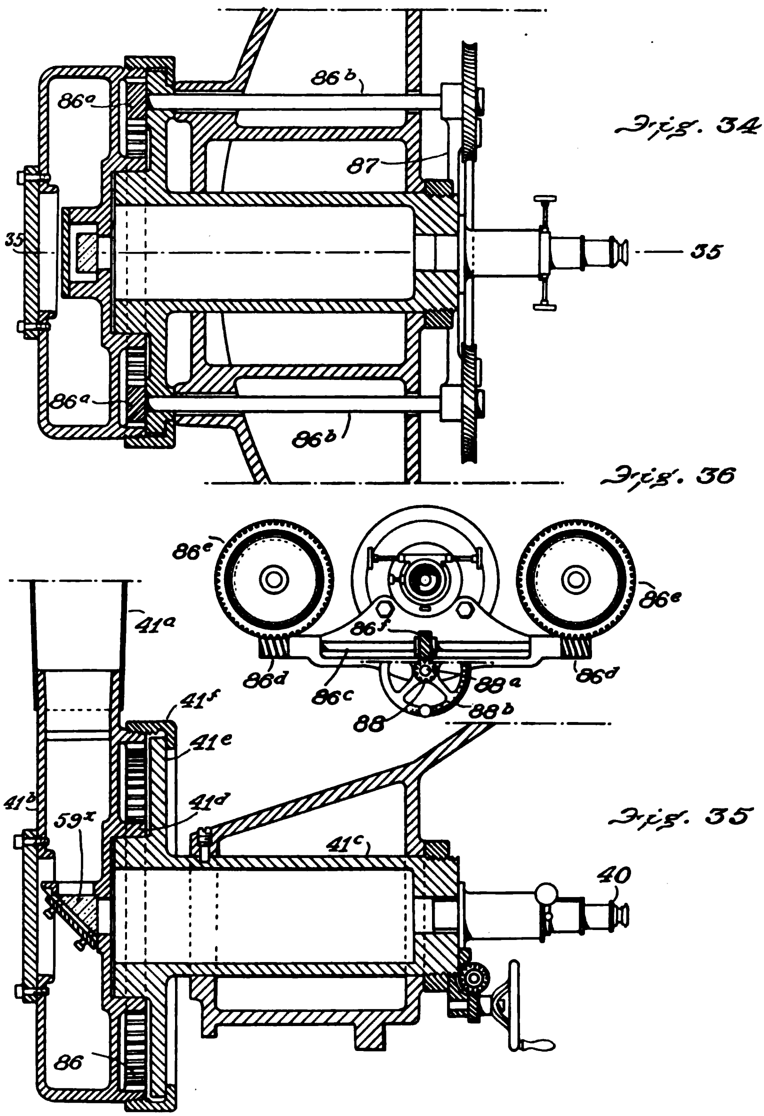

FIG. 28 A SCHEMATIC ARRANGEMENT OF THE ESSENTIAL ELEMENTS IN THE MOUNTING OF THIS TELESCOPE, NAMELY, THE FLAT CIRCULAR RING MOUNTED ON CONICAL AND CYLINDRICAL ROLLS, MEANS FOR ADJUSTING FORMATION RING AND FOR DRIVING ROLLS

Smaller turrets might be made without use of supporting rolls and by going back to the worm drive instead of the roller drive A great variety of circular hollow bearings might be used for smaller turrets, but for one of the present size a single true plane and a single circular track with rolls seem to be the best.

FIGS. 23 TO 27 VARIOUS VIEWS OF VERNIERS FOR HOUR CIRCLE




FIGS. 29 TO 33 DIAGRAMS SHOWING ONE OF THE MANY POSSIBLE MODIFICATIONS OF DECLINATION CONTROL




**Figs. 34 to 36 Details of Scheme shown in Figs. 29 to 33**

# DESIGN CONSTANTS FOR SMALL GASOLINE ENGINES

By W. D. Ennis

## ABSTRACT OF PAPER

Common rating formulae consider piston displacement as the only variable. The expression $\frac{Cd^2}{26,000}$ is suggested for brake horsepower at 1000 ft. piston speed. The factors influencing the value of $C$ are examined quantitatively, and its probable limits are found to be 5,970 and 11,008 for a 4-cycle cylinder, depending on the design and operation. These limits correspond to the range of mean effective pressures, 55 lb. to 90 lb.

An attempt is made to develop a more general expression which shall include the effect of piston speed variations. The form of this expression is

$$\text{brake h.p.} = \frac{Cd^2 fS^e}{24,200,000}$$

in which there may be employed the tentative values $f=1.85$, $e=0.9$.

The internal-combustion motor, unlike a steam engine used for traction, can develop full power only at full speed. The steam locomotive can fu nish a maximum horsepower output even at very low velocities, by using a late point of cut-off. When an automobile must run slowly against heavy resistances as in hill-climbing, the large amount of power required necessitates high piston speed and gear reduction.

As with the steam locomotive, the tractive force is (within certain limits) approximately independent of the piston speed. We may make independent assumptions as to tractive force and car velocity for one condition only. These being fixed by requirements, the horsepower, cylinder dimensions and gear are also fixed. For any other requirements, if the resistance be prescribed, this fixes the gear ratio at maximum output (which corresponds to maximum piston speed) and the corresponding car velocity may be computed from the resistance and horsepower. If on the other hand the velocity is prescribed, the gear ratio (for maximum power and piston speed) is at once fixed, and this determines the tractive force.

# DESIGN CONSTANTS FOR SMALL GASOLENE ENGINES

## WITH SPECIAL REFERENCE TO AUTOMOBILE WORK

By William D. Ennis, Brooklyn, N. Y.
Member of the Society

The following notations and expressions apply to a single-acting water-cooled cylinder in a traction engine using gasolene as fuel:

$p$ = absolute pressure of gas or mixture, in lb. per sq. in.
$v$ = volume of gas or mixture, in cu. ft.
$T$ = absolute temperature of gas or mixture
$D$ = displacement of piston per stroke, in cu. ft.
$S$ = speed of piston, in ft. per min.
$W$ = ideal work done per power stroke, in ft–lb.
$d$ = diameter of cylinder, in in.
$s$ = stroke of piston, in in.
$r$ = revolutions per minute made by engine
$N$ = revolutions per minute made by wheel of car
$w$ = diameter of loaded car wheel, in in.
$F$ = ideal tractive force, in lb.
$A$ = head-end area, in sq. ft.
$n$ = an empirical exponent, having a value between 1.29 and 1.38
$V_0$ = velocity in ft. per sec.; $V$ = velocity in miles per hour
$m$ = weight of car (loaded), in lb.
$R$ = total resistance to propulsion, in lb.
$l$ = a factor by which $W$ may be multiplied to obtain actual work at the engine shaft
$p_m$ = average continuous net effective pressure in the cylinder, lb. per sq. in.
$u$ = ratio of rotative speeds (r.p.m.) of car wheel and piston $= \frac{N}{r}$

The American Society of Mechanical Engineers, 29 West 39th Street, New York. All papers are subject to revision.

2 The preliminary relations given below at once follow:

$$d^2s = 2200\,D, \quad sr = 6S, \quad \text{h.p. (at tires)} = \frac{RV}{375.5}$$

$$336V = Nw, \quad V_o = 1.462V \quad V_o^2 = 2.15V^2$$

3 Fig. 1 is taken as the reference indicator diagram for further analysis, the lines 23 and 41 being vertical, and the value of $n$ being the same for expansion as for compression. We have

$$W = 144\left\{\frac{p_3v_3 - p_4v_4 - p_2v_2 + p_1v_1}{n-1}\right\} = \frac{144}{n-1}\left\{v_3(p_3 - p_2) + v_1(p_1 - p_4)\right\}$$

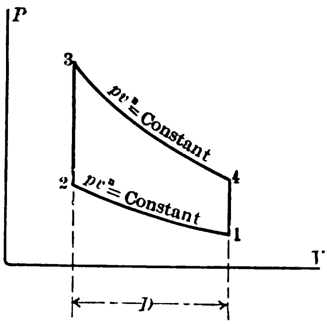



Fig. 1 Reference Diagram

Also, letting $\frac{v_2}{v_1} = a$

$$v_1 - v_2 = D; \quad v_2 = av_1; \quad v_1(1-a) = D; \quad v_1 = \frac{D}{1-a}; \quad v_2 = \frac{aD}{1-a}$$

$$W = \frac{144D}{(n-1)\ (1-a)}\left\{a\,(p_3 - p_2) + p_1 - p_4\right\} \quad \ldots\ldots\ldots [1]$$

4 Ignoring journal and transmission friction,

work at cylinder = work at tires

$$\frac{\pi p_m d^2}{4} \times \frac{2sr}{12} = F \times \frac{\pi wN}{12}$$

$$F = \frac{d^2 srp_m}{2Nw} = \frac{1100\,Drp_m}{Nw} = \frac{3d^2Sp_m}{Nw} \quad \ldots\ldots\ldots\ldots [2]$$

and since $p_m = \frac{W}{4 \times 144\, D}$, we have, letting $\frac{W}{D} = c$

$$F = \frac{cd^2sr}{1152Nw} = \frac{1.915\, cDr}{Nw} = \frac{cd^2S}{192Nw} \qquad [3]$$

5 If the car moves at a velocity $V_0$ as compared with that of the surrounding air, then, ideally, the resistance due to air is

$$R_a = 0.0025\, AV^2 \qquad [4]$$

Experimentally determined resistances on actual surfaces differ from this; but since the automobile presents several successive approximately normal resisting surfaces it may be well to retain the factor 0.0025, interpreting $A$ to mean the transverse clearance area between the bottom of the chassis and the top of the body (Fig. 2).

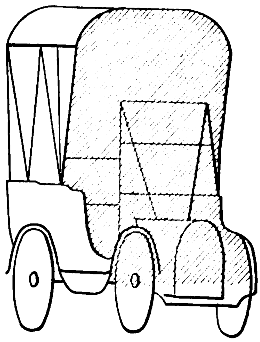



Fig. 2 Head-End Area

Hatching denotes Transverse Clearance Area, taken as Equivalent to the Head-End Area in the Formula $R = m_1 A V^2$

6 On a grade of (100$k$) per cent, the resistance due to the grade (Fig. 3) is

$$R_g = mk \qquad [5]$$

7 Acceleration conditions are seldom decisive (Par. 23). The car must then be designed to (*a*) develop a uniform speed of $V_s$ miles per hour on a straight level track, or (*b*) ascend a straight grade $k$ at a speed of $V_g$ miles per hour: the wheel-rim resistances being derived from equations [4] and [5] respectively

$$R_s = 0.0025\, AV_s^2 \text{ and } R_G = mk + 0.0025\, AV_g^2 \qquad [6]$$

8 The work done in the reference diagram of Fig. 1, per power stroke, is from equation [1]

$$cD = W \text{ ft-lb.}$$

For a single-acting 4-cycle cylinder

$$\text{h.p.} = \frac{Wr}{66000} = \frac{crD}{66000} \quad\ldots\ldots\ldots\ldots\ldots\ldots[7]$$

Alternatively, from equation [2]

$$\text{h.p.} = \frac{FV}{375.5} = \frac{1100\,Drp_m V}{375.5\,Nw}$$

But $V = \dfrac{Nw}{336}$, and $p_m = \dfrac{c}{576}$; whence

$$\text{h.p.} = \frac{1100\,DrcNw}{576 \times 336 \times 375.5\,Nw} = \frac{crD}{66000}\ldots\ldots\ldots\ldots[8]$$

$$= \frac{crd^2s}{145,200,000} = \frac{cd^2S}{24,200,000}\ldots\ldots\ldots\ldots\ldots[9]$$

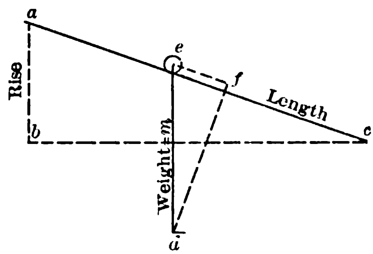



Fig. 3 Grade Resistance

$\dfrac{ab}{ac} = k \quad \dfrac{ef}{ed} = \dfrac{ab}{ac} \quad ef = km$ lb.

9 The following relations (referring to Fig. 1) will be found useful:

$$\left(\frac{v_2}{v_1}\right)^{1-n} = \frac{T_2}{T_1},\quad \left(\frac{v_2}{v_1}\right)^{n} = \frac{p_1}{p_2},\quad \frac{p_3}{p_2} = \frac{T_3}{T_2},\quad \frac{p_4}{p_1} = \frac{p_3}{p_2},\quad \left(\frac{p_2}{p_1}\right)^{\frac{n-1}{n}} = \frac{T_2}{T_1}$$

10 By making a comparatively small number of assumptions we may now arrive at an arithmetical expression for equation [1]. In general, values of $p_1$ for 4-cycle engines will be between 12 and 14. The value of $n$ will range from 1.29 to 1.38, that of $T_3$ will be taken in all cases at 3460 deg., while $T_1$ may vary between 600 deg. and 760 deg. An assumption must be made as to either $T_2$ or $p_2$: it is the temperature which really determines the condition at the state 2, but practice has pretty well standardized $p_2$ at various values for different types of engine between 45 and 100.

11 In order to establish the limits of value of equation [1], care must be taken to adopt properly contemporaneous figures. In the general case, $p_1$, $T_3$ and $p_2$ being assumed, $(v_1 - v_2)$ varies inversely as the value of $n$. Now

$$\frac{p_3}{p_2} = \frac{T_3}{T_1\left(\frac{p_2}{p_1}\right)^{\frac{n-1}{n}}}$$

$$p_3 - p_2 = \frac{p_2 T_3}{T_1\left(\frac{p_2}{p_1}\right)^{\frac{n-1}{n}}} - p_2$$

The rise of pressure during combustion thus varies inversely as the value of $n$ and inversely as $T_1$. Since it is the condition of maximum

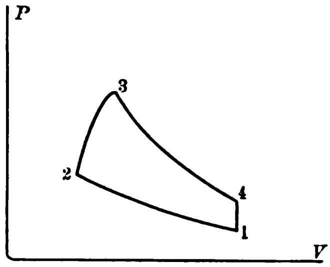



Fig. 4 Diagram at High Speed

work that both $(p_3 - p_2)$ and $(v_1 - v_2)$ should be maximum, then a low value of $n$ is desirable. It also appears that at maximum work conditions $T_1$ should be a minimum, as should $p_1$. We have then the following concurrent values:

4-Cycle Cylinders

| Type | $n$ | $p_1$ | $T_3$ | $T_1$ | $p_2$ |
|---|---|---|---|---|---|
| Best | 1.29 | 12 | 3460 | 600 | 100.0 |
| Normal | 1.32 | 12 | 3460 | 660 | 93.0 |
| Worst | 1.38 | 14 | 3460 | 760 | 45.0 |

Derived Values

| Type | $\frac{v_2}{v_1}$ | $T_2$ | $p_3$ | $p_4$ | $cl$ | (assumed) | $cl$ |
|---|---|---|---|---|---|---|---|
| Best | 0.193 | 967 | 358 | 43.0 | 12950 | 0.85 | 11008 |
| Normal | 0.212 | 1080 | 298 | 38.4 | 9786 | 0.80 | 7830 |
| Worst | 0.429 | 1049 | 148 | 46.2 | 7960 | 0.75 | 5970 |

These values will be used in the subsequent discussion, although an adequate series of experimental values of $p_m$ is to be preferred.

12 If in equation [9] we substitute the values $c = 9786$, $S = 1000$, we obtain h.p. $= \frac{d^2}{2.49}$, a close confirmation of the $\frac{d^2}{2.5}$ formula of the Association of Licensed Automobile Manufacturers. This is horsepower gross, and the power available for propulsion will be reduced to an extent determined by the amount of cylinder loss, journal and transmission friction.

13 At high piston speeds, the reference diagram (Fig. 1) becomes seriously modified, taking some such shape as that of Fig. 4. The combustion line 23 slopes away from the vertical, and $p_3$, $p_4$ and $c$ are all reduced. This effect may be expressed by substituting for $S$

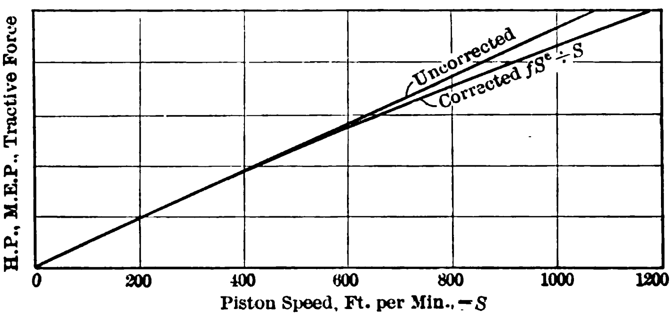



FIG. 5 EFFECT OF HIGH PISTON SPEEDS

in equation [9] or in other equations containing implicit values of $S$, the term

$$fS^e$$

in which $f > 1$, $e < 1$. Consideration of a number of comparatively slow-speed diagrams, with some power measurements at high speeds, suggests the tentative values for piston speeds exceeding 500 ft., $f = 1.85$, $e = 0.9$, as leading certainly to more nearly correct results than the assumption of constant mean effective pressure at all speeds. Fig. 5 represents on this basis concurrent values of $S$ and $fS^e$, and of horsepower, mean effective pressure and tractive power, corrected and uncorrected for piston speed.

14 There seems to be no good reason why speeds and grades should not be standardized for various types of service, so that specific values may be at hand for equations [6], say for recognized standard cars like a town car, touring car, light roadster or truck.

The power equipment may thus be more or less standardized and consequently, also, the total weights of the cars.

15 The capacity of the cylinder increases indefinitely with the piston speed, but the economy falls off as the piston speed increases. Maximum horsepower at maximum piston speed should be based on equations [6] and the relation h.p. $= \frac{RV}{375.5}$. When less horsepower is required, the piston speed should be cut down, and the required speed of car maintained by introducing a new gear. In general

$$u = \frac{336\,V}{rw} \qquad [10]$$

16 A rather limited group of observations indicates that the effect of journal and transmission friction may be represented by an equivalent constant loss of ideal tractive force. For a given car, nearly regardless of speed variations, the tractive force at the wheel rim is therefore taken at $g$ lb. less than the ideal computed tractive force.

17 Since in a given cylinder the horsepower varies as $fS^e$

$$\frac{fS_2^e}{fS_1^e} = \frac{(R_2 + g)\,V_2}{(R_1 + g)\,V_1}$$

and since $u$ varies as $\frac{V}{S}$ when, as in a given car, the wheel diameter and stroke are fixed

$$\frac{u_1}{u_2} = \frac{R_2+g}{R_1+g}\left(\frac{S_1}{S_2}\right)^{e-1} \qquad [11]$$

18 Two of the basic formulae will now be grouped for reference:

$$\text{h.p.} = (R + g)\,\frac{V}{375.5} = \frac{lcd^2fS^e}{24{,}200{,}000} \qquad (a)$$

$$F = \frac{lcd^2fS^e}{192Nw} = R + g = \frac{lcd^2fS^e}{64{,}512V} \qquad (b)$$

19 As an illustration, consider a touring car weighing (loaded) 3300 lb., having an equivalent head-end area of 26 sq. ft. (Fig. 2), driven by a 4-cylinder 4-cycle engine, and required to maintain a speed of 50 miles per hour in still air on a straight road, or of 20 miles per hour on a 9 per cent grade. The rolling circumference of the loaded rear wheels is 8.96 ft., whence their diameter is 34.1 in.

(nominally 34-in. tires). The friction loss from the cylinders to the tires is taken at 50 lb.

20 These conditions make the formulae yield

$$R_s = 0.0025 \times 26 \times 50^2 = 162.5$$
$$R_G = (0.09 \times 3300) + (0.0025 \times 26 \times 20^2) = 323$$

$$\text{h.p.}_s = (162.5 + 50)\frac{50}{375.5} = 28.25$$

$$\text{h.p.}_g = (323 + 50)\frac{20}{375.5} = 19.8$$

Maximum horsepower must be attained at a piston speed, say of 1000 ft. per min.; then, from Par. 18

$$\frac{28.25}{4} = \frac{7830d^2 \times 1.85 \times 1000^{0.9}}{24,200,000} \text{ and } d = 4.84 \text{ in.}$$

or

$$\frac{162.5 + 50}{4} = \frac{7830d^2 \times 1.85 \times 1000^{0.9}}{64,512 \times 50} \text{ and } d = 4.84 \text{ in.}$$

Assuming a stroke of 5 in., giving $r = 1200$ r.p.m. at ful speed

$$u = \frac{336 \times 50}{1200 \times 34.1} = 0.41$$

For the grade condition, we have

$$u_g = \frac{336 \times 20}{34.1\, r}$$

$$\frac{19.8}{4} = \frac{7830\ (4.84^2) f S^e}{24,200,000} \text{ and } fS^e = 657, \quad S = 700$$

and since $r = \dfrac{6S}{s} = \dfrac{4200}{5} = 840$

$$u_g = \frac{336 \times 20}{34.1 \times 840} = 0.235$$

Or, directly

$$\frac{u_g}{u} = \frac{212.5}{373}\left(\frac{700}{1000}\right)^{0.9-1.0} \text{ and } u_g = 0.235$$

21 The cylinder will then be $4\frac{7}{8}$ in. by 5 in. and the gear ratios for the two conditions 0.41 and 0.235, or as they usually described, in-

versely, 2.44 and 4.25. A single $\frac{3}{1}$ ratio might possibly be used for the two conditions, with added higher ratio gears for use when starting or ascending limiting grades. The use of a $\frac{3}{1}$ ratio involves, under the level-road condition, either a reduced velocity of car for a given piston speed, or an increased piston speed to maintain the required maximum car velocity. On the grade, the change in gear ratio cuts down the tractive force and the car will not meet the specified conditions, even though equipped with a motor of ample size.

22 The matter of gear ratios is closely associated with the characteristics of the car. For the two conditions given, the desirable ratios are 2.44 and 4.25. The grade condition is the easier one to meet, and does not require maximum horsepower. With the cylinder available, at 1000 ft. piston speed, the velocity that might be attained on the grade is found from the expression

$$28.25 = [50 + (0.09 \times 3300) + (0.0025 \times 26 \times V^2)] \frac{V}{375.5}$$

to be nearly 28 miles per hour. At this velocity

$$u = \frac{336 \times 28}{1200 \times 34.1} = 0.23$$

and a gear ratio of 4.35 becomes desirable. This does not greatly exceed the gear ratio for a grade velocity[1] of 20 miles per hour, when the piston speed is reduced to 700 ft. per min. and the horsepower to 19.8. A high ratio gives low values of $V$ at maximum piston speeds, required at the moment of starting. The lowest ratio desirable is that for maximum velocities; with ordinary wheel diameters it will never be far from $\frac{120}{V}$ at 1200 r.p.m. of the engine, where $V$ is the maximum velocity required; or generally, $\frac{\text{r.p.m.}}{10V}$.

## ACCELERATION CONDITIONS

23 When a car starts on a straight level road, the resistances to be considered are (*a*) friction, (*b*) head-end resistance and (*c*) that due to acceleration. In the following analysis, the first will be ig-

[1] The increase in grade velocity only slightly increases the resistance, tractive force and gear ratio, because the grade resistance greatly exceeds the velocity or head-end resistance.

nored and resistance and horsepower will be referred to the wheel rim rather than the cylinder.

24 The car starts under a constant tractive force, capable of overcoming a constant resistance, while the motor is getting up to full power and speed, the car meanwhile accelerating. As soon as maximum power is reached, further increase in velocity is possible only as the resistance decreases, acceleration becomes less rapid, and the product of the resistance and the velocity is constant. If we ignore the question of gears, or rather, if we assume a continuous variation of gear ratio to be possible, this condition of things will continue until the head-end resistance alone, at the attained velocity, consumes all the power. Acceleration will then cease and the car will thereafter move at constant speed, resistance and horsepower.

25 During the early part of acceleration, the head-end resistance is negligible. With any reasonable (wheel rim) tractive force, the fraction thereof not available for acceleration, at velocities below 5 miles per hour, may be safely ignored. Within this limit

$$\text{Force} = \text{mass} \times \text{acceleration}$$

$$\frac{dV_o}{dt} = \text{constant} = \frac{32.2\,R}{m}$$

where $R$ is the available tractive force. For the particular car under discussion, let the gear ratio (first) be $\frac{12}{1}$. Then assume that the motor will work with constant tractive force up to 1200 r.p.m., when the r.p.m. at the wheel will be $\frac{1200}{12} = 100$, and the miles per hour

$$V_o = \frac{34.1 \times 100\pi}{12 \times 60} = 14.83$$

and

$$V = \frac{14.83}{1.462} = 10.17$$

At this speed, the motor will develop $28.25\left(\frac{162.5}{212.5}\right) = 21.6$ h.p. at the wheels (Par. 20), and therefore

$$R = \frac{375.5 \times 21.6}{10.17} = 802 \text{ lb.}$$

Then, since $dV_o = 1.462\ dV$

$$\frac{dV}{dt} = \text{constant} = \frac{32.2 \times 802}{1.462 \times 3300} = 5.35$$

and for the attainment of a velocity of 5 miles per hour the elapsed time is $\frac{5}{5.35} = 0.94$ seconds. In the velocity-resistance diagram, Fig. 6, we therefore draw the horizontal line *cd* from $V_0=0$ to $V_0=14.83$, with $R=802$. In the speed-time diagram, Fig. 7, we draw the straight line *Oa* from $V=0$, $t=0$ to $V=5$, $t=0.94$.

26 The point *a* in Fig. 7 lies between *c* and *d* in Fig. 6. To determine the speed-time relation beyond *a* (Fig. 7) and up to *d* (Fig. 6), we must consider both head-end resistance and acceleration resistance. The sum of these remaining constants

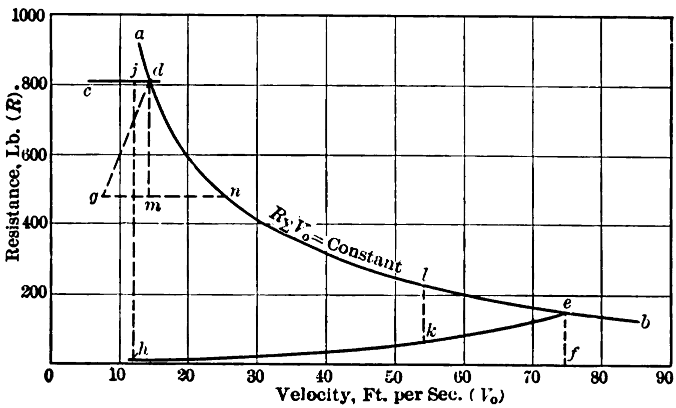



FIG. 6 HEAD-END AND ACCELERATING FORCES

$$R_\Sigma = 802 = 0.0025 A V^2 + \frac{m}{32.2}\frac{dV_0}{dt}$$

$$= 0.065 V^2 + 102.3\frac{dV_0}{dt}$$

This gives, for $V=5$, $t=0.94$; for $V=10$, $t=1.87$; and for $V=10.17$ (limit), $t=1.92$. The curve *ag* in Fig. 7 is plotted with these values.

27 From this point

$$\text{h.p.} = \text{constant}^* = \left(0.0025\, A V^2 + \frac{m}{32.2}\frac{dV_0}{dt}\right)\frac{V_0}{550}\dagger$$

* More strictly, as shown by equation [3] ,Par. 18, the horsepower does not increase quite as rapidly as the piston speed; but it seems a fair simplification of the problem to proceed in the manner suggested.

† The rate of doing work when the instantaneous force is $R_\Sigma$ and the instantaneous velocity is $V_0$, is the same as that when a constant force $R_\Sigma$ moves the car at the constant velocity $V_0$ for one second of time.

If the car moves in a vacuum, so that there is no head-end resistance

$$\text{h.p.} = \text{constant} = \frac{m}{32.2}\frac{dV_0}{dt}\frac{V_0}{550}$$

the equation of a parabola having its vertex at the origin and its focus in the time axis. In the general case

$$R_{\Sigma}V_0 = \text{a constant}$$
$$R_{\Sigma}V = \text{a constant}$$

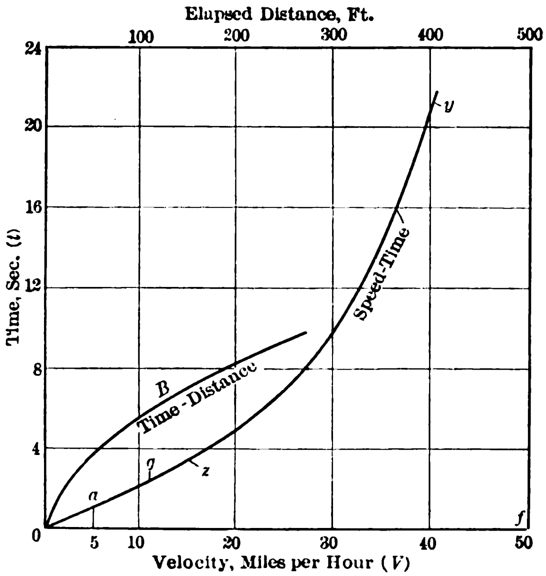



FIG. 7 ACCELERATION CURVES

equations of an equilateral hyperbola referred to its asymptotes, the axes of $R_{\Sigma}$ and $V$ or $V_0$. This is plotted as the curve *adleb*, Fig. 6, and continues until the head-end resistance alone consumes the power, when

$$\text{h.p.} = \text{a constant} = \frac{0.0025\,A\,V^2\,V_0}{550}$$

which for our conditions gives

$$V = 50,\ V_0 = 72.1$$

point *e*, Fig. 6.

28 From $c$ through $d$ to $e$, Fig. 6, the total resistance is the sum of two items, which may be separately shown. Thus, at any velocity $V_0$ $(=1.462V)$, the head-end resistance is

$$0.0025\ AV^2 = 0.0303\ V_0^2$$

from which we have

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Velocity, ft. per sec. | 10 | 20 | 30 | 40 | 50 | 60 | 70 |
| Head-end resistance | 3.03 | 12.1 | 27.3 | 48.5 | 75.9 | 109 | 148 |

These values give the curve *ohke*, Fig. 6. Any ordinate, like *hj*, *kl*, lying between this curve and *cde*, represents the force available for producing acceleration, at the given velocity.

29 The first expression in Par. 27 gives

$$dt = \frac{VdV}{54.2 - 0.000435V^3}$$

whence

$$t = 15.32\left[\frac{1}{2}\log_e\left(\frac{2500 + 50V + V^2}{2500 - 100V + V^2}\right) - 1.733\tan^{-1}\left(\frac{2V+50}{86.5}\right)\right]$$
$$\pm \text{ a constant}$$

which yields

| | | | | | | |
|---|---|---|---|---|---|---|
| Velocity, miles per hour | 10.17 | 11 | 15 | 20 | 30 | 40 |
| Elapsed time from starting, seconds | 1.92 | 2.06 | 2.98 | 4.78 | 10.10 | 20.3 |

The curve is now plotted to the right from $g$, Fig. 7.

30 To express acceleration in terms of distance traversed, a graphical approximation from Fig. 7 should be sufficient. Since $dV = \frac{dS}{t}$, $S$, the distance traversed in the time $t$ at the velocity $V$, is the area under the speed-time curve *ogy*. As far as the point $z$, where $V = 15$, it can be regarded as triangular; and the space, in feet, traversed from starting is, at $a$

$$\frac{5 \times 0.94 \times 1.462}{2} = 3.43$$

and at $z$

$$\frac{15 \times 2.98 \times 1.462}{2} = 32.6$$

From this point, accurate distances may be determined by a planimeter; or, approximately, from

$V=15$ to $V=20$, distance traversed $=17.5\times1.80\times1.462=46.0$ feet,
elapsed distance $=32.6+46.0=78.6$ feet:

$V=20$ to $V=30$, distance traversed $=25\times5.32\times1.462=194$ feet,
elapsed distance $=78.6+194=272.6$ feet.

These values give curve $B$, Fig. 7.

31 Considering the graph *cde*, Fig. 6: after the point $d$ is passed, the piston speed (a function of $V_0$ at a given gear) becomes excessive. This is corrected by throwing in a new gear. If the car can for a short time maintain its velocity, the change of gear will decrease the r.p.m. and h.p. of the motor, and the graph from $d$ will be as shown by the dotted lines *dmn*. If the car slows down, the action is as along *dqmn*. The curve *de* is then purely ideal, a sort of resultant of a series of steps like *dmn* or *dqmn*, and the degree of approach of the actual steps to the ideal curve will be related to the number of gear changes. Under a fixed maximum piston-speed limit, the velocity-resistance curve would consist of a series of alternate constant-velocity and constant-resistance paths, and the speed time curve would be made up of a series of alternate straight vertical lines and curves like *ag*, Fig. 7. Supernormal piston speeds introduce still further modifications of the ideal curve.

## CONCLUSIONS

32 *a* The horsepower developed at the engine shaft by one single-acting 4-cycle cylinder at 1000 ft. piston speed may be written

$$\frac{Cd^2}{26000}$$

where $d$ is the cylinder diameter in in. and $C$ has a value between 5970 and 11008, as specified in Par. 11.

*b* The horsepower developed at any piston speed $S$ may be written

$$\frac{Cd^2fS^e}{24,200,000}$$

tentative values for the constants being, $f=1.85$, $e=0.9$, $S>500$.

*c* The wheel-rim tractive force, in lb., necessary for speed on a level road only is

$$R_s = 0.0025\ AV^2$$

$A$ being the transverse clearance area of the car, in sq. ft., and $V$ its speed in miles per hour.

*d* That necessary for a speed $V_g$ on a grade $k$ is

$$R_g = 0.0025\ AV_g^2 + mk$$

$m$ being the weight of the car in lb.

*e* The tractive force referred to the engine shaft for a wheel-rim tractive force $R$ is

$$R+g$$

$g$ being probably about constant for a given car.

*f* The fundamental equation of design is then

$$\frac{Cd^2fS^e}{24,200,000} = \frac{(R+g)\,V}{375.5} \qquad [12]$$

which at 1000 ft. piston speed becomes

$$\frac{Cd^2}{69.1} = (R+g)\,V \qquad [13]$$

*g* Equation [13] should be used to determine $d$ at the condition of maximum power, and the corresponding necessary gear ratio is

$$u = \frac{336\,V}{Nw}$$

where $N$ = r.p.m. of car wheel having a diameter of $w$ in.

*h* For any other condition, independent assumptions as to velocity and horsepower are impossible. The engine must have sufficient speed to develop the required horsepower. If the wheel speed is also fixed, the gear ratio is fixed and the limit of tractive force established. The gear ratio for a given car is a function of both the total resistance and the piston speed.

# EXPENSE BURDEN: ITS INCIDENCE AND DISTRIBUTION

By Sterling H. Bunnell

## ABSTRACT OF PAPER

Correct cost-keeping is taking rank with the problems of construction in the work required of the engineer. Factory burden, an important item of manufacturing cost, is to be regarded not as waste, but as the continuing outlay for the maintenance of the active concern. High or low ratios of burden to direct or prime cost give no direct indication of the degree of operating efficiency. Burden items should be analysed in detail and allocated to the various producing units of the factory, so that the cost of maintaining, operating and supervising each unit may be known and charged as a time rate against the cost of each item of work passing through the unit. The method of procedure is illustrated in connection with a small machine shop. The normal running expense or burden is scheduled, and accounting methods are suggested by which the efficiency of the management in keeping expense in agreement with the schedule, may be shown. The net result of such a rational method of distributing expense burden is to stabilize the cost of product against the effect of temporary changes in the expense schedule, while providing a definite standard of running expense as a measure of the efficiency of the supervising department.

# EXPENSE BURDEN: ITS INCIDENCE AND DISTRIBUTION

By Sterling H. Bunnell, New York

Member of the Society

As the various problems of engineering design and construction are reduced to the application of known rules, precedents and data, the element of cost enters more prominently into the calculations on which the choice of plans is based. Almost any engineering construction, whether railroad, bridge, tunnel, transmission line, factory or mechanical device, can now be produced with materials and methods in easy reach. The question, "Can it be done?" has given place in importance to "Will it afford an attractive return on the investment?" The engineer must now master in addition to the mathematics of materials and of electricity, the problems of financial operation, the principles of estimating correctly and providing for fixed charges, as well as operating expense, and all the other details of accounting required for the continued successful operation of an enterprise after construction is finished.

2 By far the most difficult of the problems presented for joint solution by the engineer and the accountant is that of the distribution of factory burden on correct principles. The original conception of burden treated it as a wholly unfortunate, objectionable and regrettable outlay, to be kept as small as possible, and subtracted from the gross profit of the factory operation to obtain the figures of net profit. Every possible effort was made to charge not only wages and material, but also repairs and supervision, in some way or other into the particular product that happened to be under construction. The residue of expense which could not be disposed of arbitrarily by this method was collected into a single expense account and distributed by proportion over the cost of the products. The usual method adopted for carrying out the calculation was to distribute the expense

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either as a percentage to cost of labor, or as an hourly charge to be added to the wages cost, of every hour's labor performed. Where this conception and practice exists, every bill that happens to be paid in a given month, or at the best, every charge incurred during that month, is regarded as expense to be distributed over the product of that month. If something breaks down and is repaired at heavy expense, the goods cost more that month because of making the repairs at that particular time. Accounting of this character has made it possible to operate many a factory at a huge profit, until the economically worn-out shell could be unloaded on some capitalist innocent enough to dispense with engineering advice, and purchase on the book figures of past operation.

3 The basis of this scheme of distributing burden by scattering it as evenly as possible over everything in sight, is the wholly erroneous conception that all the operating expenses of the factory can be divided into two classes, productive and non-productive, the first including all useful work on the manufactures to be sold later, and the second all waste, a dead loss to the organization. The logical development of the theory teaches that the ratio of non-productive to productive expense should be kept as low as possible; the best manager is he whose expense ratio is the lowest; and increase of expense ratio by high-powered machinery, trained helpers to save the time of skilled workers, and liberal outlay for good tools and their upkeep, causes loss. The absurdity of the conclusion and therefore of the premise, is evident. No legitimate expense is truly non-productive and some other definition must be found for the expense burden in order to indicate its true significance.

4 Every task performed in a shop under good management is directed toward accomplishing quickly and cheaply some definite and useful end. The purposes served by the various details of the work differ widely. Some of the tasks are performed directly on particular pieces of the factory product and are properly called direct. Others, no less productive are on miscellaneous lots of pieces, like cleaning castings in the foundry; or on several dissimilar pieces at once, as in operating a group of automatic machines. Others have no direct contact with factory product, as in repairing belts, operating cranes and sweeping floors. All of those tasks which cannot be conveniently split up, measured into portions and charged direct to particular pieces of factory product are properly described as indirect.

5 The ratio of indirect to direct expense is no indication of the efficiency of the management, except as between two precisely sim-

ilar operations. In fact, a high ratio of direct to indirect may indicate extreme inefficiency, exactly the opposite of the accepted belief, and this under widely differing conditions; for instance, with a badly managed shop where every man charges his full time direct to a product, and runs his own errands or serves as his neighbor's helper on occasion; or, on the other hand, with a factory equipped with automatic machines under the care of skilled men whose time is charged direct to the cost of product.

6 Experience gained in connection with the cost accounts of factories and shops covering a wide range of manufactures shows ratios of indirect to direct varying from 20 to 150 per cent; and even higher percentages would not necessarily be surprising or discreditable to the management. The introduction of scientific management always increases the ratio of indirect to direct expense, and yet decreases gross cost as well as prime or direct cost. In fact, as between a shop under the best methods of twenty years ago and the best modern practice, prime costs afford no possible basis of useful comparison. High indirect and low direct costs are to be expected with modern equipment, even without scientific management. Heavy cuts by a powerful machine tool in charge of an efficient semi-skilled man at usual day wages often involve an operating cost of $1 per hour for the machine (an item of the expense account), against a direct wages cost of 30 cents for the man, a ratio of 330 per cent. Whenever, as in this case, the direct cost is a mere fraction of the expense burden, to keep accurate costs of the labor and material items only is nothing less than absurd.

7 Scientific management, while increasing the ratio of indirect to direct expense, decreases direct expense in greater proportion. The net saving cannot therefore be ascertained except by accurate knowledge of the details of each class of expense. This knowledge must be continuous, always at hand for instant use. The works manager cannot wait twelve months for an annual audit to show whether a new planning department has saved its cost, or increased operating expense has been followed by a greater increase in value of output. The engineer who is trying to persuade a superior officer in the financial department to authorize the purchase of newer equipment or the increase of the supervisory force will appreciate the advantages of accounting methods by which the exact results of changes in ways of doing work may be demonstrated through the factory accounts. In every factory, the exact result of each new task-setting operation, change in method, and improvement in equipment, not only in regard

to the wages and supplies of today, but also with respect to the operating expense accounts of the month and the fixed charges of the year, should be known in detail and at once. These requirements can be met only by a clear and comprehensive analysis of the true incidence of the fixed charges, and of the indirect details of operating expense, followed by the introduction of methods by which each item of factory product may be charged with that proportion of the indirect expense which corresponds to the cost of maintaining the shop facilities used in performing the manufacturing operations upon that item. The same degree of precision obtained in charging to the cost of work the direct expense for material and labor, should be reached in charging the large and important indirect expense.

8 The part of the engineer in developing the scheme of correct distribution of burden is much more than mere scientific interest in the work of some outside accountant.

9 The first step in the solution of the problem is to analyze the data and conditions. Of the items which go to make up indirect expense or factory burden, some of them are observed to have a very clear incidence upon definite points within the factory. Consider the annual interest on the value of a factory building. Surely it will not rise with an increase in wages or cost of material; nor with an increase in output; nor does it concern anything which takes place in some other building. The building is there to serve a useful purpose; and whatever benefits by that purpose should pay its share toward the interest on the cost of the building. The purpose is evidently the housing of machines and their operators, each of which machines forms a unit in the productive scheme of the factory. Let the building be divided accordingly (by imaginary lines) into productive units, and require each to earn the interest on that part of the whole building which is occupied by the equipment, operator and work in progress, of the unit.

10 Once attacked from this point, the problem of a correct distribution of expense burden becomes easy of solution. The first step in the process is to obtain a schedule of annual fixed and operating expense. This includes the reserves for interest and depreciation, taxes, insurance and other fixed charges, a reasonable allowance for the expected average repairs, and the expense for supervision, small tool upkeep and power cost. Each of these charges is to be split up and apportioned among the particular productive units to which it belongs, the total to be carried as an element of the cost of that part of the factory product which passes through that particular produc-

tive unit during the year. The incidence of each detail of the burden being clearly on the productive unit, which comprises equipment, accessories and a portion of the building and land, the whole of the annual charge has as direct an incidence on the work passing through the production center in the year as the wages of the operator on the equipment of the center. The labor cost is the amount paid the operator, on day, hour, piece, premium, bonus or whatever system is used. The equipment cost is a suitable fraction of the annual burden. As most of the burden elements (interest, taxes, etc.) have a time factor, it is convenient to reduce the annual charge to an hourly rate, and to make the charges to cost of work on the same time units that are provided by the work records of the operatives.

TABLE 1 SCHEDULE OF EXPENSE[1]

| | | | |
|---|---|---|---|
| Interest on Land and Building | $50.00 | Interest on Equipment 5 per cent on half new value | $168.25 |
| Depreciation 2½ % on $1000 Valuation | 25.00 | Depreciation per schedule | 407.00 |
| Taxes 1% on $1000 | 10.00 | Taxes 1% on assessment | 39.00 |
| Insurance, per year | 5.00 | Insurance | 35.00 |
| Heat and Light, Share of this Building | 50.00 | | |
| Building repairs estimated at | 25.00 | | |
| Total Building Charge | $165.00 | Total to Distribute to Equipment | $649.25 |

11 In the practical application of this fundamentally correct system of apportioning expense burden, several interesting and illuminating conceptions have been brought out. The labor of calculation is reduced by following a standard procedure, commencing with the schedule of expense, Table 1. The items belonging to the land are first grouped, and divided by the square feet of occupied land to obtain a land factor in dollars per year per square foot of land. Next, the portion of land belonging to each building is tabulated, and the area of each portion in square feet is multiplied by the land factor to give the total land charge for each building. This forms the first element of burden for the building. The interest, taxes and insurance are calculated on the book value of the building; the annual cost of heat and light are computed and the items totaled to obtain the annual building factor, and divided by the floor area

[1] A unit value of $1000 for land and building and a new cost of $6620 for equipment are taken as a basis for these estimates.

TABLE 2 DEVELOPMENT OF BURDEN CHARGES

| Equipment Number | No. of Machines | Description of Equipment | Equipment Appraisal: New Value: Each | Equipment Appraisal: New Value: Total | Equipment Appraisal: Life: Age | Equipment Appraisal: Life: Future | Building Factor: Sq. Ft. | Building Factor: Charge | Power: Estimated H.P. Indiv. Motor | Power: Estimated Running Time | Power: H.P. Ratio | Power: H.P. Hours | Power: Charge | Share of Accessories Value: Motor (on H.P.) | Share of Accessories Value: Small Tools and Grinders: Ratio | Share of Accessories Value: Small Tools and Grinders: Charge | Shafting and Furniture (on Sq. Ft.) | Present Value of Equipment | Total Value Accessories | Interest Taxes and Insurance (on Total Equipment and Accessories) | Depreciation | Repairs: Ratio | Repairs: Charge | Total Columns 9-14-21-22 and 24 | Foreman and Helpers | Total Annual Burden Cols. 25 and 26 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 |
| 1634 | 1 | Engine lathe, 16 in. by 6 ft., 8 in. chuck | $350 | $350 | 10 | 10 | 45 | $ 6 | 2½ | 2400 | 6000 | 2480 | $29 | $27 | 7 | $25 | $15 | $175 | $67 | $14 | 23 | Repairs apportioned by judgment, and include small tool repairs | 19 | 91 | 135 | 226 |
| 1635 | 1 | Engine lathe, 13 in. by 5 ft., 6 in. chuck | 300 | 300 | 10 | 10 | 60 | 8 | 2 | 2400 | 4800 | 1990 | 24 | 18 | 7 | 25 | 20 | 150 | 63 | 12 | 20 | | 16 | 80 | 135 | 215 |
| 1636 | 1 | Milling machine, 6 in. vise | 600 | 600 | 10 | 10 | 138 | 17 | 2 | 2000 | 4000 | 1650 | 20 | 18 | 10 | 36 | 46 | 300 | 100 | 24 | 39 | | 33 | 133 | 112 | 245 |
| 1637 | 1 | Driller, 10 in., 15 in. swing | 125 | 125 | 20 | 10 | 61 | 8 | ½ | 2400 | 4200 | 493 | 6 | 4 | 5 | 18 | 20 | 42 | 42 | 5 | 8 | | 7 | 34 | 135 | 169 |
| 1638 | 1 | Driller, 11 in., 24 in. swing | 175 | 175 | 20 | 10 | 77 | 10 | 2 | 2400 | 4800 | 1980 | 23 | 18 | 5 | 18 | 25 | 58 | 61 | 7 | 11 | | 10 | 61 | 135 | 196 |
| 1639 | 1 | 4 Spindle drill | 200 | 200 | 20 | 10 | 63 | 8 | 1 | 1000 | 1000 | 413 | 5 | 10 | 5 | 18 | 21 | 67 | 49 | 7 | 11 | | 42 | 42 | 56 | 98 |
| 1640 | 1 | 1½ Milling machine | 530 | 530 | 10 | 10 | 99 | 12 | 2 | 1800 | 3600 | 1480 | 18 | 18 | 10 | 36 | 33 | 265 | 87 | 21 | 34 | | 29 | 114 | 102 | 216 |
| 1641 | 1 | Screw press | 50 | 50 | 10 | 10 | 16 | 2 | .. | .... | .... | .... | .... | .... | .... | .... | 5 | 25 | 5 | 1 | 3 | | 3 | 9 | .. | 9 |
| 1642 | 1 | Shaper, 15 in. stroke, 8 in. vise | 330 | 330 | 10 | 10 | 16 | 2 | 2 | 1800 | 3600 | 1490 | 18 | 18 | 3 | 11 | 5 | 165 | 34 | 12 | 19 | | 18 | 69 | 102 | 171 |
| 1643 | 1 | Milling machine, small | 350 | 350 | 40 | 5 | 30 | 4 | ¼ | 1000 | 250 | 103 | 1 | 2 | 6 | 22 | 10 | 29 | 34 | 4 | 12 | | 19 | 40 | 56 | 96 |
| 1644 | 1 | No. 1 Universal Grinder | 250 | 250 | 15 | 10 | 36 | 5 | 2 | 100 | 200 | 83 | 1 | 18 | 4 | 15 | 12 | 100 | 45 | 8 | 14 | | 14 | 42 | 6 | 48 |
| 1645 | 1 | Screw machine | 550 | 550 | 20 | 10 | 25 | 3 | 2½ | 500 | 1250 | 501 | 6 | 26 | 7 | 25 | 8 | 183 | 59 | 14 | 23 | | 30 | 76 | 28 | 104 |
| 1646 | 1 | Cutter grinder | 150 | 150 | 20 | 10 | 30 | 4 | ¼ | 100 | 25 | 10 | .... | 2 | 3 | 11 | 10 | 50 | 23 | 4 | 7 | | 8 | 23 | 6 | 29 |
| 1647 | 1 | Surface grinder | 150 | 150 | 10 | 10 | 30 | 4 | ⅜ | 1000 | 375 | 155 | 2 | 4 | 1 | 4 | 10 | 75 | 18 | 6 | 9 | | 8 | 29 | 56 | 85 |
| 1648 | 1 | Surface grinder, small | 125 | 125 | 10 | 10 | 20 | 3 | 1/16 | 500 | 31 | 13 | .... | 2 | 1 | 4 | 7 | 63 | 13 | 5 | 8 | | 7 | 23 | 28 | 51 |
| 1649 | 1 | Polishing lathe | 30 | 30 | 20 | 5 | 35 | 4 | ⅛ | 500 | 62 | 26 | .... | 2 | 3 | 11 | 12 | 6 | 25 | 2 | 6 | | 2 | 14 | 28 | 42 |
| 1651 | 1 | Small forge and equipment | 40 | 40 | 10 | 10 | 35 | 4 | ¼ | 750 | 188 | 78 | 1 | 2 | 1 | 4 | 12 | 20 | 18 | 2 | 4 | | 2 | 13 | 42 | 55 |
| 1653 | 1 | Power hack saw | 40 | 40 | 10 | 10 | 35 | 4 | ¼ | 500 | 125 | 52 | .... | 2 | 2 | 7 | 12 | 20 | 21 | 2 | 4 | | 2 | 12 | 28 | 40 |
| 1654 | 1 | Speed lathe, 12 in. by 6 ft. | 75 | 75 | 10 | 10 | 48 | 6 | ⅛ | 300 | 38 | 16 | .... | 2 | 4 | 15 | 16 | 38 | 33 | 4 | 7 | | 4 | 21 | 17 | 38 |
| 1655 | 1 | Lathe with collets and turret attachment | 300 | 300 | 10 | 10 | 66 | 8 | 2 | 1000 | 2000 | 825 | 10 | 18 | 10 | 36 | 22 | 150 | 76 | 13 | 22 | | 16 | 69 | 56 | 125 |

| | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1656–1659 | 4 | Rivett bench lathes | 450 | 1800 | 10 | 10 | 92 | 12 | ¼ | 4800 | 600 | 250 | 6 | 9 | 32 | 116 | 31 | 900 | 156 | 64 | 105 | 98 | 285 | 317 | 602 |
| | | Bench space for two men | | 100 | 10 | 10 | 255 | 31 | .. | 4800 | ...... | ...... | ...... | ...... | 12 | 43 | 83 | 50 | 126 | 11 | 18 | 5 | 65 | 270 | 335 |
| | | Totals | | 6620 | | | 1312 | $165 | | | 34,144 | 14,088 | 170 | 220 | 138 | 500 | 435 | 2931 | 1155 | 242 | 407 | 361 | 1345 | 1850 | 3195 |
| | | Accessories | | | | | | | | | | | | | | | | | | | | | | | |
| 1650 | 1 | Wet grinder, 12 in | 80 | 80 | 10 | 10 | 34 | | | | | | | | | | | | | | | | | | |
| 1652 | 1 | Grindstone | 30 | 30 | 10 | 10 | 61 | | | | | | | | | | | | | | | | | | |
| | | Shafting $180; miscellaneous trucks, etc $200 | | | | | | | | | | | | | | | | | | | | | | | |
| | | Storage space | | | | | 62 | | | | | | | | | | | | | | | | | | |
| | | Total floor area of shop | | 6730 | | | 1469 | | | | | | | | | | | | | | | | | | |

[1] Value of land and building occupied by shop equipment in column 3, $1000

| | |
|---|---|
| Interest 5%, Depreciation 2½%, Tax 1%, Insurance ½% | $90 |
| Building repairs, estimated at | 25 |
| Heat $40, Light $10 | 50 |
| Total building charge | $165 |

of the building to give the square foot factor. The next step is a map or diagram showing each production center with its working floor space, including in the list of centers erecting floor spaces, benches, and all equipment on which men are employed or operations performed on factory product. The centers are then to be tabulated in order by departments as in Table 2, with the appraised value and square feet of floor space occupied by each. Multiplying the latter by the square foot factor, the total building factor of each productive unit is obtained.

12 Accessory equipment goes with the producing machine of each production center, that is, shafting, belts, all or a share of a motor, small tool equipment, and the like. The value of such equipment is generally much less than the value of the principal machine, so that absolute accuracy in apportioning accessories is not essential. If the value is very small, it may be divided among the units in proportion to the value of their producing machines; if large, shafting and belts may be apportioned to the units on the basis of the floor space occupied by each, motors driving groups on the basis of the working horsepower-hours of each productive unit, and small tools by judgment. If the greatest accuracy is desired, the accessories may be treated separately and each one measured, appraised and assigned to the productive units accordingly.

13 The remaining calculations are carried out for each unit independently, including the value of the accessories with that of the main machine. A depreciation rate is set for each unit, or class of machines, and the corresponding annual charge is computed. Interest on the value of the machine, taxes and insurance are also provided for. All these are definite quantities, not open to argument. There remain certain items not as definite: power cost, repairs, general labor, factory supplies and (in a machine shop) cost of tools, each of which requires special treatment. Power, if it could be metered separately to each productive unit, would become a direct charge; but as this is impracticable, and the power cost is not of the greatest magnitude, a reasonable approximation can be made by estimating the average power consumption, the average running time, and so the average annual horsepower-hours of each unit, and multiplying by the cost of a horsepower-hour to obtain the power factor of the burden charge. Supplies and general labor are best divided by estimate and judgment. Repairs to the individual units cannot possibly be foretold; but the average total repair cost of the plant, or even of the several departments of the plant, can be estimated with some degree of precision,

and distributed to the productive units in any of several ways. Perhaps the most practicable is to set by estimate figures representing the probable proportion of repairs likely to be required by each kind of machines, placing 1 opposite the machine likely to require the least expense for upkeep, 2 for those machines likely to require twice as much expense, and so on. By adding these figures for a denominator and using each figure separately for a numerator, the total estimate for repairs can be divided up among the several units. There is no advantage for cost-keeping purposes in attempting to charge the actual cost of repairs into the operating expense of each unit. In repairs for lightning and the like, which generally strikes without warning, there is no reason why the expense burden and therefore the cost of work done by one of several similar machines should be temporarily increased merely because that machine suffered breakage and was repaired at this particular time. Standard power and repair costs are a great help in rational cost-keeping, since they minimize fluctuations in cost not due to difference in management. By opening separate repair accounts, charging these accounts with actual cost, with all its momentary variations, and crediting the standard estimates, the varying balances tell an interesting story of the work of the repair gang, and keep the fluctuating costs of repairs from exerting a disturbing influence on the cost of product. A power-plant account similarly operated is also very useful.

14 The tabulation now includes subdivisions of all the expenses which go to make up the factory burden, up to the point at which the completed goods leave the factory, but exclusive of the administrative expense. If the total burden chargeable to each unit is divided by the respective annual working hours of the units running full time, an hourly rate for each productive unit will be obtained, which if applied to the cost of the work done by each unit, will in a normal year of full working time accumulate a credit which will balance the shop expense burden. There are, however, many lost hours in the course of the working year and such losses reduce the credit which is to stand against the annual shop burden, and tend to produce a deficit. Short time may be due to any of three causes, each of which gives to the resulting deficit a different significance. In the ordinary operation cf a factory, time is lost by the productive units through illness of operatives, changes in the force, breakages and repairs, and lack of capacity in other units. Obviously, a deficit in the credit against burden due to losses of this character is a manufacturing expense, and should be distributed to the cost of work.

15 Lost working time, however, may be due to sales department conditions, as when machinery is installed for the manufacture of goods which have a seasonable demand, so that they can be sold during only part of the calendar year. A deficit due to lost time of this character is selling expense, and not part of manufacturing cost. In such a case, the sales department undertakes to earn through profit on the sales, the necessary amount to pay for the use of the capital invested in the equipment over the period of idleness. The manufacturing cost cannot be increased merely because consumption ceases after a time, so that the machines have to be stopped. If it costs $1000 to operate equipment for three months, and another $1000 for the following three months, it is not to be supposed that it costs $2000 to operate for the first three months only. Factory product can be made continuously, stocked up during an idle period, and sold at the proper time; if such a course is inadvisable, by reason of tying up capital, or loss of interest on the money represented by stored goods, or risks taken, the expense of intermittent operation falls outside of the manufacturing account. Admittedly, someone must pay the fixed charges for each period of idleness; but the party liable in cases of the kind supposed, is not the works manager, who would be glad to operate continuously, but the selling division of the organization, which must take the consequences of sales conditions. Correct accounting practice will not justify the distribution of selling expense to goods before they are sold; wherefore, manufactured goods should not be placed in stock with a burden allowance which includes selling expense, though it is quite proper to include all other items of burden.

16 The third possibility of the deficit due to lost time is that it is a consequence of bad trade conditions. Lost time of this character is neither manufacturing nor selling expense, but a business loss which should be made up out of the profits of good years. Conservative management accumulates a surplus to give stability to the rate of distribution to the stockholders, by reserving a portion of the earnings of good years to be used in maintaining dividends in times of depression. With correct methods in distributing factory burden, the loss due to short time operation, usually buried out of sight among other expenses which have no relation to running time, is clearly shown, so that an appropriation may be made from the surplus account to carry the deficit of poor years by the extra earnings of good years.

17 The divisor used on the annual burden of each unit should therefore be less than the full annual shop hours, at least by a suit-

able allowance for holidays and other lost time. In the case of a large special machine for which there is work only part of the time, the expected working hours only should be used as a divisor, for such a unit, to be profitable, must earn its annual charges in the running time which can be given it. Whenever conditions change so that such a unit can be operated a larger proportion of the time, the hourly charge should be correspondingly reduced.

18 There remain some items like salaries and office expense, the incidence of which cannot be traced to definite productive units. This class of expenses, however, is incident to the operation of the factory as a whole. The larger productive units, with their greater capital value and heavier operating expense, involve a greater tax on the management and administration than the smaller units. The burden charges belonging to the units provide a very fair measure of the responsibility of the management in connection with each, and serve well as a basis of distribution of the overhead charges. It is proper, therefore, to express the overhead expense total as a percentage of the total burden distributed to all the productive centers together, and to raise the hourly rate of each unit by the same percentage. Thus, if $100,000 is distributed to centers, and there is an undistributed overhead of $10,000, the rates can be raised 10 per cent, which will provide for carrying the whole $110,000.

19 Each productive unit of the factory is thus valued at an hourly rate which is to be charged in the cost of each operation performed by the unit. The total cost of an operation accordingly consists of a labor charge and an equipment charge. The basis of each machine rate is a careful investigation of the operating costs of the particular machine, so that the rates set are in accordance with the facts in each case. Whatever fluctuations there may be in operating expense are likely to balance each other above and below the calculated charges. But as there will be some variation in any event, it is permissible to obtain the advantage of easy calculation by equalizing the machine rates into two, three or more round figures, each covering productive units whose exact rates fall near together. On the job-tickets by which the time or piece price of the labor is computed, a space should be provided for the burden figure, so that the completed job-tickets will give both elements of the cost. Any change in methods or men will now indicate its complete result by a comparison of the job-tickets for the same work done under former and present conditions.

20 The accounting detail of the expense burden distribution is simple and effective. A burden distribution account is opened, to

which is charged the calculated amounts of Table 1. The account is credited with the total of burden charges to cost of work, by weekly or monthly periods. The balance indicates the loss by failure to utilize the full capacity of the factory; while a credit balance, if one should occur, indicates a condition of unexpectedly good management, or good luck, by which the factory has worked to better advantage than was believed probable. A standardizing account of this kind is very useful to the management. All the variable expense accounts can, if desired, be handled as suggested for power and repairs, so that uniform credits offset the varying debits, and the balances afford gages for the efficiency of the control of the departments originating the accounts.

21 A constantly increasing balance in one of the expense accounts will occur if there has been a permanent change in policy with respect to this item. In such a case, it will be necessary to change the equipment rates affected by this change. While it is not at all difficult to go over a column of the tabulation and revise the figures, it will generally be sufficient to change the rates by proportion, enough to absorb the difference. But it is not necessary to distribute all the burden by machine rates. The overhead of salaries and office expense, the cost of storage and handling, and, if desired, any small difference in burden actual and distributed, may be distributed as a rate per pound on a homogeneous product, or as a rate per order if orders are all of the same size, or as a percentage of gross cost, if that seems the most reasonable method. In every factory, careful analysis of the facts will point out the true incidence of expense due to factory operation, or factory product as a whole, rather than individual production centers.

22 A valuable result of localizing variations in expense burden is stability in the cost of the manufactured product. Because a repair force is discharged to save expense, and everything is allowed to fall into bad order, is no reason why the cost of goods made during the period should appear to decrease. The management is in effect borrowing part of the cost from the stored energy of the organization, or discounting the future. All fluctuations not directly due to a change in manufacturing methods are objectionable if carried into cost of product. Where the cost of similar articles varies uncertainly from day to day, each fluctuation is likely to have a different cause, much time is taken in searching for the causes, and incorrect conclusions are often drawn, or it is assumed that some unknown and unusual condition is responsible, and the attempt to trace the cause is given

up. Increased labor cost is easily discernible and can be traced directly to its origin. Variations of material cost are quite as easy to explain; but where burden charges vary with labor charges, under the old percentage or hourly rate methods, a change in cost of labor involves a totally unrelated change in the burden charge, and no clear conclusion can be drawn.

23 Exact calculations are at the base of all well-planned engineering work. Exact uniform methods of cost calculation should be at the base of all factory accounting systems. Wherever associations of manufacturers operating on similar work have investigated the cost-keeping methods of the various factories, the investigators have been surprised to note the wide variation between the apparent or book cost of the same products, made under the same conditions, but figured in different ways. The inevitable result is that some factories bid for work below cost, and thereby injure the business chances of all. The remedy is not the maintenance of unduly high prices by agreement, thereby inviting competition from every outside shop; but an exact analysis and apportionment of the expense burden in such a way that each item of factory work will be properly charged for the use of that portion of the shop equipment and facilities which is devoted to it, and the true margin of profit between cost and selling price will be clearly apparent.

# THE DEVELOPMENT OF THE TEXTILE INDUSTRIES OF THE UNITED STATES

## A GENERAL STATEMENT OF PRESENT CONDITIONS

By Frank W. Reynolds


### ABSTRACT OF PAPER

The great development of the textile industries has led to a great concentration of engineering skill upon construction, power, machinery, and general plant arrangement, and the general efficiency of modern mills is high. There are, however, many unsolved problems and many difficulties the solution of which seems to depend largely upon the mechanical engineer. Automatic machinery has been developed largely in order to cut down labor cost, but in spite of these changes in machinery the producing capacity of 100,000 sq. ft. of mill surface has not appreciably increased within the past 40 years. Many machines and many processes cry out for improvements which have not yet substantially advanced in spite of many years of experimenting. Maximum possible speed of operation seems to have been reached in most machines, with the exception of the spinning machine. The situation suggests that large increase in producing capacity may have to be sought in the more or less complete abandonment of the traditional methods of manipulating textile fibers. The labor problem is in many cases serious, owing to the poor quality of operatives. Measures are suggested to meet this situation.

# THE DEVELOPMENT OF THE TEXTILE INDUSTRIES OF THE UNITED STATES

## A GENERAL STATEMENT OF PRESENT CONDITIONS

By Frank W. Reynolds,[1] Boston, Mass.

Non-Member

The importance of the textile industry in a country which, like the United States, now manufactures all the woven fabrics really necessary for the clothing of all its people, hardly needs to be argued. Yet in the case of our own country progress in the textile industry has been so rapid, and its development has had such a vital relation to other industries, that some statistical evidence of its great place may serve as an inspiration to the men, mainly the mechanical engineers, who are responsible for its continued progress and increasing efficiency. Owing to the fact that the figures from the census of 1910 are not yet available as a complete survey of the textile industries, it is necessary to cite here the figures of the census of 1900; but it should be noted that these figures do not adequately suggest the great expansion in the textile industries that has taken place since the enactment of the tariff law of 1897. Some later figures are indeed available, but even with the old figures it is possible to gage quite accurately the present position of textile manufacturers. The statistics which follow cover only the cotton, the woolen, and the silk industries, in what the census reports term the "proper" sense of those words, namely, the production of fabrics either ready to wear, or ready for the dyeing and finishing processes which precede the conversion of certain cloths into made-up clothing.

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[1] Member of firm, Lockwood, Greene & Co.

TABLE 1 VALUE OF DOMESTIC PRODUCTS, EXPORTS, IMPORTS FOR CONSUMPTION, AND TOTAL CONSUMPTION OF TEXTILES, WITH PER CENT OF IMPORTS TO TOTAL CONSUMPTION, FOR THE UNITED STATES, 1900

| | Value of Domestic Products | Exports | Domestic Consumption | Imports for Consumption | Total Consumption | Per Cent of Imports to Total Consumption |
|---|---|---|---|---|---|---|
| Total | $743,447,062 | $25,556,057 | $717,891,005 | $82,214,010 | $800,105,015 | 10.3 |
| Cotton manufactures | 339,200,320 | 24,003,087 | 315,197,233 | 39,789,989 | 354,987,222 | 11.2 |
| Wool manufactures | 296,990,484 | 1,300,362 | 295,690,122 | 15,620,487 | 311,310,609 | 5.0 |
| Silk manufactures | 107,256,258 | 252,608 | 107,003,650 | 26,803,534 | 133,807,184 | 20.0 |

TABLE 2 COTTON SPINDLES IN THE WORLD IN THOUSANDS, 1900

| | |
|---|---|
| Great Britain | 46,000 |
| Continent of Europe | 33,000 |
| United States | 19,008 |
| India | 4,400 |
| Japan | 1,500 |
| China | 600 |
| Canada | 640 |
| Mexico | 460 |

TABLE 3 VALUE OF SILK PRODUCTS OF EUROPE AND THE UNITED STATES, 1900

| Countries | Value of Products | Per Cent of Products |
|---|---|---|
| Total | $395,000,000 | 100.0 |
| France | 122,000,000 | 30.9 |
| United States | 92,000,000 | 23.3 |
| Germany | 73,000,000 | 18.5 |
| Switzerland | 38,000,000 | 9.6 |
| Russia (in Europe) | 21,000,000 | 5.3 |
| Austria | 17,000,000 | 4.3 |
| Great Britain | 15,000,000 | 3.8 |
| Italy | 13,000,000 | 3.3 |
| Spain and Portugal | 4,000,000 | 1.0 |

TABLE 4 COMPARATIVE SUMMARY, BY INDUSTRIES FOR THE UNITED STATES

| Industries | Year | Number of Establishments | Capital | Wage-Earners: Average Number | Wage-Earners: Total Wages | Cost of Materials Used | Value of Products |
|---|---|---|---|---|---|---|---|
| Combined Textiles | 1900 | 4312 | $1,042,997,577 | 661,451 | $209,022,447 | $521,345,200 | $931,494,566 |
| Cotton manufacture | | | | | | | |
| Cotton goods....... | 1900 | 973 | 460,842,772 | 297,929 | 85,126,310 | 173,441,390 | 332,806,156 |
| Cotton small wares | 1900 | 82 | 6,397,385 | 4,932 | 1,563,442 | 3,110,137 | 6,394,164 |
| Wool manufacture.... | 1900 | 1414 | 310,179,749 | 159,108 | 57,933,817 | 181,159,127 | 296,990,484 |
| Silk manufacture..... | 1900 | 483 | 81,082,201 | 65,416 | 20,982,194 | 62,406,665 | 107,256,258 |
| Hosiery and knit goods............... | 1900 | 921 | 81,860,604 | 83,387 | 24,358,627 | 51,071,859 | 95,482,566 |
| Flax, hemp and jute.. | 1900 | 141 | 41,991,762 | 20,903 | 6,331,741 | 32,197,885 | 47,601,607 |
| Dyeing and finishing textiles............ | 1900 | 298 | 60,643,104 | 29,776 | 12,726,316 | 17,958,137 | 44,963,331 |
| Combined textiles.... | 1890 | 4276 | 767,705,310 | 517,237 | 168,488,982 | $447,546,540 | 759,262,283 |

TABLE 5 COMPARATIVE SUMMARY, NOT INCLUDING FLAX, HEMP AND JUTE, WITH PER CENT OF INCREASE FOR THE UNITED STATES, 1900

| | | Per Cent of Increase |
|---|---|---|
| Number of establishments.......................... | 4,171 | 1.4 |
| Capital.......................................... | $1,001,005,815 | 35.3 |
| Wage earners, average number..................... | 640,548 | 27.7 |
| Total wages...................................... | 202,690,706 | 23.9 |
| Cost of materials used........................... | 489,147,315 | 16.1 |
| Value of products................................ | 883,892,959 | 22.4 |

2 Even the statistics of a decade ago are impressive evidence of the enormous strides made by the textile industries in this country during the last century. At the beginning of the nineteenth century the textile industries were represented by spinning mills for cotton yarn, by wool-carding factories, and fulling mills, in which cloth woven on hand looms in the households of the country was dressed and prepared for sale. It was not until 1814, less than a hundred years ago, that the first broad power loom for cotton goods was worked out by Francis C. Lowell, of Boston, and put in operation at the new plant at Waltham. From that time, progress was rapid, and in the cotton industry particularly almost numberless improvements in machinery were made during the next decade. The actual complete establishment of the cotton industry in this country as a factory industry depending wholly upon power-driven machinery dates from the establishment of the Middlesex Mills at Lowell in 1823.

It was a year or two after this that the first broad power looms were introduced into wool manufacture. The history of our textile development since that time is too intricate to be summarized in this paper. It must be sufficient to note that now the United States is the second greatest producer in the world, not only of cotton and woolen cloths but of silk; while the use of linen for carpet yarns and thread, and for towels and towelling has reached large proportions. Besides the textile industries "proper," there are also a great multitude of small factories engaged in the production of textile specialties.

### PRESENT CONDITIONS AND PROBLEMS

3 The textile manufacture, probably to a greater extent than any other industry in the country, has tended to a complexity, both mechanical and operating, that is rather exceptional. This has been the result of two main factors: the first being the peculiar conditions imposed by the character of our most used natural fiber, cotton; and further by the constant necessity for a progressive decrease in the labor expense of cotton manufacture. The cotton industry has been shaped, as no other industry has, by the peculiar limitations found in the raw material itself. The necessity for a humid air in cotton factories, both to affect the physical condition of the fiber, and to prevent the mischief caused by electricity in the fibers during manufacture, is a requirement of great importance, and one that has not even yet been satisfactorily met. The character of the cotton fiber also, whether well or ill moistened, imposes certain limitations upon the speed of the machinery handling it. On this side, the speed at which roving is now handled seems to have reached the practicable maximum, and the same thing is true of looms. In the spinning frame, however, it has been shown that the cotton fiber will stand a more rapid handling than it now receives.

4 Added to these influences from the phyiscal limitations of the cotton fiber itself, the cotton industry has had to face another rather peculiar series of problems in the cost of labor. The automatic machinery of today represents the constant effort to cut down the labor cost of production, this labor cost bearing a rather higher proportion to the total production cost in the cotton industry than in most others. Another labor problem has arisen through the changes that have taken place in the available labor supply. The disappearance of the native American labor of the middle of the last century has been followed by a greatly varied succession of labor

elements, until the industry in many places depends upon a class of alien operatives whose habits and standards are not by any means perfectly adapted to the most profitable manufacture. These latter problems, of course, emphasize the desirability of more completely automatic machinery, while they also impose new requirements in factory organization and administration.

5 The textile establishments of today, owing to the intricacy and importance of conditions, some of which have just been noted, are making full use of the best engineering skill in the design, construction, arrangement and equipment of plants. Many well informed and practical men whose work has been wholly devoted to the textile manufacture, have studied with great care the problems involved, and have made the solving of them their whole aim. The result is a highly specialized work, whose principles have become well understood and applied in all of the structural and mechanical features of the later new plants, and in the reconstruction of the older plants. Advantage has been taken of all new forms of construction wherever practicable, improved machinery for manufacturing and for power purposes has been installed to the fullest extent, and in many instances the initial trials of new forms of mechanical and electrical improvements have been made in textile mills. We find in these modern plants, buildings of either slow-burning construction or of reinforced concrete, equipped with the most modern systems of power transmission, of fire protection, electric lighting, humidifying apparatus, and the latest type of manufacturing machinery of both domestic and foreign design.

6 In spite of the great accomplishment already achieved, however, there still remain unsolved problems, and other problems of many kinds in which the cotton industry has so far only approximately reached a satisfactory position. These problems are in the main such as it is the proper function of the mechanical engineer to solve, and therefore today, as in the early period of the cotton industry, the mill calls upon the machine designer and the machine shop for better tools and better methods.

7 It is to be borne in mind that textile mills in common with other industrial plants are built for a specific purpose, which is to produce an income for the owners. All engineering problems in connection with them must be subject to this condition. It would seem very impractical, to say the least, to erect a building or to purchase machinery for that building which would be so expensive that the profit would be diminished because of the interest on unneces-

sary expenditure. The managers and designers of textile plants of all kinds must bear in mind that the productive power of machinery equipment, whether for the manufacturing process, for power, light, heat or other departments must not be so great that a proper return upon the investment is not possible.

8 It will be found upon investigation that the power plants of textile mills are as a rule especially economical and that advantage has been taken of nearly every labor-saving device and of the most approved machinery which can be obtained. At the same time managers of these plants have endeavored not to spend money which will not show a reasonable return, and it should be the aim of all engineers who approach the problems to be solved in connection with this industry, that while the most efficient machines and processes are desired, the cost of the installations of machinery necessary to produce such results must be kept at a figure which is not prohibitive.

9 The arrangement of the buildings of the plant is one of the most important features to be considered. Much unnecessary labor is often expended because of the poor arrangement of buildings forming different parts of a group, and the equally poor arrangement of the machinery within the buildings. It must be borne in mind that the least number of motions and the shortest distances to be traveled play some of the most important parts in economy of production. Whether buildings should be one or more stories high or of a greater or less width will be determined by a consideration of these points. A brief survey of present conditions and needs may be helpful.

## CONSTRUCTION

10 Nearly every engineer is familiar with what is known as the slow-burning type of mill construction. It was first brought out by some of the early designers of cotton mills, and has since been used in some form or other in nearly every other type of industrial plant. For many years this form of construction, with slight variations, has been successfully used and has been regarded as sufficient for the needs of the industry. It has developed however, that a better form of construction is available and to this form of construction attention is called in this paper.

11 Rigid, non-vibrating mill buildings are one of the immediately desirable things. The slow-burning mill construction has great virtues, but rigidity is not one of its possessions. Rigidity has been

found to produce marked economies in the maintenance of textile machinery, as well as machinery of many other types, and for this reason alone the modern type of reinforced concrete construction has proved itself highly desirable. The friction between concrete floors and machine bases is so great that with much fewer bolts than are required on a wooden floor, machinery can be so securely anchored that it will not walk out of its proper position. In consequence, shafting and machines keep in better alignment, there is less wear and tear on the machines themselves, and the cost and bother of repair are greatly diminished. Simple and effective ways of attaching shafting and motors to concrete beams have been devised, so that from the point of view of machinery installation and maintenance the rigid-frame mill building of reinforced concrete has proved itself superior to any other type. The cost of reinforced concrete is somewhat greater than that of mill construction, as a general thing; but there often exist in some localities special conditions in which concrete is as cheap or cheaper than mill construction. Against its usually higher cost there may properly be set its indestructibility by fire. The concrete building not only does not burn, but if properly built, it is so little harmed even by a serious fire that it can be equipped with new machinery and put in operation again in a very small part of the time needed to replace a damaged mill-construction building. There is a species of fire loss, the interruption of production, for which insurance is often an inadequate compensation; the concrete mill building practically eliminates this loss.

12 Another valuable advantage of the concrete mill building is that it allows a much greater window space than is possible with anything else but steel construction, which latter, if effectively fireproofed, is much more costly than concrete. A concrete building can have as much as 80 per cent of its outer wall area devoted to lighting, as against a maximum of about 50 per cent in mill construction. Existing provisions for the escape of operatives in case of fire in cotton mills are on the whole exceedingly inadequate. Most mills are equipped, in addition to stairways with the familiar type of outside fire escape consisting of galleries or balconies for each story, with ladders from the top of the series to the ground. The actual operation of this type of escape is that the population of a big workroom is, in case of fire, crowded upon a series of outside balconies from which movement to the ground is excessively slow under the best of conditions; and in case of a fire panic, is but little less dangerous than the fire within the wall. If a fire occurs in a lower floor of

the mill, it breaks from the windows of that level and the ascending smoke and flames instantly render useless the whole tier of fire-escape balconies above. It would seem that nothing more faulty in principle, or imperfect in execution, could well be imagined, and it is a fair cause for astonishment that these contrivances should for many years have been accepted by engineers.

13 The proper and only adequate device in the way of a fire escape is the isolated staircase tower. It is doubtful if the building of such towers in adequate number would at all seriously increase the construction cost of cotton factories. It is evident that only the isolated stair tower can be a real fire escape, and it would seem to be equally evident that this type of safeguard should be provided for in every new mill, and that every effort should be made to providé for it in existing buildings. It may be objected that disastrous fires in textile mills are comparatively rare, and this is indeed true. This objection, however, is beside the point. Mills several stories high cannot be built utterly without fire escapes, and if the necessity of some form of fire escape is once admitted the argument for putting in a really efficient device is a strong one.

## POWER

14 The changing conditions of power production and transmission have from the earliest days of the cotton industry had the most potent influence in shaping the material and conduct of the whole industry. The first effect was in forcing the location and even the shape of mill buildings to a large extent to suit the possibilities of the land lying in immediate contact with water privileges. As a result of building the old mills as close as possible to the water-wheel which gave them power, mills were made high and narrow and often built on curves which not a little embarrassed the mechanical transmission of power; and groups of buildings were strung out in a long line, or arranged in other peculiar groupings which the practice of today recognizes as unsuitable for effective power transmission, or for the careful arrangement of the sequence of processes, so important in the economy of the modern textile mill.

15 Aside from these direct effects on the type of textile mill construction, the power element has had other large effects which it is perhaps not easy to separate under distinct headings, though the results form together a series of complications which are familiar to every mill man. The changing conditions of power transmission

have had much to do with the grouping of machines of the same type within the mill, and even the machinery layout of the whole plant. The earlier systems also had much to do with accidents to operatives.

16 The modern use of electrical drive, either on the group system or by individual motors, dating from its first general employment in the Columbia Duck Mills in 1893, has had a revolutionary effect on many aspects of the cotton industry. It removed, at the outset, the former supposed necessity for building mills in immediate contact with water powers, and therefore permitted the arrangement of the different buildings of a plant to satisfy the requirements of speed and economy in the routing of material and product. With the modern electrical transmission line, mills may be built miles from the power generating station, in places where the supply of labor, of building materials, or of transportation facilities make it most advantageous to locate the plant. For situations of this general type, where power must be developed at water sites which do not offer the other conditions required for a mill, electric driving may hardly be disputed as the best form of power.

17 In other situations, however, particularly where power has to be obtained from steam, it is still a matter of debate among engineers as to whether electrical transmission or mechanical is the more efficient and economical. The writer believes that when power can be taken from the flywheel of the engine by a short, direct drive to the head shafts of the mill, such form of transmission is preferable to electrical drive. But whenever there is a scattered group of mills and especially where transmission shafting has to make angles, electrical transmission is decidedly the more desirable. The differences of opinion as to these two forms of power transmission are due in large part to the fact that, although the transmission losses are greater with electrical transmission than with mechanical, the motor-driven machine gains certain other things which make the equation more than the simple matter of comparing transmission losses; for example, the group system of motor drive in which losses are slightly greater than with mechanical transmission.

18 As usually arranged with mechanical drive, an average of about 72 or 74 per cent of the i.h.p. of the engine reaches the machine. With motors driving groups, about 65 to 70 per cent of the i.h.p. of the engine reaches the machine; while with the individual motor drive the similar efficiency will be from 70 to 75 per cent.

19 The virtue of electrical transmission which largely counterbalances its lower efficiency is its continuous speed. The advantage

of the motor is most apparent in individually motor-driven machines, where speed is even because of the positive action of the motor. It is true that there is a drawback to the use of individual motors, and even of group driving motors, in the high cost of motors in comparison with shafting, but even with the losses of power already mentioned, the advantages of the present type of motors will in many cases outweigh this excess of cost. The relatively low efficiency of the small motor seems to be the chief weakness of the individual drive so far as regards efficiency of power transmission. The small motor seems to offer an excellent field for improvement at the hands of the engineer.

20 Shafting bearings that will largely reduce the friction losses, which are too great even with the modern ring-oiled babbitted bearings, deserve the earnest attention of mechanical engineers. The solution seems to lie either with roller or ball bearings, and it is possible that ball bearings, properly designed and constructed with extreme accuracy of measurement from the proper qualities of steel, may prove the best type. Roller bearings have in many cases proved very efficient but it would seem that the length of contact with the shafting which they involve makes them inherently more liable to derangement than are the ball bearings. Theoretically, at least, since a ball-bearing hanger involves only a single line of contact points, it would seem that a bearing of this type might be less liable to derangement, and would offer greater latitude of adjustment than a roller bearing.

21 Where the ordinary type of shafting bearing is retained it is often possible to reduce friction losses as well as lubrication cost, by a more careful study of lubrication. Experience has shown that the necessary study and care of the cost differences between the best and merely ordinary methods on the common types of lineshafting, are more than repaid by the results. It should be obvious, however, that merely as a mechanical question the roller or ball bearing is greatly superior to any sort of sleeve contact.

22 Two special problems under the head of power deserve more attention from engineers. The first of these problems, which is how coal or ashes can be handled more economically in a given situation, may seem a trifling matter; but the effect of bad arrangements in this particular has an easily visible effect on operating expense.

23 The other problem is provided by the power situation in many New England mills where the water power has proved insufficient for expanding plants which now depend upon a combination of steam

and water power in which the latter, once the principal source, has very often become the auxiliary. There is considerable opportunity for the engineer in the proper arrangement and economical design of such combination power plants.

## MACHINERY

24 With regard to the machinery concerned in the manufacture of the cotton fiber, it is rather noteworthy that the producing capacity of 100,000 sq. ft. of mill floor has not been materially increased within a number of years. There has been a large development in making machines more automatic in their operation, with a consequent reduction in the labor cost, but increased rapidity in the processes of manufacture has been far less in evidence in the cotton than in many other industries. Apparently this situation is due to the fact that with the exception of spinning machines, cotton machinery of the existing types is already running at as high speeds as the nature of the fiber will allow. In the ring-spinning machine it seems fairly sure that when certain improved devices already in operation have been brought to perfection, spindles will run 15,000 r.p.m. where the maximum is now ordinarily about 9000 or 10,000. As the labor cost in the cotton industry has also been reduced less than in any other industry, it becomes a pertinent question for the mechanical engineer to consider whether the existing processes really represent substantially the maximum possible speed at which the fiber can be handled. The writer does not wish to assert that radically new types would make possible a great increase in speed, but with the facts before us it may be reasonable to suggest the desirability of making a careful study of the chances for improvement by a departure from present types of machinery. While the fact is not proof that much better types of machinery are still possible, it is true, nevertheless, that the existing methods for the manipulation of the cotton fiber are those of tradition. The question that might well be considered is whether the pioneers in cotton processes, on which succeeding generations have merely made piecemeal mechanical improvements, hit upon the only principles by which cotton can be successfully manufactured; or whether, on the contrary, more rapid production can be attained by the adoption of some different methods of manipulation. If the principles of the present processes are to be considered a finality, it would seem that the only possible gains will be small, and accomplished by making existing types of machinery more fully

automatic, and by training the necessary operatives to a condition of higher efficiency. There is some room for improvement in this latter direction when it is realized that the average producing output of textile machinery is about 85 per cent of the theoretical capacity of the machines, while some of the best mills have maintained an efficiency of well over 90 per cent.

25 There is a chance to make considerable saving by the combination of some of the processes which are now performed separately. As an example, it is possible to do away with the spooling machine, and a machine has already been designed for this purpose, although it is not in general use in this country. Careful study would probably show that this plan of concentration could be carried still further.

26 The providing of satisfactory machinery for the manipulation of cotton waste is another problem the thorough solution of which would benefit both the machine manufacturer and the cotton mill.

### HUMIDITY AND TEMPERATURE

27 One of the most important unsolved problems in the cotton manufacture is that of maintaining within mill buildings the temperature and humidity necessary for the most successful handling of the cotton fiber. The almost universal cooling off of the air of mills during the night and over holidays greatly reduces the absolute humidity in the cold season, even if it does not lower the relative humidity of the air. But a high relative humidity at a low temperature does not put the fiber in the best condition for working. There is needed not only a certain absolute humidity, but in addition a temperature which allows the fiber to absorb the moisture in a way to bring it to its best condition.

28 Most of the humidifiers now in use, those of the self-contained type, are essentially the same in principle as the primitive method of admitting steam through rose heads; they depend upon throwing a fine spray of vapor into the room, where it must be absorbed by the room air and diffused until it meets and affects the fiber under manipulation. The true principle would seem to require that heating and humidifying be combined, those two functions, and also that of ventilating, being performed by the same equipment. With the positive-pressure air system of heating, temperature can be regulated automatically and a uniform temperature can be maintained. It seems evident that the best system for humidifying will be that in

which the entering current of air for heating and ventilating is also provided, before it enters the room, with the requisite degree of humidity. It is certainly as possible to secure automatic control of humidity in the entering supply, as automatic control of temperature. Such a system, while it might be difficult to reduce it at the outset to perfectly reliable action, is in principle much simpler than any system of numerous heads distributed throughout a room; and under adequate study and experiment it will probably turn out to be simpler also as a piece of mechanism. By such a system it should be easy to secure not only proper conditioning of the fiber itself, but also proper conditioning of the operatives, the latter being quite as important in the long run as the state of the fiber.

29 The maintenance of a uniform temperature and humidity during all the non-working hours would greatly improve the condition of the fiber. When, as is often the case, mills are allowed to cool down during the night, either as a result of mistaken notions of economy, or through the carelessness of watchmen, the cotton cannot be in the best condition for manipulation at the beginning of the working hours. It must wait for its proper conditioning until the mill has slowly reached the temperature, and the air the proper humidity. There is also required in the heat of summer some adequate way of cooling the room air when the outside temperature is too high. Both results can best be obtained by combining the supply of moisture with the supply of hot or cool air as the case may be.

## REMOVAL OF LINT

30 Another unsolved problem is some method of removing lint from machinery, motors, and wall, ceiling and belt surfaces that shall prevent soiled lint from damaging the quality and appearance of the product. In some mills this task is handled by having machines and surfaces continually wiped off with cloths, a method that is not entirely efficient, and undeniably costly. The practice of blowing lint from machines and surfaces with a blast of compressed air is familiar, and also unsatisfactory. The lint blown from the motors and from belts, walls and ceilings is in large part diffused again into the air, and tufts, often soiled, descend upon the cotton in process of manufacture and appear as more or less soiled lumps in the finished product. The air blast is also objectionable for the way in which it breaks or disturbs yarn or roving in the process of production. The lint evil is naturally most serious in the carding and weaving rooms.

For the former there is already a portable pneumatic suction machine which can be removed from card to card in order to take up the lint set free when each card is cleaned. The device is successful in removing a considerable part of the lint, but it does not cover the whole problem. The practical difficulty lies not so much with the system itself, for pneumatic suction is adequate, and we know how to use it, but in applying it without becoming involved in prohibitive expense. It is of course mechanically possible to provide a system of exhaust hoods, even in a crowded card room, which would take care of all lint; but the body of air that would have to be handled by such a system would require a large expenditure of power, to say nothing of the rather heavy cost of hoods, ducts, fans and separating chambers. It would be interesting to know whether, and how far, it is economically and mechanically practicable to equip the individual machine with its own suction-cleaning device, operating as a part of the machine itself, somewhat after the manner in which the automobile motor runs its own fan for the cooling of its cylinders.

## LIGHTING

31 The artificial lighting of textile mills is a field which offers great room for improvement. Electric lighting is usually adopted. There are many mills where gas lighting is still used and a few where the old oil lamp may be found. A clear white light is the best for all purposes, but with many forms of the incandescent bulb the light actually obtained is usually quite yellow. On all white work the Cooper-Hewitt light has been used with very good results, since it is steady and gives a powerful illumination. It has been found very serviceable in machine shops, and it has the virtue of allowing one to concentrate his gaze without undue fatigue of the eyes. In cotton mills, however, the operatives generally prefer local to general lighting, but this involves many difficulties in securing the right arrangement of the different lights. The placing of a hooded bulb close to that part of the machine which the operative must keep under his eye has been one solution of the difficulty of cross shadows which arises when a series of lights are placed near a row of machines. The hooded local light, while it seems at first sight desirable, probably tends to provoke accidents, owing to the deep shadow surrounding most of the machines; and the alternation of the operative's gaze between the brilliantly lighted patch of his machine and the comparative darkness which surrounds that lighted patch has been found

to be very hard on the eyes. This would seem an inevitable result, because a quick glance from a brightly lighted spot to a dark spot and then back again to the light spot involves two very rapid accommodations of the eye mechanism, and a consequent excessive strain. The artificial lighting of a textile mill is in fact almost a special field of engineering.

### WOOL AND WORSTED MANUFACTURE

32 While much that has been said of the cotton mills applies as well to woolen and worsted mills, there are many problems that are more or less peculiar to woolen and worsted mills. Some of the more important of these are here noted.

33 Machinery offers a great field for improvement. One of the greatest present wastes comes in the extremely short life of the leather aprons and dabbing brushes on worsted combs. The annual cost of renewals of the leather apron which carries the stock to the combs in a large mill may easily exceed $10,000. Metal rolls have been tried as a substitute for the leather apron, but without success. The problem is as old as the industry and it would seem that a solution should be forthcoming. The ineffectiveness of many devices tried in the past raises the question whether an entirely different type of machine is not needed. Dabbing brushes often wear out in about two days, and apart from the expense of the new brushes themselves, the bother of the whole operation is a great nuisance. Something new is needed here, possibly something new in principle.

34 The French system of spinning raises another serious problem in the difficulty of getting the right conditions for the best handling of the fiber. There is much electricity. Proper conditioning of the air for the fiber demands both high temperature and high humidity. The crux of the whole difficulty seems to be in the heating of the rolls of the machine, the temperature of which is the most important single item in successful spinning. They must have the same temperature as the air of the room; if they are only a little cooler spinning goes badly, while if they are comparatively cold, spinning is practically out of the question. The problem here is whether the roll can be heated to an efficiency temperature by some internal application of heat, so that its temperature shall be practically independent of the air.

35 A variety of other problems may be grouped together, not because they are individually unimportant, but because there is no need of enlarging upon them after what has already been said in more

detail of the problems of the cotton mill. Dust in the singe-room is one of these problems. This dust falls to the floor and can be cleared away with an air blast or air suction rather more easily than cotton lint; but some kind of continuous removing process is necessary because of the extremely irritating effect of this dust when breathed into the lungs. Sulphur dioxide gases in the bleachery offer another problem in removal; a somewhat similar problem arises also in the carbonizing room where the treatment of wool with acids gives rise to very destructive action upon shafting and wood work. Ventilation of hot-rooms and dye-houses is another removal problem. These air-borne by-products of the woolen industry, comprising as they do, steam, various destructive gases, dust, an excess of heat and humidity, might seem again to furnish material for a special branch of engineering. Proper utilization of the waste products from wool washing presents another opportunity for the engineer. In regard to machinery, there is at present much trouble from soiling of fabrics by the oil used on the machines through which they pass, especially in the finishing machines. Such stains are of course disastrous on white or light-colored goods and are more serious than similar stains on cotton fabrics because of the much greater value of the material itself. There seems to be in the woolen manufacture the same question that arises in respect to cotton, whether the whole machinery of manufacture cannot in some way be made to give more output and better product by some departure from traditional methods. Existing processes leave something to be desired, not only on the side of their producing efficiency and maintenance cost, but perhaps quite as much in the deterioration of the wool fiber that results from existing processes.

## MANAGEMENT AND LABOR EFFICIENCY

36 There remain to be mentioned some apparently minor matters relating to the efficiency of operatives and to details of administration within the mill that are at least worth attention and that may hold the possibility of considerable economies. The influx of labor from the near East and from Southern Europe has brought mills in some sections to dependence on a class of labor whose neatness, efficiency and general adaptability to the conditions of cotton manufacture are considerably less than ideal. Certain classes of operatives for instance, who in their foreign homes never recognized the need for clean hands, bring their old point of view into the cotton mill, where in making piecings, and tying warp threads with smudgy fingers they

multiply troubles for the overseer. This one problem of getting the operative's hands clean enough for the handling of white goods is a tolerably serious one in some mills. Certain plants provide each operative in the spinning and weaving departments with a pail of water in which he is expected to wash his hands as often as is necessary to keep them clean. Operatives of this class will not go to set basins at considerable distance from their working stations. It might be well to have a small hand basin between every pair of windows.

37 Prevention of accidents to operatives seems to require that some special instruction should be given to this lower grade of labor before the new operative is allowed to come into the mill. It is not unlikely that if green operatives had a week of preliminary instruction in which they made the acquaintance of various types of machinery and were shown what part of the machines might lead to accidents, the mill managements might find the expense of such instructions a profitable outlay.

38 In view of acknowledged defects of certain kinds of mill labor there is the question whether employers would not find it profitable to institute and maintain some continuing scheme for the instruction of new operatives, the picking out and retaining of those operatives who showed themselves capable of high efficiency, and the rejecting of those operatives with whom the instruction did not take. Up to the present time textile improvements designed to reduce the labor cost have been in the direction of requiring less labor and some of those who are alive to the defects of some of the present labor supply, see a remedy only in making textile machinery still more automatic.

39 Finally, in many of the older textile plants of the country the typical American policy of scrapping inefficient equipment needs to be extended to the buildings themselves. The comparatively recent erection and profitable operation of various new mills located in parts of New England removed from the traditional manufacturing centers emphasizes the necessity, under the conditions of today, of having the best possible plant arrangement in the matter of buildings. Some mills have gone under and others are weak, because they have been unwilling or unable to discard wholly a plant layout which no amount of internal improvement could raise to the pitch of cost efficiency required for successful competition with new mills properly laid out at the beginning. As reorganizations take over unsuccessful properties, it is fairly certain that a considerable number of old mill buildings will be razed, so that new ones may be put on the same sites; or that the old buildings will be altogether abandoned as manufacturing plants.

# VARIABLE-SPEED POWER TRANSMISSION

By George H. Barrus and Chas. M. Manly

## ABSTRACT OF PAPER

The paper describes a variable-speed power-transmitting mechanism called the "Manly Drive," and a series of efficiency tests on the same, conducted by Mr. Barrus. The mechanism is fundamentally a hydraulic device, which consists of a pump attached to the driving shaft, one or more fluid pressure motors on the driven shaft or shafts, the latter being placed in any desired location with reference to the driving shaft, hydraulic connections between pump and motor, and a single operating lever. The fluid used is ordinary machine oil. When the operating lever is moved to its extreme position at one end, the driven shaft revolves in the same direction as the driving shaft and at its highest speed. When the lever is moved to its extreme position at the other end, the driven shaft revolves in the opposite direction at its highest speed. When the lever occupies a central position the driven shaft comes to rest and the machine acts like a brake. When it is gradually moved from either extreme position towards the centre, or from the centre towards either extreme, the speed is gradually changed in a corresponding degree, either forward or backward. These changes occur without varying either the speed, or direction of motion, of the driving shaft. Furthermore, as the speed of the driven shaft decreases the torque increases in like proportion. The tests covered a range of speed of the driven shaft varying from 105 to 350 r.p.m., and the efficiency of transmission, viz., the percentage which the power delivered by the drive bore to the power received, averaged 87.7 per cent.

# VARIABLE-SPEED POWER TRANSMISSION

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Chas. M. Manly, New York
Non-Member

In the rapid extension of the use of electric motors it has been found necessary in many applications to provide for a considerable range of speeds in the machinery operated by them. While this requirement has been met to a certain extent in direct-current motors either by speed-control systems, involving means for varying the field strength, by inserting resistance in the armature circuit, by multiple voltage systems, or by a combination of one or more of these means with others of a similar character, still, in a great many applications these methods have failed to give the results desired. Where only an alternating-current supply is available, the speed control of motors has been much less satisfactory, as even with a polyphase current not only the range in speed variations obtainable with alternating-current motors has been very small, but their torque characteristics at starting under load have been far from satisfactory.

2 The rapidity with which the internal-combustion or gas engine has been applied to various purposes in recent years, although remarkable, would no doubt have been greater had not the torque-speed characteristics been so unsatisfactory, especially at very low speeds, with what might be called a negative torque at starting, since power from some other source must be provided for starting. This has practically necessitated the introduction between the engine and the apparatus which it is to drive, of a clutch or some other disconnecting device, so that the engine itself may first be set to work and the driven apparatus started later by decreasing gradually the slip of the clutch.

[1] Vice-President, Manly Drive Co.

The American Society of Mechanical Engineers, 29 West 39th Street, New York. All papers are subject to revision.

In some cases where the driven mechanism has required only occasional reversal, the combination of a clutch with a reverse gear has prevented the rejection of the gas engine in those applications where its other advantages made it especially desirable, such as automobile, motor boat, and similar uses. On the other hand, the application of the gas engine has not been so satisfactory where the torque required to start the driven mechanism has been several times that required at full speed, such, for example, as heavy automobile trucks, where other factors have made it undesirable to provide an engine capable of developing the same amount of horsepower in proportion to the starting resistence to be overcome, as is practised in pleasure automobile construction. In pleasure automobiles the high speeds desired on relatively steep hills necessitate the use of such a high-powered engine that its size is really determined by this factor rather than by the amount of torque required to start the vehicle. The gas engine has likewise proved somewhat unsuccessful in the attempts which have been made to use it in connection with road rollers, hoisting work and similar applications where repeated reversal of motion and a strong starting torque are necessary.

3 If a power generator were available which possessed in combination all the valuable characteristics of the steam engine, the electric motor and the gas engine, many of the problems of the engineer would be simplified. In the absence of such a power generator the need of a variable-speed mechanism for transmitting power from generator to machine becomes more and more urgent.

4 This paper relates to the hydraulic variable-speed power-transmission mechanism, designed by C. M. Manly, which, when introduced between an engine, or power generator, or even a single-phase alternating-current motor, and any device to be driven by it, not only gives a speed range from maximum in one direction through every intermediate speed down to zero, and then up to maximum in the reverse direction, but does so with the torque increasing in proportion to the decrease in speed, within the limits of strength of the device; and which, furthermore, permits of the most rapid and continuous reversal of the driven device without any possibility of injuring the power transmission mechanism itself or the driving mechanism operating it. The first machine to be actually applied to regular work was installed in January 1907, on a 2-ton automobile truck. This machine is still in operation on the streets of New York. Although its use has been confined largely to testing work, it has covered a total of something more than 8000 miles, always carrying a

load of 2 tons or more, and the drive itself appears to be in as good condition as when originally installed. In fact, when it was recently taken apart to determine how much it had been worn, no evidence could be found of any deterioration whatever in its various parts.

5 The device consists of a pump connected to the power generator, with one or more fluid pressure motors attached to the driven shaft or shafts and placed in any desired location with reference to the pump, hydraulic connections between them, and a single operating lever. The pump is of multicylinder construction with variable

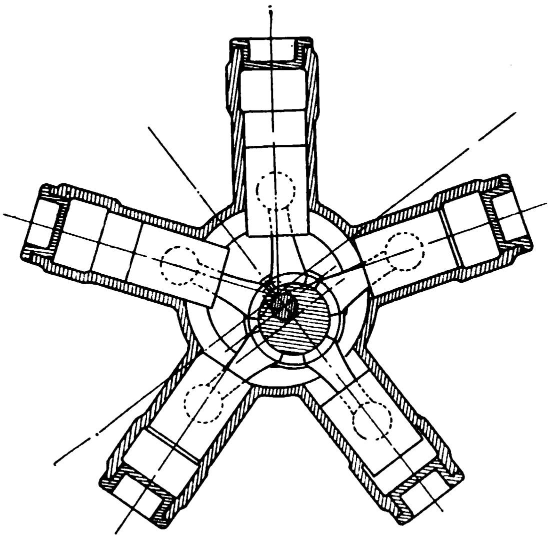

Fig. 1 Multicylinders Located around Central Crank Chamber

stroke, attached to the driving shaft. The multicylinder motors have a fixed stroke, and are attached to the driven shaft, the pipe connections or passages between them transmitting the working fluid. The various cylinders, both of the pump and motors, radiate equidistantly from a central crank chamber, and the pistons or plungers are connected to a single crank pin, which is common to all. The fluid used is ordinary machine oil, the lubricating qualities of which and its freedom from danger of freezing admirably fit it for such a purpose. When once filled the oil is used over and over again, being in continuous circulation from pump to motor through one set of pipes or passages and back again from motor to pump through another set.

6 Figs. 1, 2 and 3 show, in an elementary way, the leading features of the arrangement. Fig. 1 illustrates the location of the multicylinders around the central crank chamber, the number in use in the instance illustrated being five. Fig. 2 shows a cross-section through the crank pin of the pump. Fig. 3 is an elementary sectional elevation showing the cylinders and valves of both pump and motor, and the pipes forming the connection between them. *A* represents the plungers, and *B* the valves of the pump. Connection between the two is made by passages leading from the head ends of the pump cylinders to the centers of the corresponding valve chambers. *C* represents the valves, and *D* the plungers of the motor. Here the passages between the valve chambers and the plunger cylinders lead from the center of the valve chambers to the head end of the motor

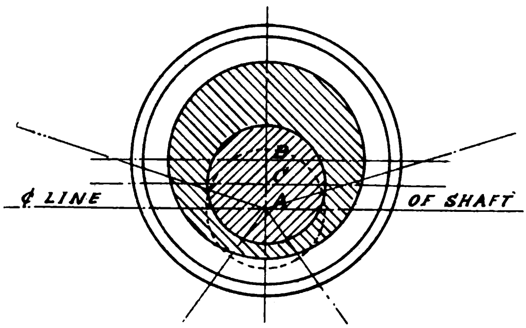


FIG. 2 CROSS-SECTION THROUGH CRANK PIN OF THE PUMP

cylinders. The corresponding ends of the two valve chambers are connected by the pipes *E* and *F*. One pipe carries the oil in one direction, and the other pipe returns it in the opposite direction. The outer ends of the five valve chambers of the pump are connected by the circular passage *G*, and the inner ends by the circular passage *H*; likewise the five valve chambers of the motor are connected by the circular passages *I* and *J*. In this elementary diagram the two shafts, both driving shaft *K* and driven shaft *L*, are shown in the same line, although disconnected. It will readily be seen that the two shafts may occupy any angular position with reference to each other, and any distance apart, the connecting pipes being arranged accordingly.

7 The stroke of the pump may be varied at will; that of the motor is fixed. The variation of pump stroke is accomplished by a

crank on which is mounted an eccentric bushing. By revolving the bushing with reference to the crank, its center line is brought into alignment with the center of the shaft, and when this position is reached no reciprocating motion is communicated to the pump plungers. When the pump is running at full stroke the motor operates at the highest speed. By varying the pump stroke and thereby the velocity of the oil in circulation, the motor runs at a speed which is exactly in proportion to the amount of oil that passes through it. Any desired rotative speed can therefore be secured and maintained. For reversal, the pump stroke first passes through the zero point.

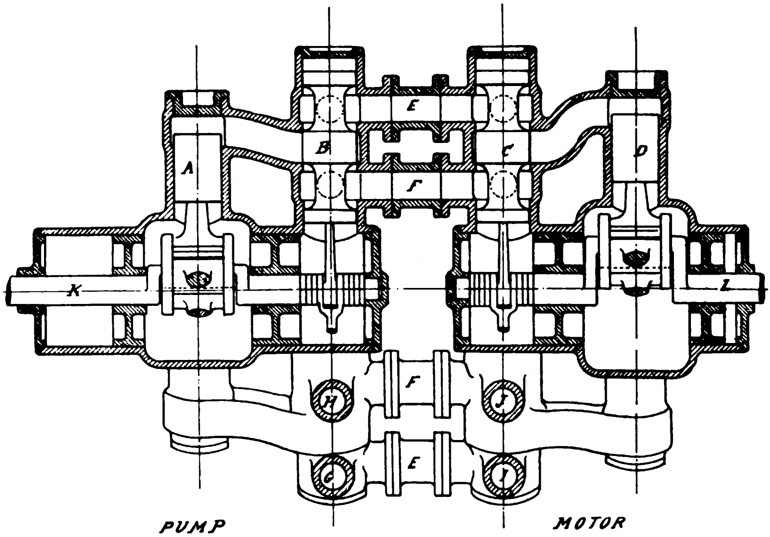


Fig. 3 Sectional Elevation of Pump and Motor

Then the valves change, and the oil is simply pumped in the opposite direction through the ports and pipes. Referring to Fig. 3, when the motor is going forward, pipe *E* furnishes a supply to the motor transmitting the oil under pressure from pump to motor, while pipe *F* returns it from motor to pump, thereby answering the purpose of an exhaust pipe. When the motor goes backward, pipe *F* becomes the supply under pressure, and pipe *E* changes to the exhaust pipe, the direction of circulation through the connecting pipes being completely reversed. In case of a sudden check in the speed or a quick reversal, the momentum due to running in one direction is taken up in the device itself. A safety valve, set at 2000 lb. per sq. in., opens a by-pass when there is an over-pressure and this acts as a cushion preventing injury to the machine.

8 Fig. 2 shows the arrangement of the crank by which the length of the pump stroke is adjusted. *A* is the center of the shaft, *B* is the center of the bushing, while *C* is the center of the crank. Point *C* lies halfway between points *A* and *B* when all three are in line. With this arrangement, it is readily seen that when the bushing is rotated 180 deg. around the center *C* of the crank, the center of the bushing, which is the real crank pin, is brought into exact alignment with the center of the shaft, and when this occurs, the length of the crank becomes zero, and the reciprocations cease, as already explained.

9 The rotation of the crank bushing from the position of maximum stroke to the no-stroke point, is accomplished by the use of an auxiliary piston, lying parallel to the shaft, and supplied with power from the fluid pressure of the pump, and this piston operates on the bushing through appropriate mechanism. It is under the control of a pilot valve, which is moved at will by means of a hand lever. By simply moving this lever from one end of its throw to a central position, the speed of the motor shaft is varied from its maximum speed to a condition of absolute rest, and by moving the lever to the other end of its throw the motion is reversed and any speed is secured ranging from zero to a maximum speed in the reverse direction. Meanwhile the driving shaft continues to run at constant speed, whatever the speeds or direction of motion of the driven shaft.

10 The speed-controlling feature of the drive serves a most important purpose when applied to vehicles such as automobiles, railroad motor cars, power boats and elevators. When the motor comes to absolute rest, the pump stroke being reduced to zero, no motion of the motor is permissible in either direction until the adjustment is changed so that the fluid again begins to flow from pump to motor. Its effect at such times is that of a brake applied to the wheels, though much more positive and reliable. The importance of the brake feature can hardly be overestimated when it is remembered that all the effects as to varying speed, reversal of motion, and brake action are brought about by the movement of a single hand lever. Many accidents occur owing to the confusion of the driver having a number of different controlling devices to operate. The single-control lever of the drive prevents this. When the lever is in its forward position, the machine goes forward at maximum speed. When the lever is pulled over to the middle position, the machine comes to rest, and is locked there as with a brake. When the lever is pulled over still

farther to its extreme backward position, the machine goes backward at maximum speed.

11 Another feature of the drive, the increase of torque in the driven shaft as the speed is reduced, should be mentioned. This is peculiarly adapted to road vehicles traveling in a hilly country. By slowing down the driven shaft, the torque or pulling power may be increased to any degree within the limiting blow-off pressure of the safety valve. Whatever the capacity of the engine, the vehicle may be propelled up any hill, however steep the grade, provided the speed is slow enough, and the wheels do not slip.

## RECORD OF TEST

12 The drive tested was one built for a 5-ton automobile truck. It was mounted on a temporary wooden rack representing a truck frame and fastened to the floor of the shop. In all its essential features it was a duplicate in design of the 2-ton truck drive, which had been used in actual work for two years, but it was larger and embodied in its construction certain refinements of detail regarding the main castings and the interior parts of the mechanism not possessed by the earlier machine. As applied to the truck, the present machine under consideration comprised one 5-cylinder pump and two hydraulic motors, each having 5 cylinders. The motors were placed at right angles to the pump shaft for connection to the driving wheels of the automobile, dispensing with the differential gears. For adaptation to general use, as already noted, the motor and pump might either be in line with each other and firmly bolted together without intermediate pipes, or placed at any angle, or in any plane with respect to each other, or at any distance apart without changing the underlying principles embodied in the apparatus tested.

13 While the controlling mechanism permitted the variation of speed from a maximum in one direction down to zero, and then up to a maximum in the reverse direction, the tests were made with the motion in one direction only. The conditions of operation were the same, however, in both directions and the results were unaffected by the precise direction of rotation.

14 For the purposes of the present tests it was desirable to use only one motor so that the whole power might be measured by the use of a single brake. The second motor (which is used in the automobile outfit) was removed, and the pipe connections to it from the pump were blanked off. The whole work was thus thrown upon a

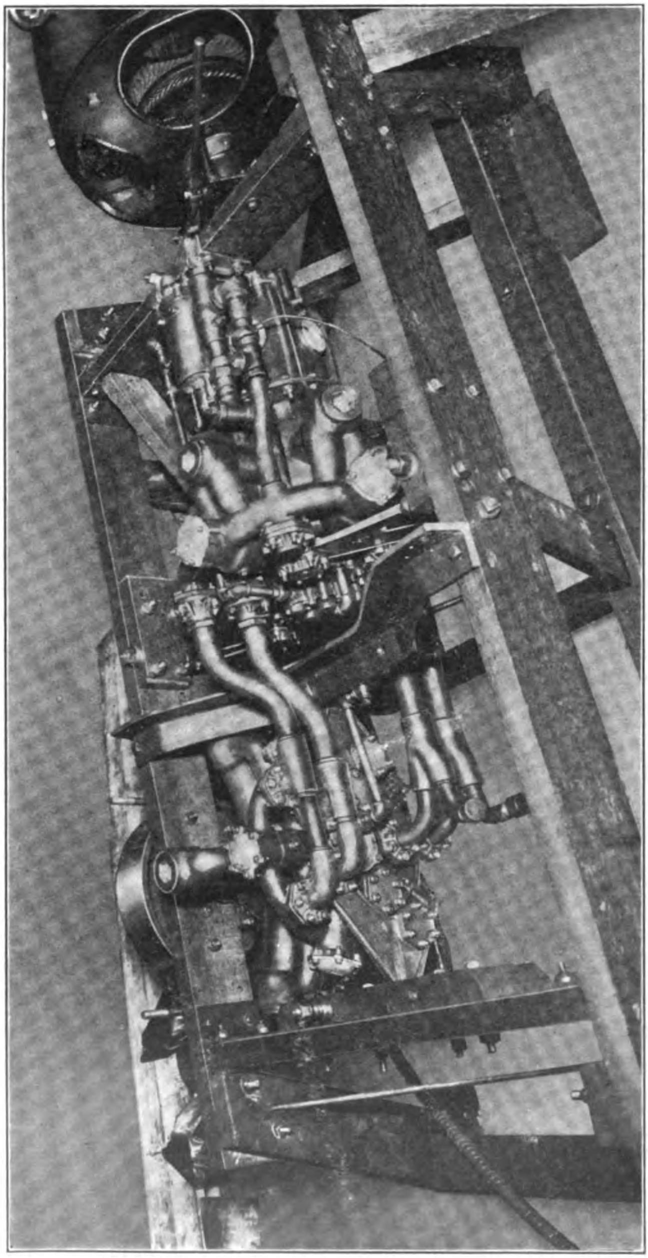

FIG. 4 GENERAL VIEW OF APPARATUS

single motor, thereby increasing the fluid resistance. This point is especially to be noted, because the ports and passages were proportioned for a truck equipment in which two motors share equally the fluid delivered from the pump. With one motor transmitting the total quantity of oil designed to be handled by two, the operating conditions were less favorable than those of actual service.

15 To supply power for operating this apparatus, the pump shaft was coupled to a 15-h.p. direct-current electric motor made by the General Electric Company. The type and size of this motor were as follows: Shunt-wound motor No. 79,214; type C.E., class 4, 15 h.p., 690 r.p.m.; form A, 230 volts, 55½ amperes. This motor was the most convenient, inasmuch as the quantity of power supplied by electricity is a matter of ready determination.

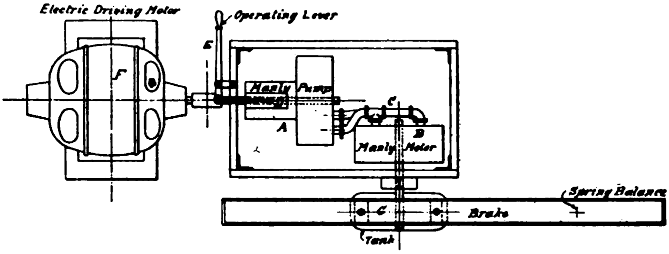


Fig. 5 Diagram showing Arrangement of Test Apparatus

16 Fig. 4 shows an exterior view of the apparatus. It was taken at comparatively close range and the perspective is not altogether satisfactory, but the leading features are fully exhibited. The electric driving motor is shown at the extreme end of the frame work. Next comes the pump, the driving shaft of which is in line with, and a continuation of, the electric motor shaft. A system of piping leads from the pump to the hydraulic motor, one set of pipes carrying the circulating oil from the pump to the motor and another returning it to the pump. The shaft of the hydraulic motor, as already stated, is at right angles to the pump shaft. A pulley is attached to the end of this shaft. Just outside the pulley may be seen the upper ends of two bolts. These come from the lower brake shoe, used in the tests, which is hidden from view. The upper ends of the bolts, which are provided with nuts, hold down the upper brake shoe. This part of the brake was not in place, and is not shown in the figure. Attention may be called to the operating lever at the extreme end of the pump, near the electric motor, which regu-

lates the speed of the drive shaft to any desired point. The adjustment is so sensitive that the speed can readily be cut down to as low a point as 1 r.p.m., if desired, the pulley at such times just barely dragging along, the main driving shaft still operating at maximum speed.

17 Fig. 5 is an elementary drawing showing at a glance the leading features of the apparatus. *A* is the pump, *B* the motor, *C* the connecting pipes, *D* the pilot valve, *E* the controlling lever, *F* the electric motor, and *G* the brake. The dimensions of the leading parts of the pump and hydraulic motor in the test apparatus are given in Table 1.

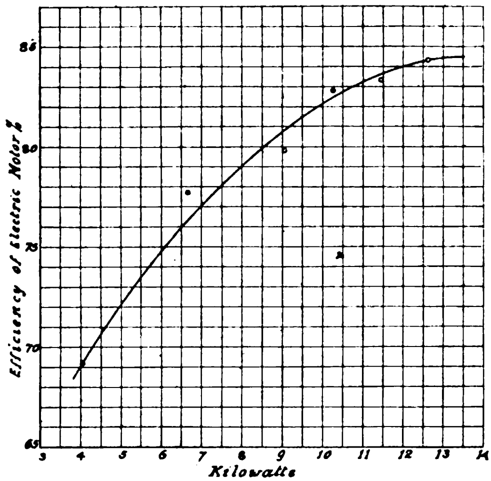


FIG. 6 · TEST OF ELECTRIC MOTOR, NOVEMBER 28, 1908

18 On these tests the apparatus was filled with a mineral oil, called by the trade Arctic machine oil, costing 25 cents per gal. The quantity in circulation with a single motor is about 5 gal. With both hydraulic motors in use, the quantity is increased to about 7 gal.

19 With the dimensions in Table 1, each revolution of the pump shaft causes the circulation of sufficient oil to produce about one-half a revolution of the motor at maximum speed. Consequently, the maximum speed of the motor shaft and brake wheel is about one-half that of the pump shaft and electric motor.

20 The general object of the tests was to determine the efficiency of this system of transmitting power, in other words, the proportion which the power taken out bears to the power put in it.

21 The scope of the tests was sufficient to make this determination not only under conditions of full load and full speed of the driven shaft, but under all other conditions of load and speed at which the testing apparatus could be used. The tests were therefore made in

TABLE 1 DIMENSIONS OF PUMP AND MOTOR IN TEST APPARATUS

| | Pump | Motor |
|---|---|---|
| Number of cylinders | 5.0 | 5.0 |
| Diameter of cylinders, in. | 2.5 | 2.5 |
| Maximum stroke of plungers | 1.5 | 3.0 |
| Diameter of circle enclosing pump plunger cylinders and motor valve chambers, in. | 24.0 | 24.0 |
| Diameter of circle enclosing pump valve chambers and motor plunger cylinders, in. | 18.0 | 18.0 |
| Distance from center of motor shaft to front end of pump, in. | 46 | |
| Distance from center line of pump shaft to outboard bearing of motor, in. | 20 | |
| Length of pump over all, in. | 30 | |

several series. During each the apparatus was operated first at the full speed of the driven shaft, and then step by step at reduced speed down to the minimum that could be satisfactorily handled by the brake. Four series were made, two when the apparatus was at a

TABLE 2 DATA AND RESULTS OF ELECTRIC MOTOR TESTS

| No. | Amperes | Volts | Watts | Electric Horsepower or Power Supplied | Rev. per Min. | Net Weight in Brake Arm | Brake H.P. or Power Delivered | Efficiency or Percentage Borne by Col. 8 to Col. 5 |
|---|---|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| 1 | 54 | 233.5 | 12609 | 16.9 | 720 | 26.0 | 14.25 | 84.3 |
| 2 | 49 | 232 | 11368 | 15.23 | 725 | 23.0 | 12.72 | 83.3 |
| 3 | 44 | 233 | 10252 | 13.74 | 729 | 20.5 | 11.38 | 82.8 |
| 4 | 39 | 232 | 9048 | 12.13 | 727 | 17.5 | 9.68 | 79.8 |
| 5 | 29 | 230 | 6670 | 8.94 | 730 | 12.5 | 6.95 | 77.7 |
| 6 | 19 | 214 | 4066 | 5.45 | 708 | 7.0 | 3.77 | 69.2 |

medium temperature, and two after it had been operated a sufficient time to warm the oil to its maximum temperature. Each of the double series was made first with a constant amount of power passing into the apparatus and passing out at the reduced speed, increasing the torque, or the weight on the brake arm, inversely as the speed decreased; and second, with a constant weight on the brake arm, and the amount of power passing into the apparatus reduced step by step as the speed of the hydraulic motor was reduced.

22 As already noted, the power delivered was absorbed by a friction brake surrounding the hydraulic motor wheel. This brake was of the ordinary Prony brake pattern, consisting of two blocks, fitting the periphery of the wheel, one above and one below. An arm or lever, extending from the upper block horizontally, was attached to a spring balance. The point of attachment, which was exactly 4 ft. from the center, was level with the center of the shaft, and the direction of motion was such that the pull of the brake lever was exerted vertically downward, the balance being suspended from a beam overhead.

23 The brake shoes were lined with circular pieces of cork set into the wood to obtain a uniform friction. The lower half of the pulley dipped beneath the surface of water in a small tank which surrounded it, and this tank was kept partially filled with cold water to absorb the heat of friction. The brake arm was housed in, to prevent undue throwing of the cooling water. The requisite amount of pressure on the brake shoes was obtained by screwing down the nuts holding the two halves together, using an ordinary hand wrench.

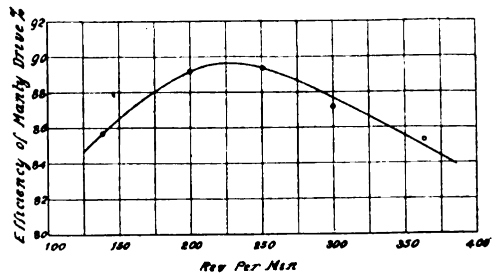


Fig. 7 Efficiency Test of Manly Drive, Series *A*, December 8, 1908

24 The power supplied by the electric motor was determined by measuring the amount of electric current consumed, and determining the output of this motor by employing the proper coefficient of efficiency. This coefficient was found by disconnecting the motor from the apparatus, attaching the same pulley to the shaft as that used for the brake wheel, and using the same brake as that employed on the main efficiency tests. The electric tests were made by comparing the amount of current supplied to the electric motor, reduced to horsepower, with the amount of power delivered, as determined by the

brake test. This was done for the whole range of current used on the main efficiency tests. By this means an efficiency curve was obtained

TABLE 3 DATA AND RESULTS OF EFFICIENCY TESTS, SERIES *A*

TEMPERATURE OF CIRCULATING OIL, MEDIUM. GENERAL CHARACTERISTICS: CONSTANT POWER, DRIVING SHAFT; CONSTANT SPEED, DRIVING SHAFT; VARYING SPEED, DRIVEN SHAFT; CONSTANT POWER, DRIVEN SHAFT; VARYING WEIGHT ON BRAKE ARM. DATE OF TEST, DECEMBER 8, 1908.

| | | | | | | |
|---|---|---|---|---|---|---|
| 1 | Amperes | 55.0 | 55.0 | 55.0 | 55.0 | 55.0 |
| 2 | Volts | 234.0 | 239.0 | 236.0 | 235.3 | 232.0 |
| 3 | Watts (line 1 × line 2) | 12870.0 | 13145.0 | 12980.0 | 12941.0 | 12760.0 |
| 4 | Electric h.p. of current (line 3÷746) | 17.25 | 17.62 | 17.40 | 17.35 | 17.10 |
| 5 | Efficiency of electric motor, taken from curve on Fig. 7, per cent | 84.4 | 84.4 | 84.4 | 84.4 | 84.4 |
| 6 | Power supplied to driving shaft (line 4 × line 5), h. p. | 14.56 | 14.87 | 14.68 | 14.64 | 14.43 |
| 7 | R.p.m., driving shaft (electric motor) | 755.0 | 760.0 | 755.0 | 755.0 | 750.0 |
| 8 | R.p.m., driven shaft, (Manly hydraulic motor) | 363.0 | 299.0 | 250.7 | 200.3 | 139.7 |
| 9 | Temperature of oil in circulation, deg. | 115.0 | 116.0 | 117.0 | 118.0 | 120.0 |
| 10 | Net weight on brake arm, lb. | 45.0 | 57.0 | 68.7 | 85.7 | 116.3 |
| 11 | Brake h.p., or power delivered to driven shaft | 12.42 | 12.97 | 13.12 | 13.07 | 12.36 |
| 12 | Efficiency of drive, or percentage borne by line 11 to line 6 | 85.3 | 87.2 | 89.4 | 89.2 | 85.7 |

TABLE 4 DATA AND RESULTS OF EFFICIENCY TESTS, SERIES *B*

TEMPERATURE OF CIRCULATING OIL, MEDIUM. GENERAL CONDITIONS: VARYING POWER, DRIVING SHAFT; CONSTANT SPEED, DRIVING SHAFT; VARYING SPEED, DRIVEN SHAFT; VARYING POWER, DRIVEN SHAFT; CONSTANT WEIGHT ON BRAKE ARM. DATE OF TEST, DECEMBER 9, 1908.

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 1 | Amperes | 55.0 | 49.0 | 42.0 | 36.0 | 29.0 | 22.2 |
| 2 | Volts | 230.0 | 227.0 | 228.0 | 224.0 | 221.0 | 221.0 |
| 3 | Watts (line 1 × line 2) | 12650.0 | 11123.0 | 9576.0 | 8064.0 | 6409.0 | 4906.0 |
| 4 | Electric h.p. of current (line 3÷746) | 16.96 | 14.91 | 12.84 | 10.81 | 8.59 | 6.58 |
| 5 | Efficiency of electric motor, taken from curve on Fig. 7, per cent. | 84.3 | 83.3 | 81.4 | 79.1 | 75.8 | 71.8 |
| 6 | Power supplied to driving shaft, (line 4 × line 5), h.p. | 14.3 | 12.38 | 10.45 | 8.55 | 6.51 | 4.72 |
| 7 | R.p.m., driving shaft (electric motor) | 750.0 | 745.0 | 745.0 | 740 0 | 730.0 | 730.0 |
| 8 | R.p.m., driven shaft, (hydraulic motor) | 352.0 | 310.0 | 264.0 | 215.0 | 160.0 | 112.0 |
| 9 | Temperature of oil in circulation, deg. | 122.0 | 124.0 | 127.0 | 128.0 | 129.0 | 130.0 |
| 10 | Net weight on brake arm, lb. | 46.0 | 46.0 | 46.0 | 46.0 | 46.0 | 46.0 |
| 11 | Brake h.p., or power delivered to driven shaft | 12 33 | 10.86 | 9.24 | 7.54 | 5.60 | 3.92 |
| 12 | Efficiency of drive, or percentage borne by line 11 to line 6 | 86.2 | 87.6 | 88.4 | 88.2 | 86.1 | 83.1 |

which applied to the motor as actually operated on the work in question.

25 All the instruments employed were either standardized, or compared with recognized standards, and any errors allowed for.

TABLE 5 DATA AND RESULTS OF EFFICIENCY TESTS, SERIES *C*

TEMPERATURE OF CIRCULATING OIL, MAXIMUM. GENERAL CONDITIONS: CONSTANT POWER, DRIVING SHAFT; CONSTANT SPEED, DRIVING SHAFT; VARYING SPEED, DRIVEN SHAFT; CONSTANT POWER, DRIVEN SHAFT; VARYING WEIGHT ON BRAKE ARM. DATE OF TEST, DECEMBER 9, 1908.

| | | | | | | |
|---|---|---|---|---|---|---|
| 1 | Amperes | 55.0 | 55.0 | 55.0 | 55.0 | 55.0 |
| 2 | Volts | 230.0 | 236.0 | 239.0 | 238.0 | 237 0 |
| 3 | Watts (line 1 × line 2), | 12650.0 | 12980.0 | 13145.0 | 13090.0 | 13035.0 |
| 4 | Electric h.p. of current (line 3—746), | 16.96 | 17.4 | 17.62 | 17,55 | 17.47 |
| 5 | Efficiency of electric motor, taken from curve on Fig. 7, per cent | 84.3 | 84.4 | 84.4 | 84.4 | 84.4 |
| 6 | Power supplied to driving shaft (line 4 × line 5), h.p. | 14.3 | 14.68 | 14.87 | 14.81 | 14.74 |
| 7 | R.p.m., driving shaft (electric motor) | 750.0 | 755.0 | 760.0 | 760.0 | 755.0 |
| 8 | R.p.m., driven shaft, (hydraulic motor) | 350.0 | 310.0 | 270.0 | 202.0 | 163.0 |
| 9 | Temperature of oil in circulation, deg. | 132.0 | 133.0 | 134.0 | 135.0 | 135.0 |
| 10 | Net weight on brake arm, lb. | 47.0 | 56.5 | 66.5 | 86.0 | 103.5 |
| 11 | Brake h.p., or power delivered to driven shaft | 12.50 | 13.33 | 13.66 | 13.23 | 12.83 |
| 12 | Efficiency of drive, or percentage borne by line 11 to line 6 | 87.4 | 90.8 | 91.9 | 89.3 | 87.0 |

TABLE 6 DATA AND RESULTS OF EFFICIENCY TESTS, SERIES *D*

TEMPERATURE OF CIRCULATING OIL, MAXIMUM. GENERAL CONDITIONS: VARYING POWER, DRIVING SHAFT; CONSTANT SPEED, DRIVING SHAFT; VARYING SPEED, DRIVEN SHAFT; VARYING POWER, DRIVEN SHAFT; CONSTANT WEIGHT ON BRAKE ARM. DATE OF TEST, DECEMBER 9, 1908.

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 1 | Amperes | 55.0 | 49.0 | 39.5 | 32.5 | 25.5 | 20.2 |
| 2 | Volts | 230.0 | 228.0 | 226.0 | 236.0 | 236.0 | 238.0 |
| 3 | Watts (line 1 × line 2) | 12650.0 | 11172.0 | 8927.0 | 7670.0 | 6018.0 | 4808.0 |
| 4 | Electric h.p. of current (line 3 ÷ 746) | 16.96 | 14.98 | 11.97 | 10.28 | 8.07 | 6.44 |
| 5 | Efficiency of electric motor, taken from curve on Fig. 7, per cent. | 84.3 | 83.4 | 80.5 | 78.4 | 74.8 | 71.5 |
| 6 | Power supplied to driving shaft (line 4 × line 5), h.p. | 14.3 | 12.46 | 9.63 | 8.06 | 6.04 | 4.60 |
| 7 | R.p.m., driving shaft (electric motor) | 750.0 | 745.0 | 740.0 | 755.0 | 755.0 | 760.0 |
| 8 | R.p.m., driven shaft, (hydraulic motor) | 350.0 | 315.0 | 245.0 | 200.0 | 145.0 | 105.0 |
| 9 | Temperature of oil in circulation deg. | 134.0 | 136.0 | 137.0 | 137.0 | 136.0 | 136.0 |
| 10 | Net weight on brake arm, lb. | 47.0 | 47.0 | 47.0 | 47.0 | 47.0 | 47.0 |
| 11 | Brake h.p., or power delivered to driven shaft, | 12.50 | 11.26 | 8.76 | 7.14 | 5.19 | 3.76 |
| 12 | Efficiency of drive, or percentage borne by line 11 to line 6 | 87.4 | 90.2 | 90.9 | 88.6 | 85.9 | 81.6 |

The tests were made on November 28, December 8, and December 9, 1908. Other tests of a preliminary nature were made on November 21 and 22, 1908.

26 The data and results of the tests on the electric motor are given in Table 2 and Fig. 6 on which the results are plotted. Fig. 6 also represents the true curve of efficiency of the motor, based on the observations made.

27 The data and results of the four series of efficiency tests are given in Tables 3–6. The results are plotted on Figs. 7–10, together with efficiency curves based on these results.

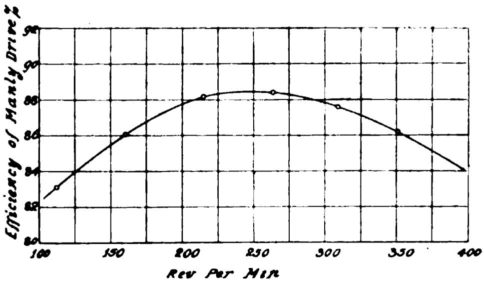


FIG. 8 EFFICIENCY TEST OF MANLY DRIVE, SERIES *B*, DECEMBER 9, 1908

28 Referring to Tables 3–6 the efficiency obtained on the tests of Series *A*, with medium temperature of oil and constant power, is 85.3 per cent at the full speed of 363 r.p.m., increasing 89.4 per cent with speed reduced to 250 r.p.m., and then decreasing to 85.7 per cent with speed further reduced to 140 r.p.m. On the tests of Se-

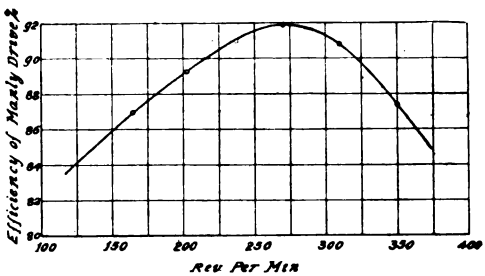


FIG. 9 EFFICIENCY TEST OF MANLY DRIVE, SERIES *C*, DECEMBER 9, 1908

ries *B*, with medium temperature of oil and constant weight on the brake arm, the efficiency is 86.2 per cent at the full speed of 352 r.p.m., increasing to 88.4 per cent with speed reduced to 264 r.p.m., and falling back to 83.1 per cent with speed decreased to 112 r.p.m.

29 On the tests of Series *C*, with maximum temperature of oil and constant power, the efficiency is 87.4 per cent at the full speed of

350 r.p.m., increasing to 91.9 per cent with speed reduced to 270 r.p.m., and then falling back to 87.0 per cent with a further reduction of speed to 163 r.p.m. On the tests of Series *D*, with maximum temperature of oil and constant weight on the brake arm, the efficiency is 87.4 per cent at the full speed of 350 r.p.m., increasing to 90.9 per cent with a reduction of speed to 245 r.p.m., and dropping to 81.6 per cent with a further reduction of speed to 105 r.p.m. The tests with maximum temperature of circulating oil show a material advantage over those with lower temperature as might be expected from the nature of the fluid. The average of all the figures of efficiency given computed numerically, is 87.7 per cent.

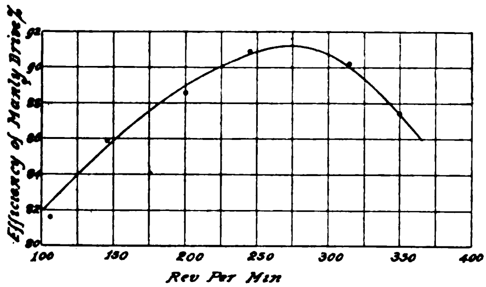


FIG. 10 EFFICIENCY TEST OF MANLY DRIVE, SERIES *D*, DECEMBER 9, 1908

30 The operating features of the drive, viewed as a power transmitting machine, were entirely satisfactory. On some days the apparatus was worked almost constantly under a brake load for a 10-hr. run, and the machine was always in excellent condition whether at the end of the period or at the beginning.

31 There was never any sign of overheating. It was always noticeable that as the temperature of the circulating oil increased, the percentage of efficiency increased; thus showing that the frictional losses were reduced as the oil became less viscous under the higher temperature.

# AIR-CONDITIONING APPARATUS

## PRINCIPLES GOVERNING ITS APPLICATION AND OPERATION

By Willis H. Carrier and Frank L. Busey

## ABSTRACT OF PAPER

This paper treats of the construction, application and operation of apparatus used in the artificial production and control of atmospheric conditions as applied in various processes of manufacture and in heating and ventilation. A general description is given of the various forms of air-conditioning apparatus of the spray type. The different methods of controlling the humidity are considered together with a full description of humidity-controlling and recording devices, and full engineering data relative to the design and operation of air-conditioning apparatus and systems are presented, particular attention being paid to the theory of air cooling and dehumidifying with cooling coils. The rate of heat transmission in indirect surface air heaters and coolers is considered and a new theory of heat convection under forced circulation is developed and established by experiment. A rational formula for calculating the rate of heat transfer and temperature rise at various air velocities and temperature differences is given in conformance with this experimental data.

# AIR-CONDITIONING APPARATUS

## PRINCIPLES GOVERNING ITS APPLICATION AND OPERATION

By Willis H. Carrier, Buffalo, N. Y.
Associate Member of the Society
and
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Non-Member

Air conditioning is a term which may be generally applied to the positive production and control of desired atmospheric conditions within an enclosure, with respect to moisture, temperature and purity. Its particular concern is the regulation of humidity.

2 The fundamental principles underlying the art of air conditioning have already been discussed in an accompanying paper.[2] It is the purpose of the present paper to describe the apparatus employed and to submit comprehensive data relating to its practical application and operation. While much of this material pertains to humidifying and humidity control, some important original data are given on heat transmission by convection, which is an important factor in many air-conditioning processes. Among these may be mentioned the heating of air by passing over steam coils; the simultaneous heating and cooling of air, as in a heat interchanger as employed in dehumidifying; and the dehumidifying and cooling of air with surface condensers. Upon these data as a basis a new theory of heat transmission by convection is established. A rational formula is derived embracing both the effect of velocity and temperature difference with a correction for variation of air density in the surface film.

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The American Society of Mechanical Engineers, 29 West 39th Street, New York. All papers are subject to revision.

[1] Engineer, Experimental Sta., Univ. of Illinois.

[2] Rational Psychrometric Formulae, The Journal, November 1911, p. 1309.

3 Air-conditioning apparatus for controlling the humidity of air may be broadly classified, according to use, into humidifiers proper. which add moisture to the air in required amounts; and dehumidifiers, which remove a variable quantity of moisture from the air to reduce it to the required standard. The relative humidity of air

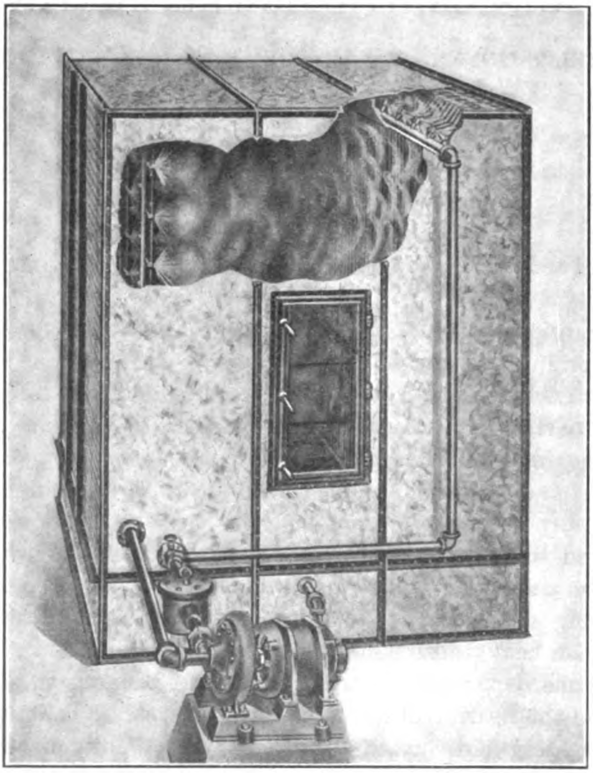


Fig. 1 Air Washer

may also be altered, and in a measure regulated simply by changing its temperature without affecting its moisture contents.

## TYPES OF HUMIDIFIERS

4 Humidifiers may be classified into the spray and evaporative types, and the latter being divided again into direct and indirect. The humidity of the air may also be increased by the direct intro-

duction of steam into the air supply or into the room. Since the total heat of the vapor at atmospheric temperature is somewhat less than the total heat at steam temperature, this raises the temperature of the air perceptibly and is therefore intolerable in the majority of cases. Added objections to the direct use of steam are that it frequently gives a noticeable odor and that it is difficult to

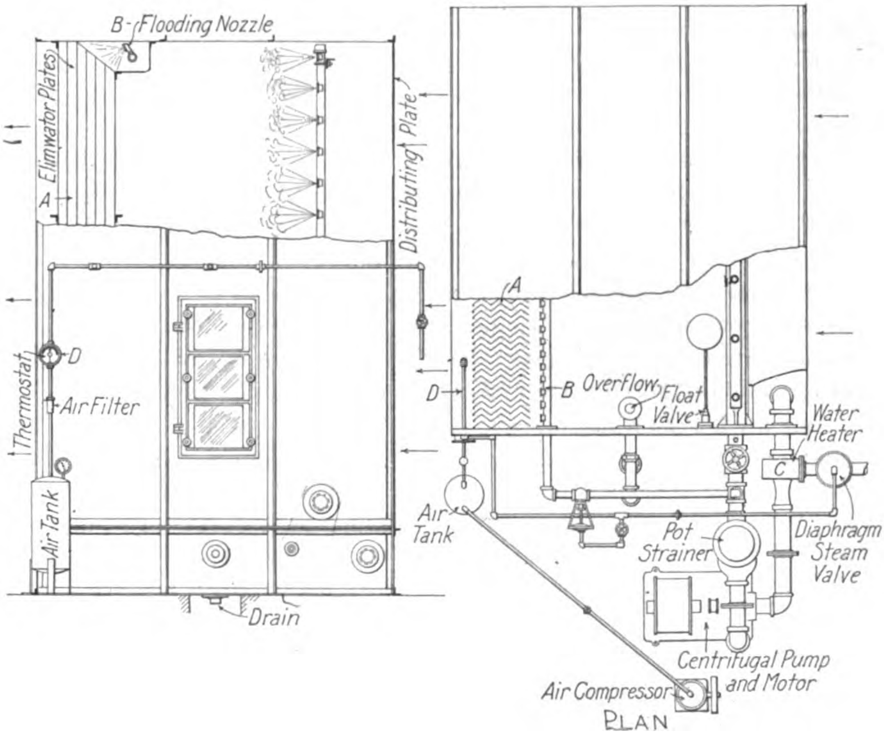



Fig. 2 Air Washer with Humidity Control

regulate. Its use is of so little engineering interest or value that it need not here be considered.

5 The spray and evaporative types of humidifiers have a distinct value aside from humidifying in their possession of a cooling effect which is in direct proportion to their moistening effect. The direct spray type of humidifier is distinguished from the evaporative type in that it introduces a finely divided or atomized spray directly into the room in constant volume, while the evaporative type introduces only the water vapor. There is also a mixed type which discharges both moist air and free moisture into the room.

6 In what may be termed the indirect evaporative humidifier the air is partly or entirely taken from the outside and is humidified and conditioned before it is introduced into the room. In the direct evaporative type the water vapor passes directly into the air of the room. The indirect system of air conditioning is also termed the central system.

7 A disadvantage of the direct spray type is that it always introduces a fixed quantity of moisture regardless of the needs or condition of the room until it is closed off by hand, or through a separate automatic control. In the evaporative type, on the contrary, there is an inherent self-regulating feature owing to the fact that the rate of evaporation is in direct proportion to the moisture deficit in the air. This is especially true in the indirect evaporative type, which, with all outside air, will maintain an absolutely uniform relative humidity, other conditions remaining constant.

8 Since the indirect evaporative type is capable of the greatest development and widest application, and therefore is of greatest engineering interest, this paper will be devoted largely to the theory of operation of this system and methods of its application.

9 Figs. 1 and 2 show the type of air purifier and humidifier adapted for use in the ventilation of auditoriums, offices and public buildings. Its primary object is the removal of impurities from the air, but combined with this is the very important function of regulation of the humidity, when below the minimum standard. When the humidity is above the required minimum standard it is designed to wash the air without objectional increase in its moisture contents. The essential features of this type of apparatus are:

- *a* A distributing plate for the purpose of reducing eddies and distributing the air uniformly over the area of the washer.
- *b* A system of atomizing sprays so arranged as to fill the air completely with water particles uniformly distributed over the chamber area.
- *c* A centrifugal pump for maintaining the proper pressure on the spray nozzles.
- *d* A settling chamber provided with proper strainers for the removal of dirt from the spray water.
- *e* An eliminator, *A*, of proper construction and ample surface for washing the air by impact and centrifugal force and for the removal of all free moisture (Fig. 3).

*f* Flooding nozzles, *B*, to distribute an additional amount of water on the eliminators to increase the amount of available wetted surface, to flush the eliminators and to provide a means of washing the air without greatly affecting the humidity.

*g* Automatic water heater, *C*, for supplying heat and moisture to the air through the water spray. This may be either of the closed type or of the open, ejector type.

*h* Dewpoint thermostat at *D*, subject to the temperature of saturation and connected to motor valves controlling the supply of heat to the spray water.

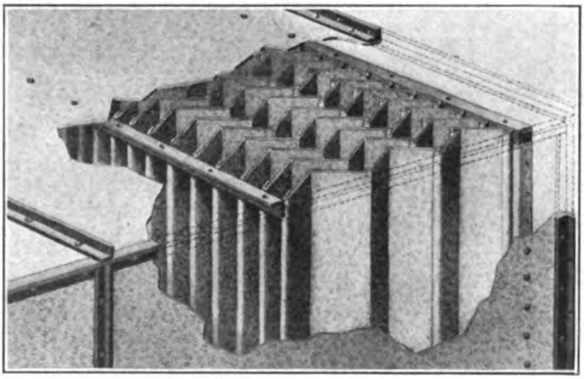


Fig. 3 Detail of Eliminator for Removing Free Moisture

10 Air is drawn through this humidifier by means of a centrifugal fan at a velocity of about 500 ft. per minute. The temperature of the air is raised immediately in the humidifier from any outdoor temperature to that necessary to hold the desired amount of moisture, ordinarily to about 40 deg. fahr.

11 The indirect humidifier designed for industrial application is shown in Figs. 4 and 5. This is intended primarily to deliver completely saturated air, even when the saturation temperature is above the minimum point. This condition of saturation and the cooling effect are of primary importance; the cleaning effect being usually of secondary consideration. The industrial humidifiers differ from the public building air washer in the following particulars (Figs. 6 and 7):

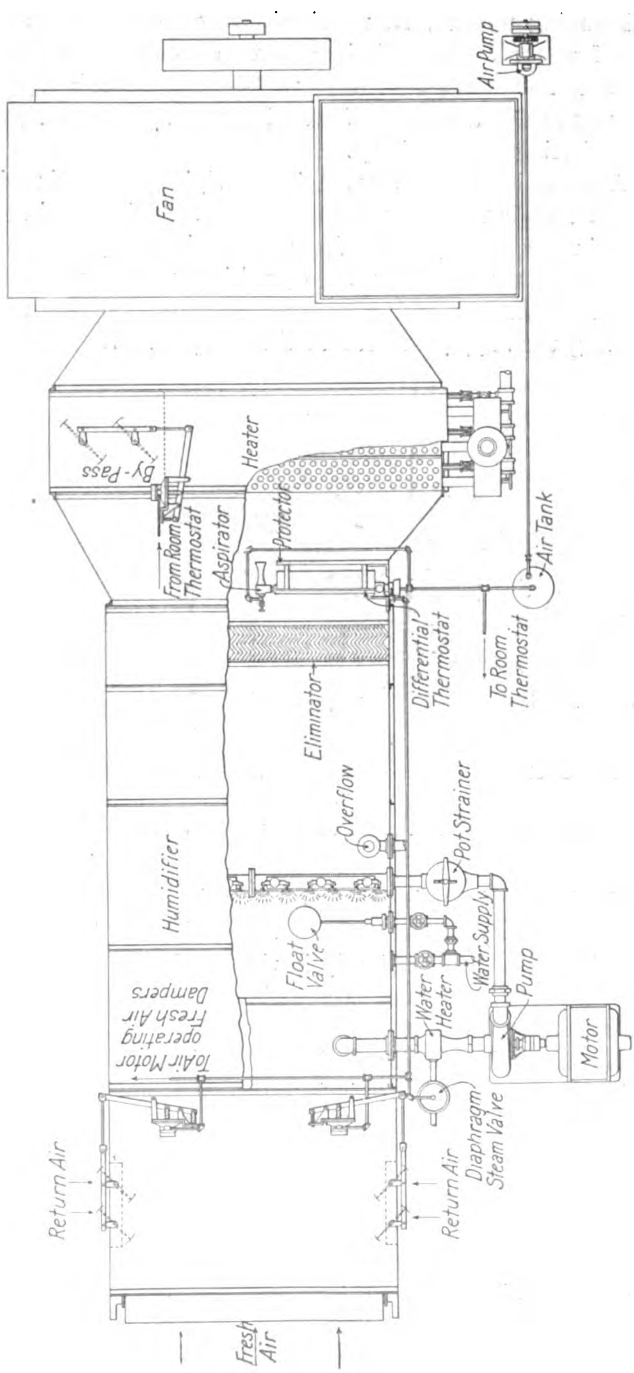



FIG. 4 AIR WASHER WITH HUMIDITY CONTROL—PLAN

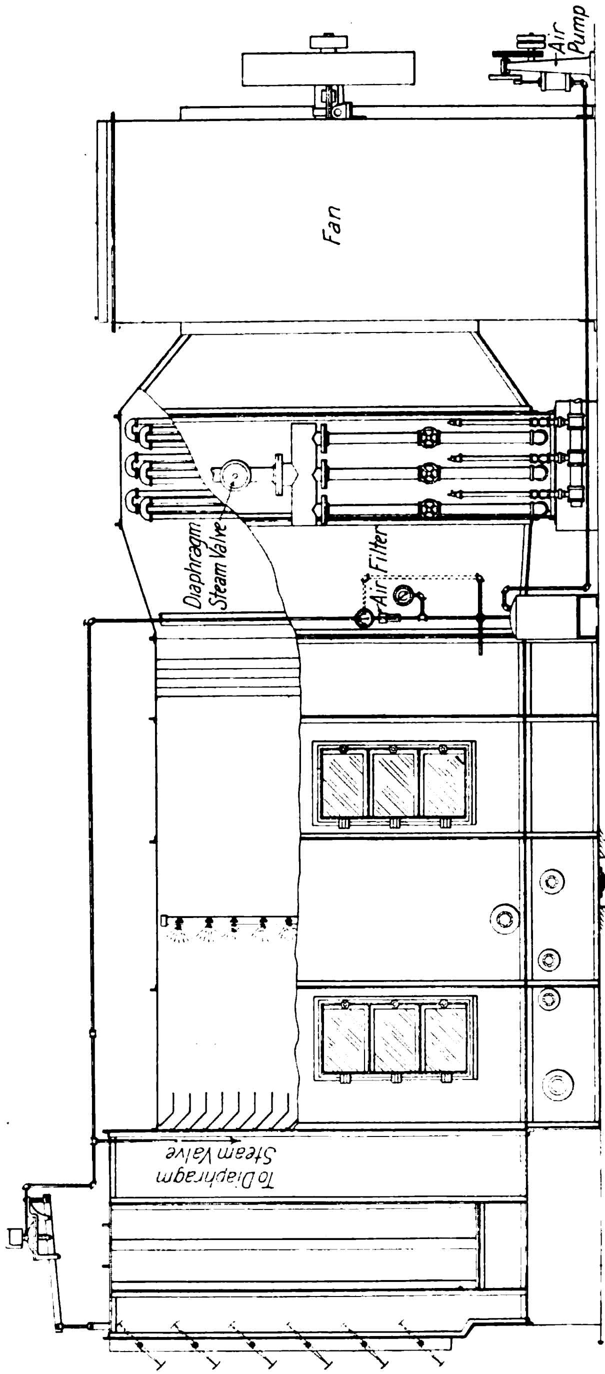



FIG. 5 AIR WASHER WITH HUMIDITY CONTROL—ELEVATION

*a* The centrifugal atomizing sprays are more numerous, and operate at higher pressure to give a more finely divided mist, and discharge in the opposite direction to the air flow.

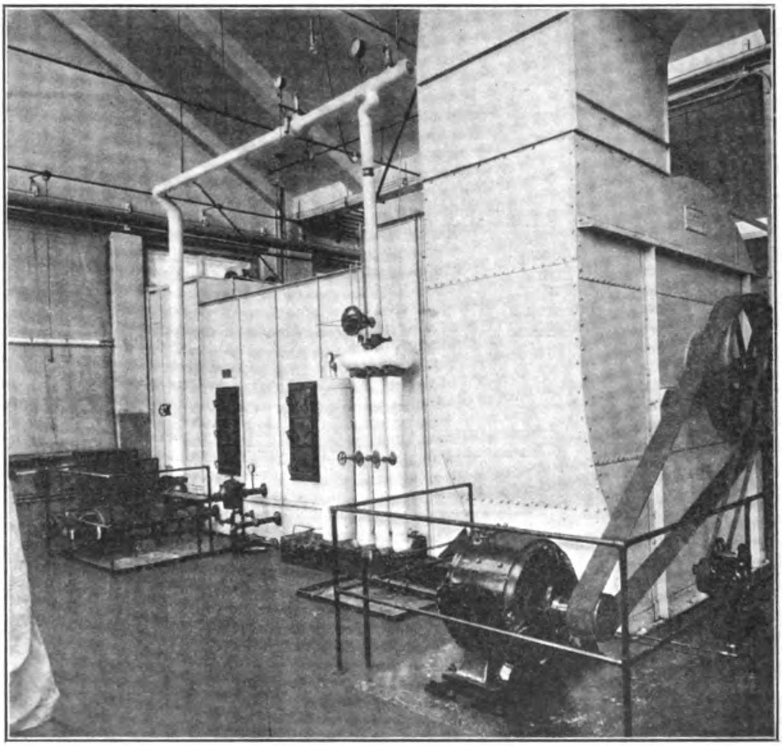


FIG. 6 GENERAL VIEW OF HUMIDIFIER

*b* The distributing plate is replaced by a diffuser composed of horizontal plates which serve also as eliminators to prevent water from being carried outward against the air current.

*c* The humidifying chamber is longer in order to give greater opportunity for saturation.

*d* The eliminator is not as deep and is not provided with flooding nozzles.

### THE DEHUMIDIFIER

12 In the dehumidifier (Figs. 8 and 9) relatively cold spray water is used to condense the moisture out of the air. This water is either refrigerated or taken from an artesian well. When the water is artificially cooled the refrigerating coils are usually placed in a chamber underneath the spray chamber, and the water is so distributed as to flow uniformly over the cold surface, dropping to the tank underneath. The dehumidifier has its sprays opposed to the direction of air flow as in the humidifier, but differs from the latter in having usu-

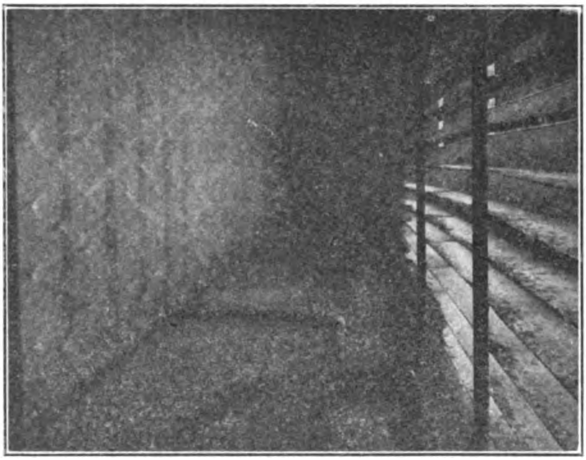


FIG. 7 HUMIDIFIER SHOWING SPRAYS IN OPERATION

ally two sets of sprays in series instead of one. Two or more dehumidifiers are frequently placed in series when the range of air temperature is great or when an economy of cooling water is essential.

### ROTARY STRAINER

13 Whenever the air handled by air-conditioning apparatus is full of impurities, such as lint in textile mill applications, the ordinary type of strainer would require too much attention and an automatic, self-cleaning rotary strainer, shown in Fig. 10, is essential. This consists of a fine-mesh brass or copper screen, covering a cylin-

drical drum. As this drum rotates it is cleaned at the water surface by a revolving brush. The use of this strainer is of great advantage in humidifiers, since it permits the use of smaller nozzles which give a more finely divided spray, with increased efficiency.

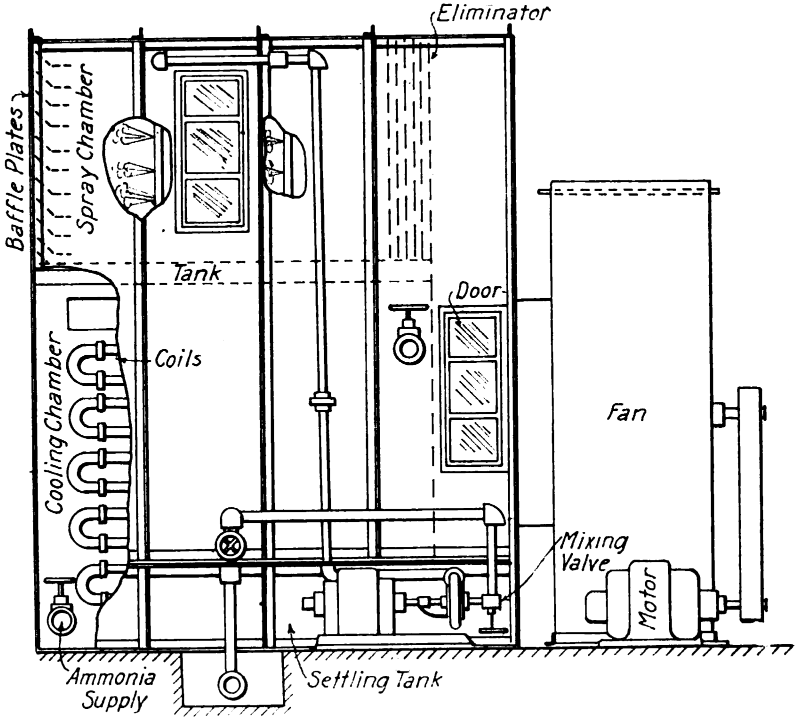



FIG. 8 SECTIONAL VIEW OF DEHUMIDIFIER

## DEWPOINT METHOD OF HUMIDITY CONTROL

14 Any one of the three spray types of air conditioners previously described are admirably adapted for humidity control by what is known as the dewpoint method. This system is applicable only where the absolute moisture content of the air in the room is unaffected to any great extent by extraneous sources of moisture supply or by moisture absorption. It depends upon supplying the enclosure with conditioned air having a definite dewpoint and maintaining a predetermined relationship between this dewpoint temperature and the room temperature. The dewpoint of the air supply is deter-

mined by saturating the air and removing all free moisture at the apparatus at a definite temperature. This dewpoint will evidently remain constant regardless of subsequent variations in air temperature. It may be shown that the percentage of relative humidity in an enclosure is dependent upon the difference between the dewpoint temperature and the room temperature and that it is substantially constant for any variation in room temperature so long as the differ-

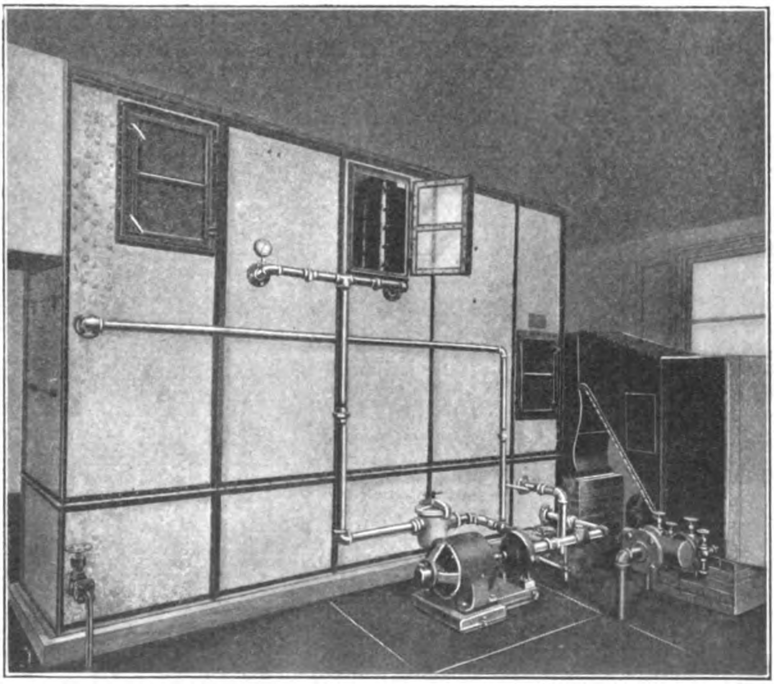


Fig. 9 General View of Dehumidifier

ence between the dewpoint and room temperatures is maintained constant (Tables 1 and 2).

15 It is evident that this system is particularly adapted to thermostatic control of (*a*) the dewpoint (saturation temperature at the apparatus) and the room temperature independently; (*b*) of the dew point with reference to a variable room temperature; or (*c*) of the room temperature with reference to a variable dewpoint temperature. System (*a*) is generally applied to air washers and humidifiers

TABLE 1 DEWPOINT TEMPERATURES AND TEMPERATURE DIFFERENCES REQUIRED IN CARRIER SYSTEM OF HUMIDIFYING FOR VARIOUS PERCENTAGES OF HUMIDITY AND ROOM TEMPERATURES

| Room Temperature Deg. | Percentage Relative Humidity | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 85 | | 80 | | 75 | | 70 | | 65 | | 60 | | 55 | | 50 | | 45 | | 40 | | 35 | |
| | Dewpoint Temperature | Difference Between Dewpoint and Room Temperature | Dewpoint Temperature | Difference Between Dewpoint and Room Temperature | Dewpoint Temperature | Difference Between Dewpoint and Room Temperature | Dewpoint Temperature | Difference Between Dewpoint and Room Temperature | Dewpoint Temperature | Difference Between Dewpoint and Room Temperature | Dewpoint Temperature | Difference Between Dewpoint and Room Temperature | Dewpoint Temperature | Difference Between Dewpoint and Room Temperature | Dewpoint Temperature | Difference Between Dewpoint and Room Temperature | Dewpoint Temperature | Difference Between Dewpoint and Room Temperature | Dewpoint Temperature | Difference Between Dewpoint and Room Temperature | Dewpoint Temperature | Difference Between Dewpoint and Room Temperature |
| 65 | 60.5 | 4.5 | 58.8 | 6.2 | 56.75 | 8.25 | 54.75 | 10.25 | 52.8 | 12.2 | 50.7 | 14.3 | 48.3 | 16.7 | 45.8 | 19.2 | 43.0 | 22.0 | 40.0 | 25.0 | 36.75 | 28.25 |
| 70 | 65.4 | 4.6 | 63.5 | 6.5 | 61.6 | 8.4 | 59.6 | 10.4 | 57.5 | 12.5 | 55.3 | 14.7 | 53.0 | 17.0 | 50.5 | 19.5 | 47.5 | 22.5 | 44.5 | 25.5 | 41.0 | 29.0 |
| 75 | 70.1 | 4.9 | 68.25 | 6.75 | 66.3 | 8.7 | 64.3 | 10.75 | 62.25 | 12.75 | 60.0 | 15.0 | 57.75 | 17.25 | 55.25 | 19.75 | 52.75 | 22.75 | 49.0 | 26.0 | 45.5 | 29.5 |
| 80 | 74.8 | 5.2 | 73.2 | 6.8 | 71.2 | 8.8 | 69.25 | 10.75 | 67.2 | 12.8 | 64.8 | 15.2 | 62.3 | 17.7 | 59.75 | 20.25 | 56.75 | 23.25 | 53.5 | 26.5 | 49.75 | 30.25 |
| 85 | 79.75 | 5.25 | 78.0 | 7.0 | 76.2 | 8.8 | 74.1 | 10.9 | 71.75 | 13.25 | 69.4 | 15.6 | 66.9 | 18.1 | 64.25 | 20.75 | 61.25 | 23.75 | 58.0 | 27.0 | 54.2 | 30.8 |
| 90 | 84.75 | 5.25 | 83.0 | 7.0 | 80.9 | 9.1 | 78.8 | 11.2 | 76.7 | 13.3 | 74.2 | 15.8 | 71.6 | 18.4 | 68.75 | 21.25 | 65.75 | 24.25 | 68.55 | 27.5 | 59.0 | 31.0 |
| 95 | 89.7 | 5.3 | 87.8 | 7.2 | 85.75 | 9.25 | 83.6 | 11.4 | 81.3 | 13.7 | 78.8 | 16.2 | 76.25 | 18.75 | 73.35 | 21.65 | 70.3 | 24.7 | 67.0 | 28.0 | 63.2 | 31.8 |

under winter conditions, where the outside temperature is considerably lower than the room temperature and to dehumidifiers where it is possible to maintain a definite dewpoint temperature throughout the entire year. Outlets in the dewpoint air-conditioning are shown in Fig. 11.

16 However during summer conditions the saturation point at the apparatus will frequently and unavoidably be higher than the required minimum dew point. Under such variable temperature

TABLE 2 HEAT REQUIRED TO CONDITION 1000 CU. FT. OF AIR (MEASURED AT 70 DEG. FAHR.) FROM VARIOUS ENTERING WET-BULB TEMPERATURES TO VARIOUS DEWPOINT TEMPERATURES

| Wet-Bulb Temperature of Entering Air | At 70 Deg. Fahr., 30 Per Cent Humidity, Dewpoint, 37.25 Deg. Fahr. | | | At 70 Deg. Fahr., 40 Per Cent Humidity, Dewpoint 44.5 Deg. Fahr. | | | At 70 Deg. Farh. 50 Per Cent Humidity, Dewpoint 50.5 Deg. Fahr. | | |
|---|---|---|---|---|---|---|---|---|---|
| | Sensible Heat | Latent Heat | Total Heat | Sensible Heat | Latent Heat | Total Heat | Sensible Heat | Latent Heat | Total Heat |
| −10 | 856 | 338 | 1194 | 981 | 471 | 1452 | 1086 | 567 | 1653 |
| 0 | 673 | 311 | 984 | 802 | 444 | 1246 | 907 | 540 | 1447 |
| 10 | 480 | 270 | 750 | 622 | 403 | 1025 | 730 | 498 | 1228 |
| 20 | 307 | 203 | 510 | 443 | 336 | 779 | 550 | 433 | 983 |
| 30 | 200 | 100 | 300 | 263 | 233 | 496 | 370 | 330 | 700 |
| 40 | | | | 82 | 96 | 178 | 190 | 194 | 384 |

| Wet-Bulb Temperature of Entering Air | At 70 Deg. Fahr., 60 Per Cent Humidity, Dewpoint 55.3 Deg. Fahr. | | | At 70 Deg. Fahr., 70 Per Cent Humidity, Dewpoint 59.6 Deg. Fahr. | | | At 70 Deg. Fahr., 80 Per Cent Humidity, Dewpoint 63.5 Deg. Fahr. | | |
|---|---|---|---|---|---|---|---|---|---|
| | Sensible Heat | Latent Heat | Total Heat | Sensible Heat | Latent Heat | Total Heat | Sensible Heat | Latent Heat | Total Heat |
| −10 | 1161 | 699 | 1860 | 1243 | 801 | 2044 | 1310 | 935 | 2245 |
| 0 | 991 | 672 | 1663 | 1066 | 774 | 1840 | 1131 | 908 | 2039 |
| 10 | 814 | 631 | 1445 | 888 | 733 | 1621 | 955 | 867 | 1822 |
| 20 | 635 | 565 | 1200 | 710 | 667 | 1377 | 779 | 802 | 1581 |
| 30 | 457 | 463 | 920 | 532 | 565 | 1097 | 600 | 700 | 1300 |
| 40 | 276 | 327 | 603 | 353 | 430 | 783 | 423 | 564 | 987 |
| 50 | 83 | 137 | 220 | 154 | 240 | 394 | 244 | 375 | 619 |
| 60 | | | | | | | 63 | 118 | 181 |

conditions it is necessary to control temperature with reference to the dewpoint according to system (*c*), and a humidifier is employed to give the air complete saturation under these conditions. One of the forms of differential thermostats which will be described later effects this control.

## AUTOMATIC HUMIDITY CONTROL

17 In many industrial installations where humidifying or dehumidifying systems are used, some means of positively and accurately maintaining the proper temperatures and humidities is essential. While much can be accomplished by hand regulation, this would require the constant attention of a highly skilled operator, which in most instances is impracticable. In many processes of manufacturing, as, for example, the weaving of silk and in the conditioning of tobacco for the manufacture of cigars, a uniformity of humidity

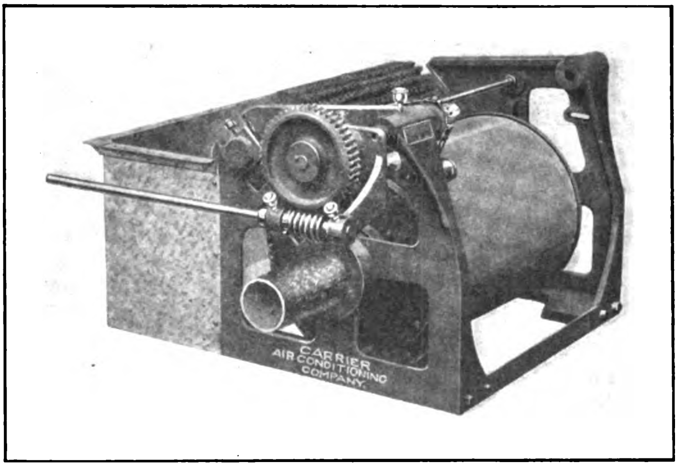



Fig. 10 Rotary Strainer

conditions is quite as essential as the quantity of moisture, as any variation in humidity, either above or below a standard, reduces the output and causes lack of uniformity in the product. In many cases a sensitive automatic humidity control is as important as some means of humidifying. There are three distinct methods by which such automatic control can be secured:

*a* By two separate thermostats, one of which, *D*, is placed at the humidifier just behind the eliminator plates shown at *A* (Fig. 2). This controls the temperature of the dewpoint, by an automatically operating valve or damper, governing a means of varying the temperature of the spray water, of the entering air, or of both in conjunction. The other thermostat, placed in the

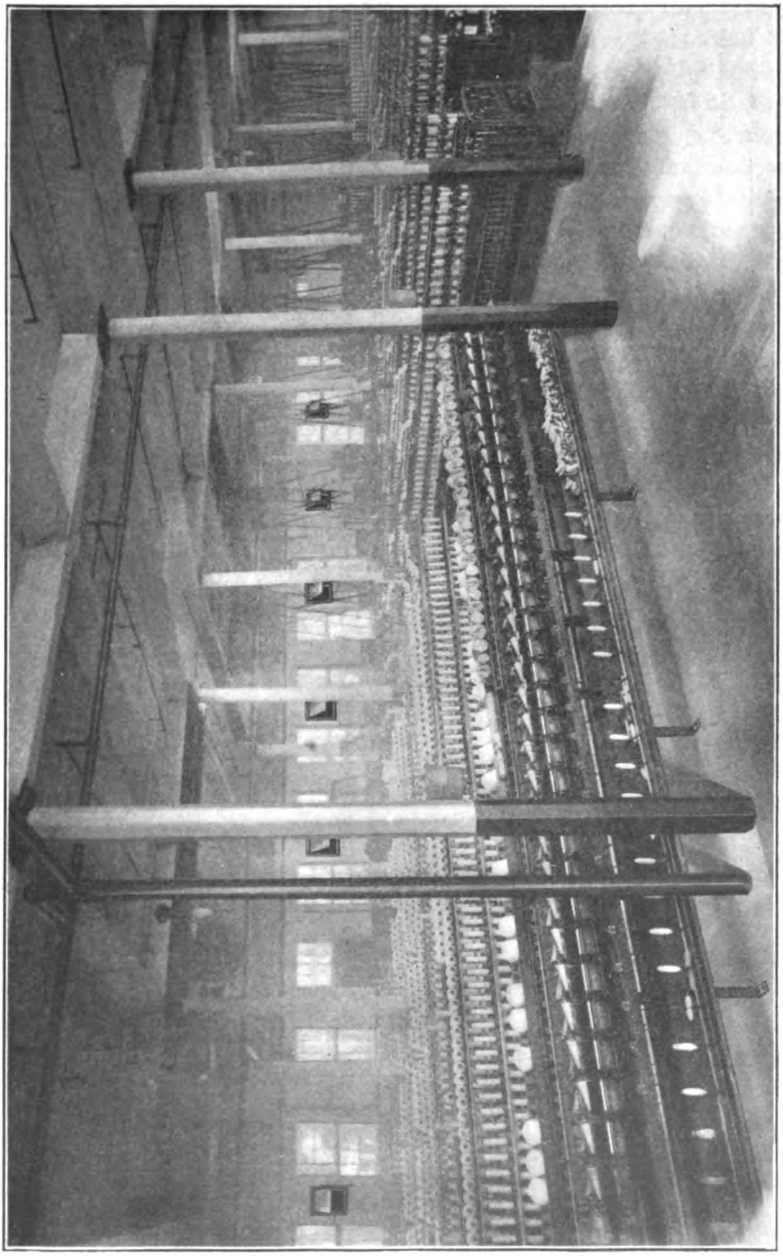


Fig 11 Spinning Room showing Outlets in Dewpoint Air-Conditioning Systems

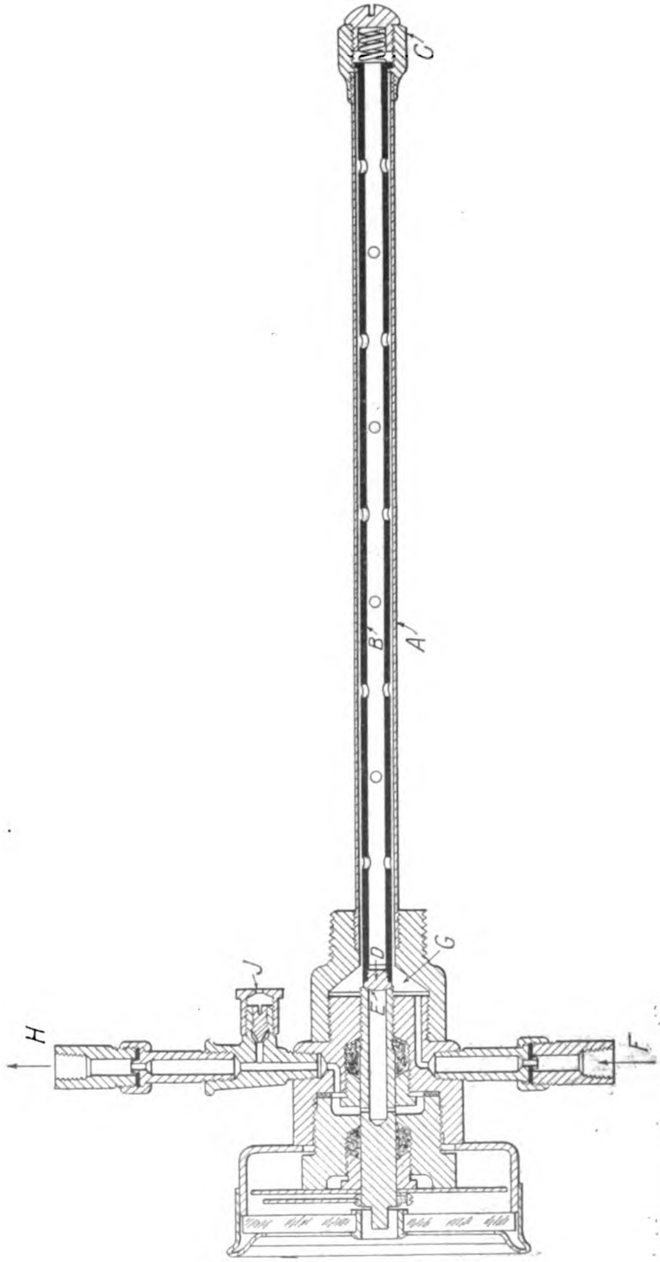



FIG 12 DEWPOINT THERMOSTAT

room where the humidity is controlled, maintains a constant room temperature, either by controlling the temperature of the air entering the room, or by controlling some source of heat within the room. With these two temperatures maintained constant, the percentage of humidity in the room will remain constant, and will depend upon the difference between the dewpoint temperature maintained at the humidifier and the temperature maintained in the room, as previously shown in Table 1.

*b* By a differential thermostat either of the form shown in Fig. 12, or as shown in Fig. 14. This type of dewpoint control is required wherever it is impracticable to maintain either a constant dewpoint or a constant room temperature. In this method there are two elements, one of which is exposed to the dewpoint temperature, while the other is exposed to the room temperature. They are so connected that they act conjointly upon a single thermostatic valve connected with operating motors arranged to control the dewpoint temperature in relation to the variable room temperature, or to control the room temperature with respect to the variable dewpoint temperature.

*c* By means of some form of differential hygrostat as shown in Figs. 17, 21 and 22. This controls the wet-bulb temperature with respect to the dry-bulb temperature, so as to maintain a constant relative humidity without regard to the dewpoint or variation in room temperature.

## DEWPOINT THERMOSTAT

18 The type of thermostat usually employed in maintaining a constant dewpoint is shown in Fig. 12. This consists of an outer expansive member *A*, usually brass, and an inner non-expansive member *B* of nickel steel. These two members are firmly connected at the end *C*. The other end of the inner member *B* is provided with a bronze valve *D*, ground to fit the adjustable valve seat *E*, supported by the member *A*. Compressed air is admitted through the connection *F* to the annular chamber *G* between the inner and outer tubes. As the outer member expands the valve *D* recedes from its seat, allowing the compressed air to escape into the outlet connection *H*, which connects with the diaphragm valve controlling the

temperature of the spray water, so as to reduce the temperature of the dewpoint. When the dewpoint temperature falls below the point desired, the outer member contracts, closing off the air supply to the

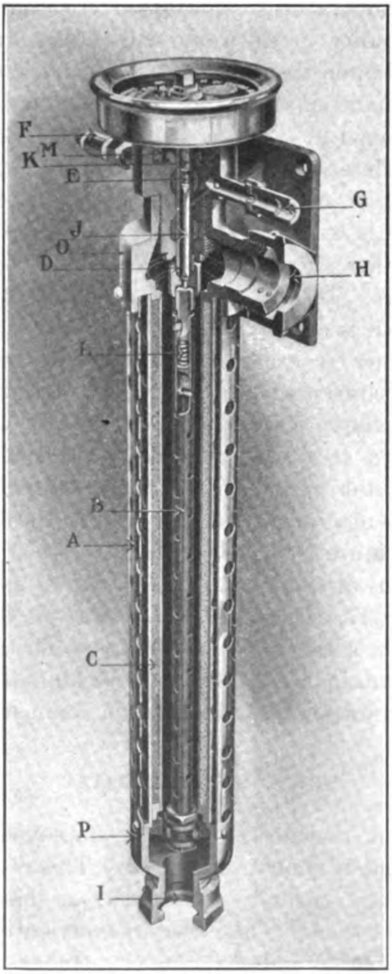



FIG. 13 METALLIC DIFFERENTIAL THERMOSTAT

diaphragm valve, connected to $H$, and the air pressure to the diaphragm motor is released through the adjustable vent $J$. This vent allows an air leak varying with the pressure on the diaphragm motor. Therefore the relation of the area of opening through the valve *D-E*, to the constant area of the vent opening *J*, determines

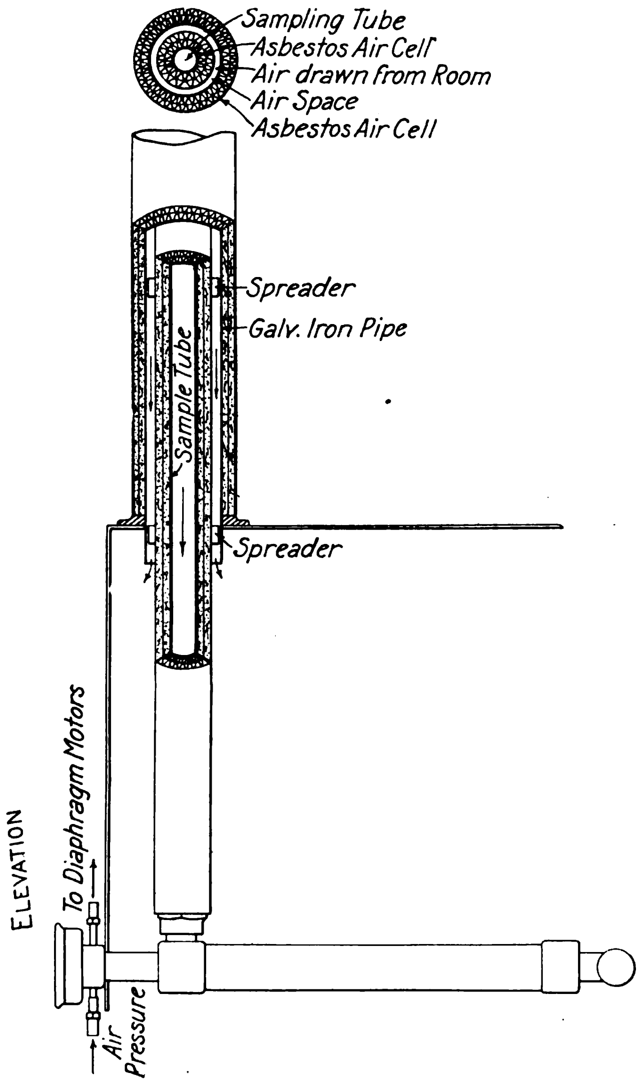



FIG. 14 SAMPLING TUBE OF DIFFERENTIAL THERMOSTAT

the graduated pressure on the diaphragm motor, at any instant. This is found in practice to give a very sensitive as well as positive control.

### METALLIC DIFFERENTIAL THERMOSTAT

19 The differential thermostat shown in Fig. 13, resembles the dewpoint thermostat in many features of construction, except that it consists of two expansible members operating conjointly, instead of one. The outer member *A* is subjected to the dewpoint temperature at the humidifier, while the inner member *B* is subjected to a strong current of air drawn from the room to be conditioned by means of an aspirator or fan, through an insulated tube. The two members are insulated from each other by an annular space *C*, filled with mineral wool. These two members are connected at the base *P* and act conjointly upon the double-ported valve, *D-E*. Compressed air is admitted to the chamber *M* through the connection *F*, and passes through the valve *E* to the chamber *J*, which is joined by the connection *G* to the diaphragm motor closing off the supply of heat to the spray water. Whenever the difference between the dewpoint and the room temperature is greater than that for which the instrument is adjusted, by means of the dial, the outer member *A* contracts with reference to the inner member *B*. This closes the port *E*, cutting off from the chamber *J* the supply of compressed air, simultaneously opening the port *D*, and allowing the air to escape from the diaphragm valve, which then operates to raise the temperature of the spray water.

20 The means employed for bringing the sample of air from the room to the thermostat is shown in Fig. 14. The sample of air is drawn through the insulated inner tube, while room air is also drawn through the annular space between this insulation and the outer pipe by means of a fan draft. This outer tube is also insulated outside of the room. The sampling tube usually connects with the thermostat at *H*, while the aspirator is connected at *I*.

### FLUID DIFFERENTIAL THERMOSTAT

21 This type of differential thermostat (Fig. 15) is adapted for use where there are several floors to be controlled independently and conditioned from a central apparatus. The dewpoint member and room member each consist of hermetically sealed chambers filled with air or other fluid under pressure. The air or fluid in either of these members will tend to expand and will increase the pressure, with constant volume, in direct proportion to the increase of temperature. The pressure in the dewpoint member, *B*, is conveyed either directly

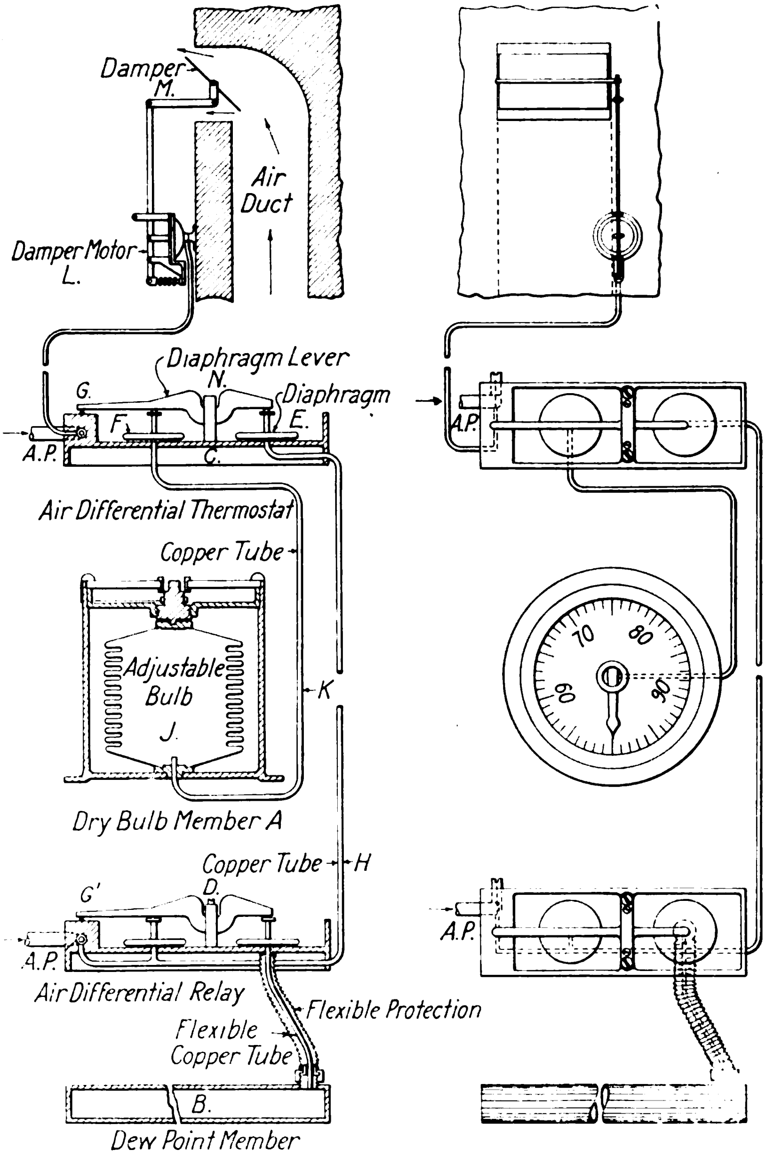



FIG. 15 FLUID DIFFERENTIAL THERMOSTAT AND HUMIDITY CONTROL

or proportionately to the diaphragm *E* of the differential thermostat *C*, through the differential relay *D* and connecting tube *H*. The room member *A*, which has an adjustable bulb *J*, connects through tube *K* to diaphragm *F* of the differential thermostat. The pressures or proportionate pressures in these two elements are thus opposed to each other through the lever *N*. Any unbalancing of pressures operates the valve *G*, which is shown in detail in Fig. 16. So long as the temperature difference between the dewpoint temperature at the apparatus and the room temperature remains constant, the pressures on the diaphragms *E* and *F* will remain balanced and no movement of

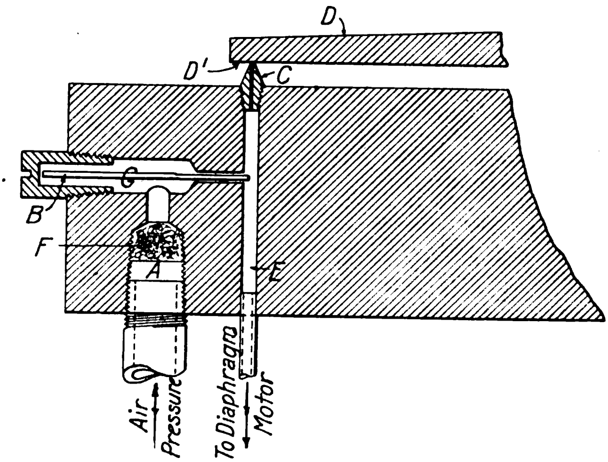



Fig. 16 Construction of Thermostatic Valve

the valve *G* will take place. If, however, an excess of moist air is admitted to the room, until its temperature is reduced to a point where the difference between it and the dewpoint temperature is less than the predetermined amount, the pressure on the diaphragm *F* will be less than the pressure on diaphragm *E*. This will permit the valve *G* to operate, bringing pressure on damper motor *L* and closing the damper *M*, cutting off the supply of cool moist air.

22 Adjustable bulb *J*, exposed to the room temperature and provided with a dial, permits the thermostat to be adjused for any desired difference between dewpoint temperature and room temperature, and consequently for any percentage of relative humidity regardless of variation in room temperature.

23 The construction of the thermostatic valves $G$ and $G'$ is shown in Fig. 16. Compressed air is admitted at $A$ through filter $F$ into the restriction chamber $G$, and also in a constant amount through restriction into chamber $E$, connecting in case of the differential

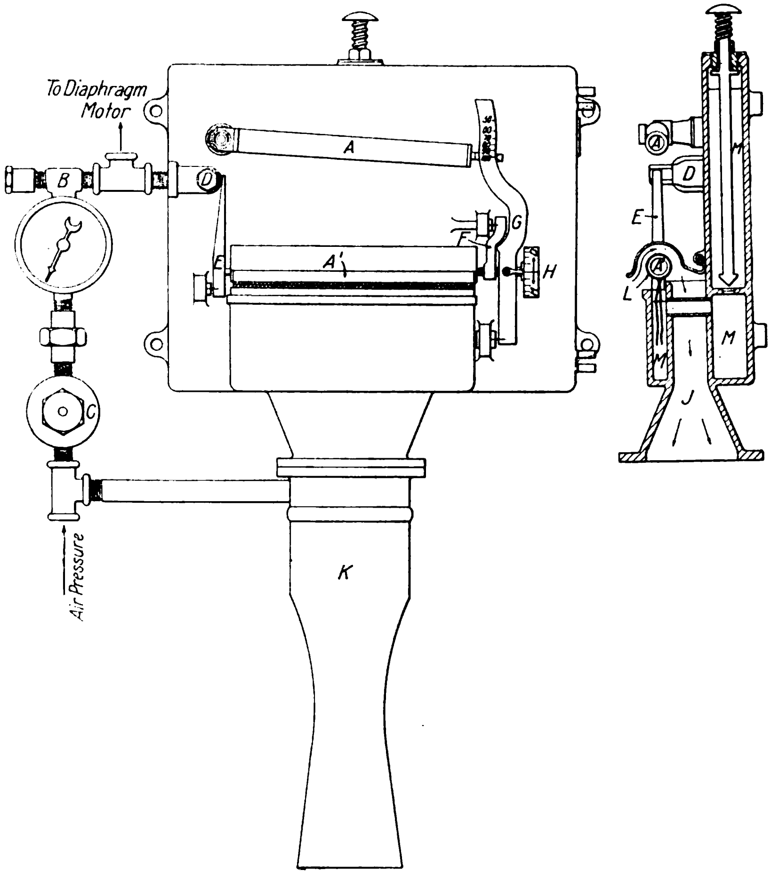



Fig. 17 Carrier Differential Hygrostat

relay with diaphragm $E$, of the differential thermostat, and in case of the differential thermostat, with the diaphragm motor controlling damper $M$. Upon the lower side of the diaphragm lever $D$ is a uniformly ground and polished surface $D'$ which approaches or recedes from the nozzle $C$ as the pressure on one diaphragm overcomes that on the other, increasing or decreasing the pressure in $E$ correspondingly.

## DIFFERENTIAL HYGROSTAT

24 In many instances the dewpoint system of humidity control cannot be applied to advantage. In such cases a differential hygrostat may be employed. The differential hygrostat (Figs. 17 and 18) consists of two members, one of which is subjected to the dry-bulb temperature of the room, while the other is subjected to the wet-bulb temperature. The expansive dry-bulb member *A*, and the wet-bulb member *A'*, of hard rubber tube, connected by levers *F* and *G*, operate conjointly the valve lever *E*. Valve *D* and restriction *B* are

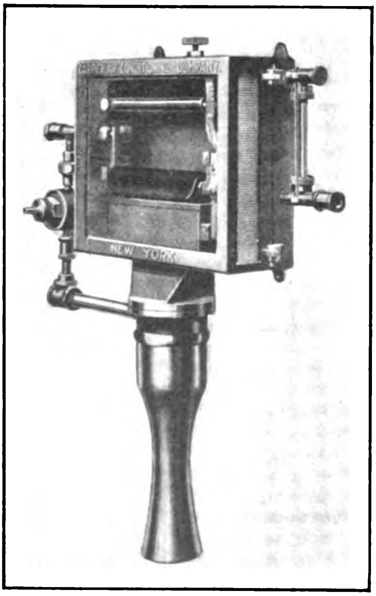
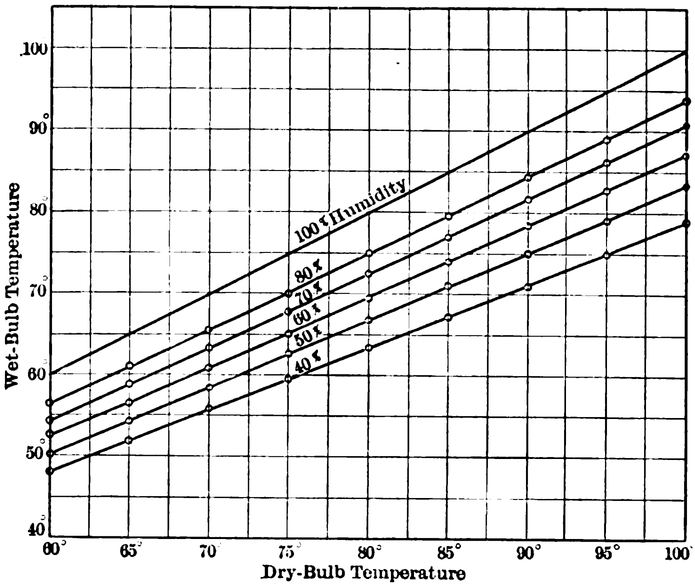
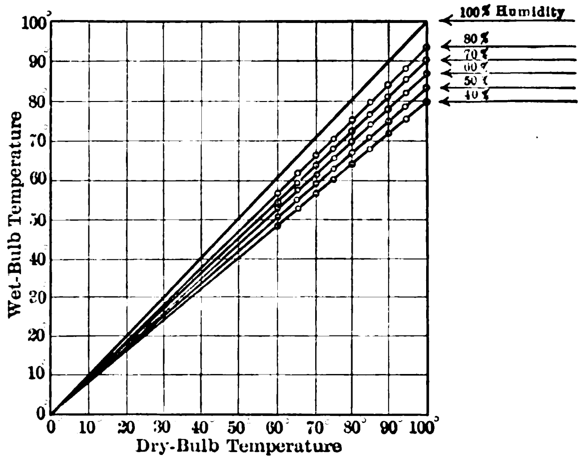


Fig. 18 Carrier Differential Hygrostat

similar in construction to the valve shown in Fig. 16 and operate in the same way. As will be seen from Figs. 19 and 20, the difference between the dry and wet-bulb temperature for a given per cent of humidity is not constant at different dry-bulb temperatures, i.e., a constant difference maintained between dry and wet-bulb temperatures would not result in a constant percent of humidity during this change. For instance, with 50 per cent of humidity at a dry-bulb temperature of 70 deg. the wet-bulb temperature is 58.42 deg., a difference of 11.58 deg. At 80 deg. the wet-bulb temperature is 66.65 deg., or a difference of 13.35 deg. Thus it will be seen that the dry-bulb temperature has risen 10 deg., while the wet-bulb has risen but 8.23 deg.,




FIGS. 19 AND 20 RELATION BETWEEN WET AND DRY-BULB TEMPERATURE FOR DIFFERENT RELATIVE HUMIDITIES

a difference of 1.77 deg. To compensate for this difference a change of leverage is effected, as indicated by graduations on lever *G*. An adjustment *H* permits of regulation to any desired humidity. As shown in sectional view, a wick *L′* covers *A′*, being moistened by water held in chamber *M*. A sufficient current of room air is drawn by means of an aspirator *K*, over *A′* through chamber *J*.

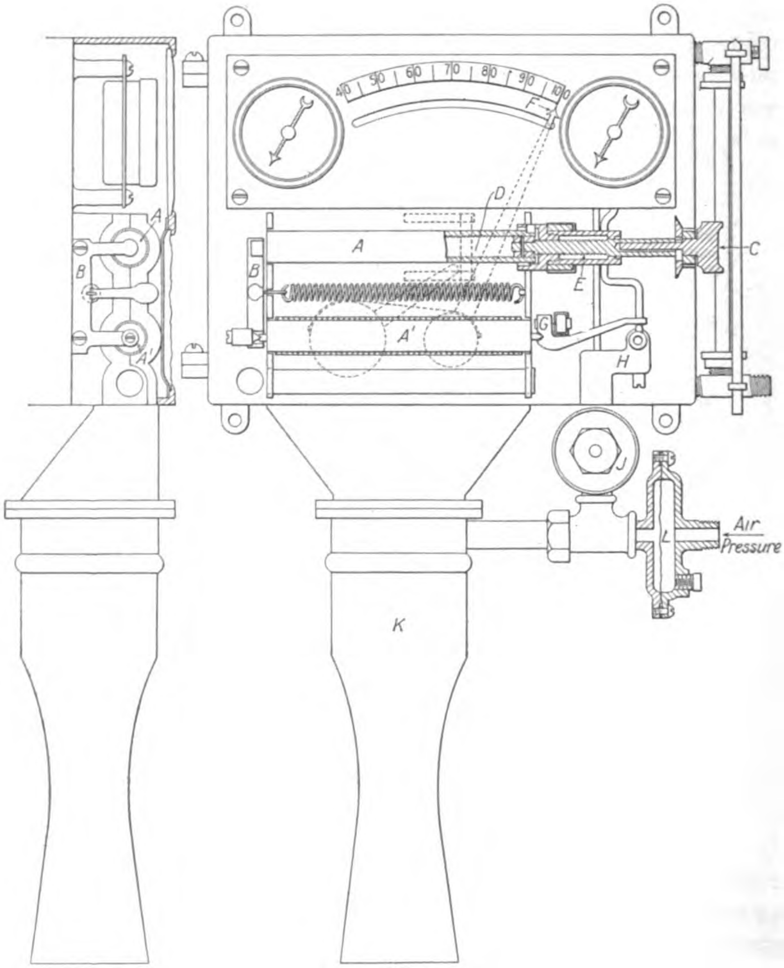



Fig. 21 Improved Form of Carrier Differential Hygrostat

25 An improved form is shown in Fig. 21. It differs essentially in three features: (*a*) the air current is drawn over both expansive members; (*b*) the action of a portion of the expansive member, *A*, is cut out in the adjustment instead of its action being decreased by a

change of leverage; (c) the unique feature of this form is that it requires but one adjustment. A differential thread is used, making it a compound adjustment. The pitch of the thread $D$, in $A$, is greater than the pitch of the thread on the adjusting screw. As the screw moves along to shorten $A$, sufficient to compensate for change of difference of dry and wet-bulb temperatures for varying dry-bulb temperature, as shown by graduations $A$ and $A'$ acting conjointly

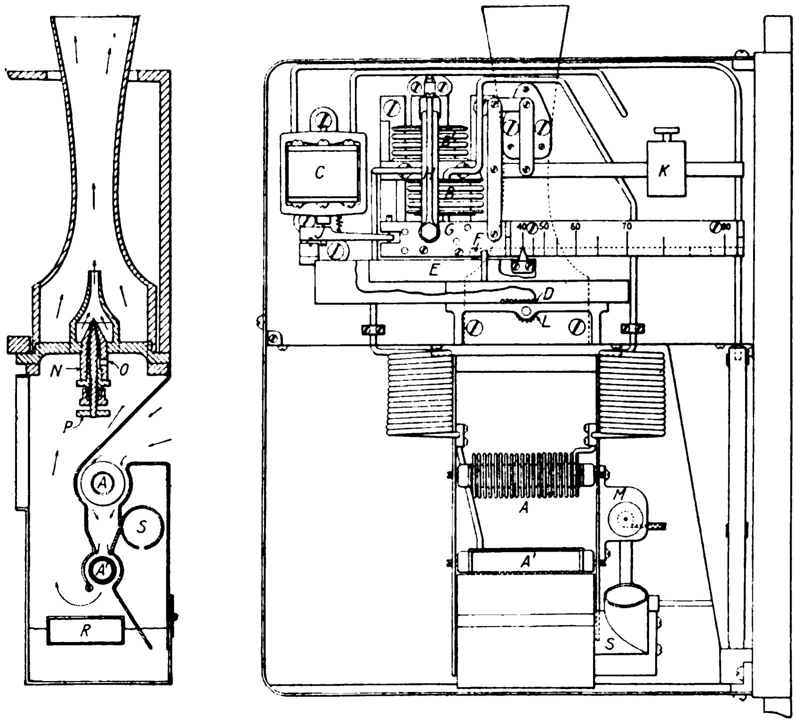



Fig. 22 Vapor Pressure Hygrostat

through rocker arm $B$ are carried back, so adjusting lever $G$, as to maintain the humidity for which the indicator is set.

26 *Vapor Pressure Hygrostat.* Fig. 22 shows an improved form of hygrostat operated by the relative pressures of a volatile liquid subjected to the wet and dry-bulb temperatures. These vapor pressures act through suitable diaphragms upon a common lever at variable distances from the fulcrum. Referring to Fig. 22, $A$ is the dry-bulb member, $A'$ the wet-bulb member, covered with a

wick or absorbent material and moistened by anatomized spray produced by the atomizing nozzle *M* (Fig. 22, shown in detail in Fig. 23). A current of air is drawn over both the dry and wet bulbs by means of the aspirator, as shown in sectional view (Fig. 22). The vapor pressures in these bulbs are conducted to the corresponding diaphragms by means of tubes. Diaphragm *B′* is connected with the wet bulb *A′*, and the diaphragm *B* connects with the dry bulb *A*. The diaphragm *B′* acts upward on the lever *G* through the link *H*, while the diaphragm *B* acts downward at point *G*, between the link *H* and the fulcrum *F*. Fulcrum *F*, consists of a hardened steel ball having a rolling contact with the lever *G*, and the adjusting bar *E*. The adjusting bar *E* is moved by a rack and pinion *D-L*. The scale in per cent of humidity is attached to the lever G, while the pointer is carried on the adjusting bar *E* and therefore moves proportionally with the fulcrum. Any

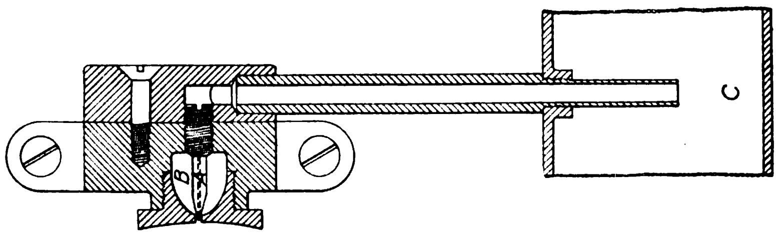



FIG. 23 CONSTRUCTION OF ATOMIZER USED IN CARRIER VAPOR PRESSURE HYGROSTAT

adjustment of *F* changes the relative leverage of *B* and *B′*; so that by adjustment of it any ratio of leverage may be secured. Any movement of the lever *G* operates the balanced thermostatic valve *C*, which controls the source of humidification. The particular fluid adapted for use in this type of instrument is sulphur dioxide, the temperature pressure properties of which are remarkably adapted to this purpose, as shown in Table 3 and Fig. 24. The ratio of sulphur dioxide pressures corresponding to wet and dry-bulb temperatures is substantially constant at any per cent of humidity for any range of dry-bulb temperatures between 60 and 100 deg. This makes it possible to oppose the pressures at any desired ratio corresponding to the required per cent of humidity, where it will control throughout any range of dry-bulb temperatures.

27 *Recording Hygrometer*. The same principle is applied to great advantage in the recording hygrometer shown in Fig. 25. In this we have dry bulb *A* and wet bulb *A′* connected respectively to dia-

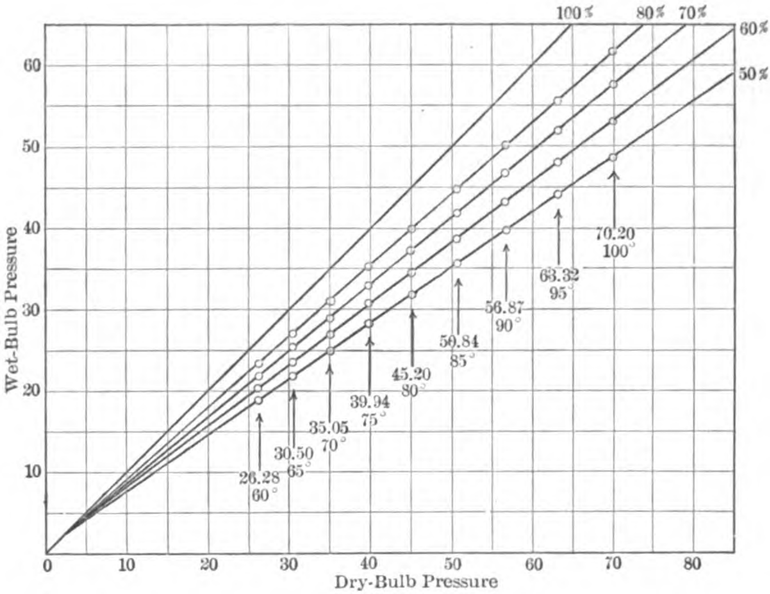



FIG. 24 PSYCHROMETRIC WET AND DRY-BULB TEMPERATURES FOR VARIOUS PERCENTAGES OF HUMIDITY

TABLE 3 RELATIVE PRESSURES OF SULPHUR DIOXIDE VAPOR CORRESPONDING TO PSYCHROMETRIC WET AND DRY-BULB TEMPERATURES FOR VARIOUS PERCENTAGES OF HUMIDITY

| | | 50 Per Cent | | | 60 Per Cent | | | 70 Per Cent | | | 80 Per Cent | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Dry-Bulb Temperature, Deg. Fahr. | $SO_2$ Pressure (Gage) | Wet-Bulb Temperature, Deg. Fahr. | $SO_2$ Pressure (Gage) | Ratio of Pressures −2.75 Lb. | Wet-Bulb Temperature, Deg. Fahr. | $SO_2$ Pressure (Gage) | Ratio of Pressures −2.75 Lb. | Wet-Bulb Temperature, Deg. Fahr. | $SO_2$ Pressure (Gage) | Ratio of Pressures −2.75 Lb. | Wet-Bulb Temperature, Deg. Fahr. | $SO_2$ Pressure (Gage) | Ratio of Pressures −2.75 Lb. |
| 60 | 26.28 | 50.24 | 18.90 | 0.6863 | 52.28 | 20.35 | 0.7479 | 54.30 | 21.80 | 0.8096 | 56.28 | 23.30 | 0.8733 |
| 65 | 30.50 | 54.32 | 21.85 | 0.6863 | 56.54 | 23.55 | 0.7495 | 58.81 | 25.35 | 0.8144 | 61.05 | 27.10 | 0.8775 |
| 70 | 35.05 | 58.42 | 24.95 | 0.6873 | 60.86 | 26.95 | 0.7489 | 63.22 | 28.95 | 0.8111 | 65.63 | 31.05 | 0.8761 |
| 75 | 39.94 | 62.53 | 28.35 | 0.6883 | 65.22 | 30.65 | 0.7502 | 67.80 | 33.00 | 0.8134 | 70.34 | 35.35 | 0.8766 |
| 80 | 45.20 | 66.65 | 31.95 | 0.6878 | 69.58 | 34.60 | 0.7503 | 72.39 | 37.35 | 0.8151 | 75.07 | 39.95 | 0.8762 |
| 85 | 50.84 | 70.72 | 35.75 | 0.6862 | 73.95 | 38.85 | 0.7507 | 77.00 | 41.95 | 0.8151 | 79.72 | 44.85 | 0.8754 |
| 90 | 56.87 | 74.89 | 39.80 | 0.6846 | 78.32 | 43.35 | 0.7502 | 81.61 | 46.90 | 0.8158 | 84.50 | 50.15 | 0.8758 |
| 95 | 63.32 | 79.01 | 44.15 | 0.6835 | 82.72 | 48.20 | 0.7503 | 86.04 | 52.05 | 0.8139 | 89.21 | 55.85 | 0.8767 |
| 100 | 70.20 | 83.33 | 48.80 | 0.6827 | 87.07 | 53.20 | 0.7479 | 90.64 | 57.65 | 0.8139 | 94.00 | 61.95 | 0.8777 |

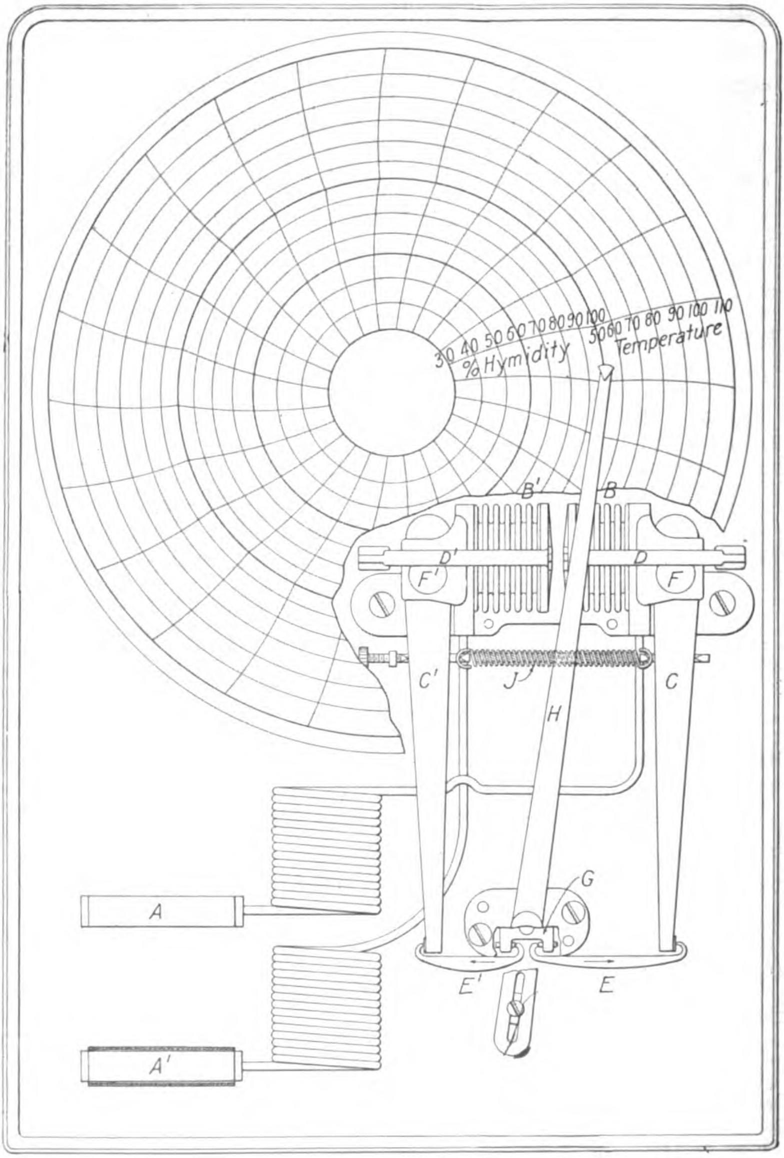



FIG. 25 MECHANISM OF CARRIER RECORDING HYGROMETER

phragms *B* and *B′*, which act through the links, *D* and *D′*, upon the levers *C* and *C′*, which act upon ball-bearing fulcrums *F* and *F′*. The relative forces are transmitted from the levers *C* and *C′* through the links *E* and *E′* to the rocker arm *G*, which is firmly supported by minute ball bearings. To the rocker arm *G*, is connected the recording pen *H*. By referring to Table 3 and Fig. 24, it will be seen that any per cent of humidity may be represented at all temperatures by

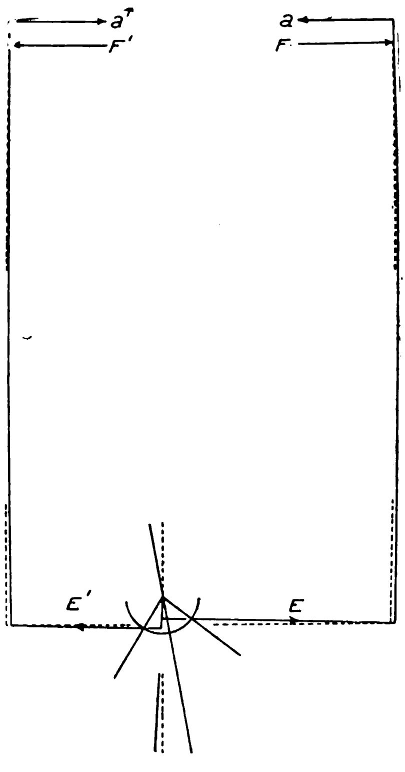



FIG. 26 LEVERAGE DIAGRAM OF CARRIER RECORDING HYGROMETER

a pressure ratio. The rocker arm *G* acts as an evener. When it is acted upon by the stronger force of the dry bulb through the link *E*, it rotates toward *C*, decreasing the leverage of *E* and increasing the leverage of *E′*, until the two moments are exactly balanced as shown in diagram Fig. 26. The angular deflection of the rocker arm will then indicate the ratio of pressures in the diaphragms *B* and *B′*. Therefore the angular deflection is constant for any percentage of humidity regardless of temperature variations. The spring *J* has an important function as a compensator, both for the small pressure subtractions required to obtain an exact ratio, and for the slight resistance of the diaphragms *B* and *B′*. The latter compensation while exceedingly simple is effectual and complete, allowing for any amount of diaphragm resistance. This permits the instrument to give perfect indications regardless of the temperature variations, or the weight of the material used in the construction of the diaphragms.

## ELEMENTS OF DESIGN OF HUMIDIFIERS AND OF AIR-CONDITIONING SYSTEMS

28 The degree of saturation of the air leaving any type of air washer depends upon the intimacy of the contact of the air and water, and upon the relation of the water temperature to the wet-bulb temperature of the entering air. It also depends to some degree upon the length of the spray chamber as well as upon the velocity of the air passing through it. With the centrifugal type of spray nozzles the water pressure is a most important element affecting the degree of saturation. Fig. 27 shows the humidifying effect secured with various velocities and at different pressures on the spray nozzle, in a standard humidifier having four $\frac{3}{32}$-in. orifice centrifugal spray nozzles per sq. ft. These data were obtained from a test in which the wet-bulb depression of the entering air was maintained constant at 16 deg. It will be noted that an increase of 2½ lb. per sq. in. in the spray pressure permitted a greatly increased velocity with perfect saturation, an effect which was undoubtedly due to the increased fineness of the spray rather than to the increase in the amount of water discharged. In this test, as in all standard humidifiers, the water was discharged in the direction opposite the air flow, which greatly increased the efficiency of saturation.

29 When the spray water is recirculated without heating as in warm weather, it remains at all times substantially at the wet-bulb temperature of the entering air while the wet-bulb temperature of the air leaving the washer or humidifier is unchanged. Therefore it follows, in conformance with the theory, that when the air is completely saturated as in the humidifier the air is cooled to the wet-bulb temperature of the incoming air. This cooling effect is due to the transformation of sensible heat into latent heat of evaporation and is therefore in direct proportion to the moisture added to the air. The wet-bulb depression in atmospheric air averages

from 12 to 15 deg. in summer, while occasionally a depression of 20 to 30 deg. is found in extremely hot and dry weather. In every case the humidifier will cool the incoming air a corresponding number of degrees.

30 When saturation is incomplete, as in the ordinary air washer, the wet-bulb depression of the air leaving the washer is found to be a constant percentage of the initial wet-bulb depression, when the air velocity remains constant.

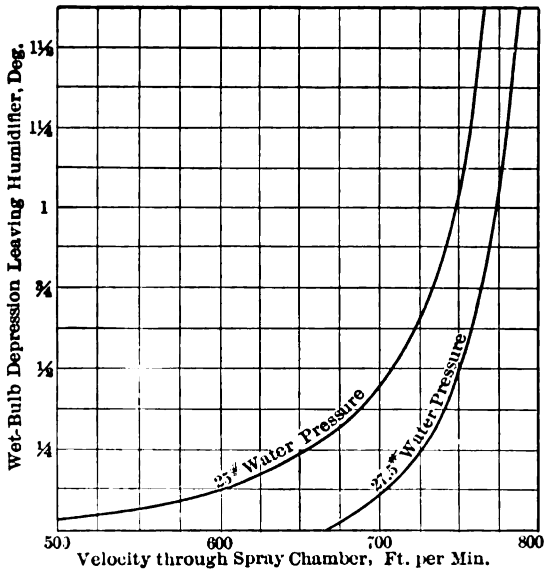



FIG. 27 EFFECT OF SPRAY PRESSURE AND AIR VELOCITY UPON THE DEGREE OF SATURATION. INITIAL WET-BULB DEPRESSION = 16 DEG. FAHR.

31 It also follows that the cooling effect is a constant percentage of the initial wet-bulb depression. This may be expressed by the formulae

$$\frac{t_2 - t'}{t_1 - t'} = R \qquad [1]$$

$$\frac{t_1 - t_2}{t_1 - t'} = 1 - R = E \qquad [2]$$

where

$t'$ = constant wet-bulb temperature

$t_1$ = temperature of air entering washer

$t_2$ = temperature of air leaving washer
$R$ = constant ratio depending upon intimacy of contact, air velocity, etc.
$1 - R = E$ = efficiency of saturation

### POWER REQUIRED FOR OPERATING HUMIDIFIERS

32 Table 4 exhibits the power required to saturate 1000 cu. ft. of air per minute at various velocities. This is based on overcoming the resistance of the humidifier, using a fan with a static efficiency of 45 per cent, a fair value.

TABLE 4 RESISTANCE OF CARRIER HUMIDIFIERS AND HORSEPOWER REQUIRED TO HUMIDIFY 1000 CU. FT. OF AIR

| Velocity through Spray Chamber in Ft. per Min. | Resistance in In. of Water | Resistance in Oz. per Sq. In. | Horsepower to Move 1000 Cu. Ft. Air per Min. At 45 Per Cent Fan Efficiency | Horsepower for Spray per 1000 Cu. Ft. of Air ($\frac{1}{16}$ Orifice Nozzle) | Total Horsepower Required per 1000 Cu. Ft. of Air |
|---|---|---|---|---|---|
| 350 | 0.112 | 0.0647 | 0.0391 | 0.1408 | 0.1799 |
| 400 | 0.147 | 0.0850 | 0.0513 | 0.1231 | 0.1744 |
| 450 | 0.186 | 0.1075 | 0.0652 | 0.1095 | 0.1747 |
| 500 | 0.229 | 0.1322 | 0.0800 | 0.0985 | 0.1785 |
| 550 | 0.277 | 0.1600 | 0.0968 | 0.0897 | 0.1865 |
| 600 | 0.330 | 0.1906 | 0.1150 | 0.0822 | 0.1972 |
| 650 | 0.387 | 0.2240 | 0.1350 | 0.0758 | 0.2108 |
| 700 | 0.450 | 0.2600 | 0.1570 | 0.0704 | 0.2274 |
| 750 | 0.516 | 0.2990 | 0.1810 | 0.0658 | 0.2468 |

33 This does not include the power required to overcome the resistance of the ducts, which varies considerably, but which should not exceed that required for the humidifier. The resistance of the heating coils is not considered, because in summer when the largest supply of air is usually required the air is by-passed around the heaters, while in winter the requirements are so much smaller that the total horsepower is greatly reduced and the total resistance is but slightly increased.

34 The power required to pump the water is based on the use of centrifugal pumps giving 55 per cent efficiency and using $\frac{1}{16}$-in. orifice nozzles with rotary self-cleaning strainers.

### RELATION OF COOLING EFFECT TO PERCENTAGE OF RELATIVE HUMIDITY

35 In the moist air system of humidifying it is evidently essential, as shown in Table 1, that the difference between the dewpoint temperature of the incoming air and the room temperature

shall not exceed a predetermined value depending upon the percentage of humidity to be maintained. The minimum temperature at which air can be introduced is evidently the dewpoint or saturation temperature at the apparatus. This permissible temperature rise limits the possible cooling effect to be obtained from each cubic foot of air as shown in Table 5. This relationship is of primary importance in the design of the humidifying system and the disregard of it has been the chief cause of failure or of unsatisfactory operation.

36 In the majority of industrial applications the problem during warm weather, and in some instances throughout the entire year, is as much a question of cooling as of humidifying. Indeed, in the

TABLE 5 COOLING CAPACITY OF CARRIER HUMIDIFYING SYSTEM

| Per Cent Humidity in Room | Difference between Dewpoint and Room Temperature | Cu. Ft. of Air at 70 Deg. Fahr. Required per B.t.u. Cooling Effect |
|---|---|---|
| 50 | 20.3 | 2.71 |
| 55 | 17.7 | 3.11 |
| 60 | 15.2 | 3.63 |
| 65 | 12.8 | 4.31 |
| 70 | 10.8 | 5.10 |
| 75 | 8.8 | 6.27 |
| 80 | 6.8 | 8.11 |

moist air system, as has just been shown, one is dependent on the other. In every industrial air-conditioning plant there are four sources of heat which must be taken into account in the design of the system:

*a* Radiation from the outside owing to the maintainence of a lower temperature inside. At ordinary humidities this is negligible, but at high humidities and in dehumidifying plants it is an important factor, owing to the increased temperature difference. This may be calculated from the usual constants of radiation.

*b* The heating effect of direct sunlight. This is especially noticeable from window shades and exposed windows and skylights where the entire heat energy of the sunlight is admitted to the room, and from the roof which constitutes the greater amount of sunlight exposure and which in the ordinary construction transmits heat much more readily than the walls. Precautions should be taken where high humidities are desired to shade exposed windows and to insulate the roof thoroughly. Ventilators in the roof are of great advantage in removing the hot layer of air next it and those of ample capacity should always be provided.

*c* The radiation of heat from the bodies of the operatives. This amounts to about 400 to 500 B.t.u. per operative, about one-half of which is sensible heat, the other half being transformed into latent heat through evaporation.

*d* The heat developed by power consumed in driving the machinery and in the manufacturing processes in general. According to the laws of conservation of energy, all power used in manufacturing is ultimately converted entirely into its heat equivalent. Each horsepower of energy therefore creates $42\frac{1}{2}$ B.t.u. of heat per minute which must be cared for by ventilation. In high-powered mills this is the chief source of heating and is frequently sufficient to overheat the building even in zero weather, thus requiring cooling by ventilation the year round.

TABLE 6 POSSIBLE ROOM TEMPERATURES OBTAINABLE IN CARRIER SYSTEM OF HUMIDIFYING, AT VARIOUS OUTSIDE WET-BULB TEMPERATURES AND VARIOUS PERCENTAGES OF HUMIDITY IN THE ROOM

| Outside Wet-Bulb Temperature | Percentage Humidity in Room | | | | | |
|---|---|---|---|---|---|---|
| | 55 | 60 | 65 | 70 | 75 | 80 |
| 50 | 67.0 | 64 3 | 62.0 | 59.8 | 57.7 | 56.0 |
| 55 | 72.0 | 69.6 | 67.5 | 65.2 | 63.1 | 61.1 |
| 60 | 77.5 | 74.9 | 72.5 | 70.4 | 68.3 | 66.3 |
| 65 | 82.8 | 80.2 | 77.6 | 75.6 | 73.5 | 71.6 |
| 70 | 87.2 | 85.6 | 83.1 | 80.0 | 78.7 | 76.7 |
| 75 | 93.7 | 90.8 | 87.3 | 85.9 | 83.9 | 81.9 |
| 80 | 99.1 | 96.2 | 93.4 | 91.2 | 89.0 | 87.0 |

## RELATION OF ROOM TEMPERATURE TO OUTSIDE WET-BULB TEMPERATURE

37 During cool weather the dewpoint or saturation temperature at the apparatus is secured and controlled artificially at whatever point required. During warm weather, however, it is impossible during the greater part of the time to obtain as low a dewpoint as desired without refrigeration, which in the majority of cases of humid-

ifying is impracticable. The lowest saturation temperature that can be obtained is the same as the outside wet-bulb temperature, as has been shown. Therefore, the dewpoint in the room will always be the same as the outside wet-bulb temperature. Since the difference between the dewpoint and the room temperature is dependent upon the percentage of relative humidity maintained, the minimum room temperature and the percentage of humidity required in the enclosure will be as shown in Table 6. It will be noted that the higher the humidity carried, the lower the room temperature may be kept.

TABLE 7 B.T.U. REFRIGERATION REQUIRED TO COOL 1000 CU. FT. OF AIR (MEASURED AT 70 DEG.) FROM A GIVEN WET-BULB TEMPERATURE TO A GIVEN DEWPOINT

| Leaving Dewpoint | Ammonia Temperature | Suction Pressure (Gage) | Per Cent Compressor Ratings at 15 Lb. | Per Cent Horsepower Compared with Horsepower Required at Rated Suction Pressure of 15 Lb. Gage | Entering Wet-Bulb Temperature | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 50 | 55 | 60 | 65 | 70 | 75 | 80 | 85 |
| 65 | 45 | 65.96 | 270 | 41.5 | ...... | ...... | ...... | ...... | 296 | 606 | 961 | 1350 |
| 60 | 40 | 58.29 | 244 | 45.5 | ...... | ...... | ...... | 259.0 | 553 | 865 | 1220 | 1609 |
| 55 | 35 | 51.22 | 220 | 49.5 | ...... | ...... | 221.5 | 480.5 | 777 | 1086 | 1440 | 1840 |
| 50 | 30 | 44.72 | 199 | 54.5 | ...... | 203 | 425.0 | 683.0 | 980 | 1290 | 1570 | 2030 |
| 45 | 25 | 38.73 | 182 | 59.5 | 185 | 388 | 611.0 | 869.0 | 1165 | 1474 | 1830 | 2220 |
| 40 | 20 | 33.25 | 164 | 66.0 | 359 | 569 | 791.0 | 1050.0 | 1345 | 1656 | 2010 | 2400 |

## ELEMENTS OF DESIGN OF SPRAY TYPE OF DEHUMIDIFIERS

38 Dehumidifiers may be of the spray type previously described or of the surface type. A knowledge of the relation of water temperature to the leaving air temperature in either type is essential. In the spray type of one stage having two banks of opposed nozzles, the air temperature leaving is practically identical with the temperature of the leaving water, the difference never exceeding 1 deg. in a properly designed apparatus. The air will always be saturated when leaving and under some conditions there is a slight tendency to entrainment even after thorough elimination.

39 The degree of entrainment is dependent upon the range of temperature of both the air and the water. In general the smaller the temperature range, the greater the tendency is to moisture entrainment or supersaturation. This may be reduced where a

considerable lowering of air temperature is required by passing it successively through two or more dehumidifiers in series. When the system is properly designed the entrainment should not be sufficient to raise the true dewpoint temperature more than 1 deg.

### REFRIGERATION REQUIRED FOR DEHUMIDIFYING

40 The heat to be removed in cooling a known weight of air from a given temperature and moisture content to a given dewpoint temperature is evidently the difference of the total heat quantities contained in the air under these respective conditions. These values of total heat are given in Figs. 1 and 2 of the accompanying paper on Rational Psychrometric Formulae.[1] It is there shown that the total of latent and specific heat in 1 lb. of pure air is dependent upon the wet-bulb temperature only. Table 7 shows the amount of refrigeration required to cool and dehumidify 1000 cu. ft. of air between various given wet-bulb temperatures and final dewpoints.

41 The amount of water required to cool air in a one-stage spray system dehumidifier may be calculated from the foregoing data as follows:

$$W(t_W - t_2) = N(H_1 - H_2) = N(t'_1 - t_2)\frac{\Delta H}{\Delta t'} \qquad [3]$$

$$W = N\left(\frac{H_1 - H_2}{t_W - t_2}\right) = N\left(\frac{t'_1 - t_2}{t_W - t_2}\right)\frac{\Delta H}{\Delta t'} \qquad [4]$$

where

$W$ = weight of water in lb.
$N$ = weight of air in lb.
$t_W$ = initial water temperature
$t'_1$ = initial wet-bulb temperature of air
$t_2$ = final dewpoint temperature of air
$H_1$ = initial total heat in 1 lb. of air at wet-bulb temperature, $t'$
$H_2$ = total heat in 1 lb. of air at final dewpoint $t_2$
$\frac{\Delta H}{\Delta t'}$ = approximate rate of total heat change at the given temperature per degree change in wet-bulb temperature, $t'$

42 To find the final temperature possible with a given weight of water and of air at temperature $t_W$ and $t'_1$, respectively, we have from [3]

[1] The Journal, November 1911, p. 1309.

$$Wt_W - Wt_2 = Nt'_1 \frac{\Delta H}{\Delta t^1} - Nt_2 \frac{\Delta H}{\Delta t'} \quad [5]$$

Hence

$$t_2 = \frac{Nt'_1 \frac{\Delta H}{\Delta t'} - Wt_W}{N \frac{\Delta t}{\Delta t'} - W} \quad [6]$$

## ECONOMY OF THE SPRAY TYPE OF DEHUMIDIFIER

43 The chief advantage, aside from economy of space, of the spray type of dehumidifier over the surface type, lies in its ability to bring the spray water and the air to substantially the same temperature, while in the surface type there is usually from 15 to 25 deg. difference. This permits a much increased efficiency of cooling with the spray type where artesian well water is used. When the spray water is cooled by artificial refrigeration, using the compression system, this higher water temperature permits a much increased ammonia pressure in the water cooler, often doubling the absolute pressure. As shown in Table 7, this increases the capacity of the ammonia compressor correspondingly and greatly reduces the horsepower required per ton of refrigeration. The ammonia condenser, of course, remains unchanged.

## HEAT INTERCHANGER

44 When the reduction of the moisture contents is of more importance than the cooling effect, a heat interchanger or economizer may be used to great advantage. In this apparatus the cold air leaving the dehumidifier is passed through the inside of a system of tubes while the warm incoming air is passed over the outside of these tubes and in the opposite direction. This permits an effectual transfer of heat, often cooling the incoming air to a lower temperature than that of the dehumidified air leaving the interchanger. The saving effected in this way is often more than one-third of the total refrigeration. The calculation of the dehumidifying surface required may be effected by the use of the formula for heat transmission given in a Par. 91. Precaution must be taken in this calculation, however, to note that the convection resistances on each side of the surface must be taken into account, as the rate of heat transmission is greatly reduced on this account.

## AIR COOLING AND DEHUMIDIFYING WITH COOLING COILS

45 Calculation of the cooling effect of condensing coils for different velocities through the clear area and various temperature differences is fully discussed under the theory of convection in Par. 62 to 75. The same formulae may be applied in both cases.

46 Condensing coils give a much more rapid rate of conductivity per degree difference in temperature than steam coils, owing to the additional effect of condensation. This relationship however has

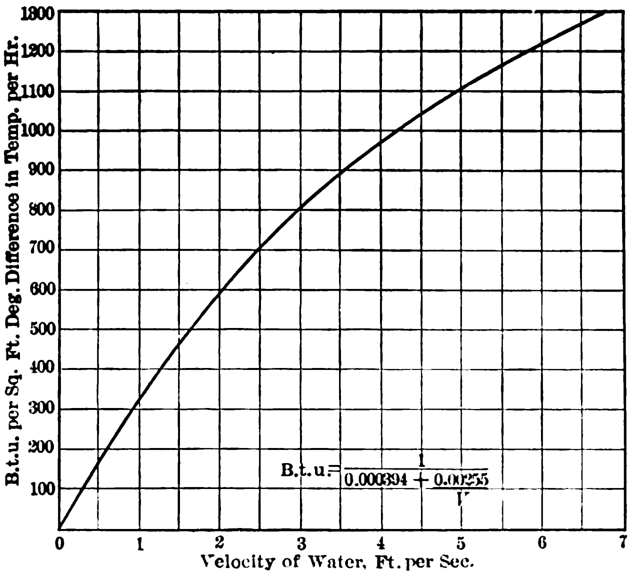



FIG. 28 HEAT TRANSMISSION FROM STEAM TO WATER

never before been investigated nor have there been any data previously available. The fact that the moisture contents of the air may be greatly reduced without leaving it saturated is explained and means for the accurate calculation of the moisture contents are given.

47 Where the air is simply cooled and no condensation takes place, the rate of heat transmission from cooling water to air is the exact inverse of the sum of the convection resistances of both the air and the water films.

48 We have the rate of heat conduction between steam and water approximately given by the curve shown in Fig. 28, as plotted by the

authors from condenser tests. This gives for the rate of conductivity for steam to water

$$K = \frac{1}{0.000394 + \dfrac{0.00255}{V}} \quad \ldots\ldots\ldots\ldots\ldots\ldots [7]$$

where $V$ = velocity in ft. per sec.

49 When $V_W$ = velocity of the water in feet per minute, the resistance through a conducting wall from steam to water is

$$R_\Sigma = \frac{1}{K_W} = 0.000394 + \frac{0.153}{V_W} \quad \ldots\ldots\ldots\ldots [8]$$

Of the constant factor, 0.000394, the resistance between the surface films, probably considerably less than one-half is due to the water film alone, or less than 0.0002. For heat transmission from steam to air we have, as shown later

$$K_A = \frac{1}{0.0447 \dfrac{\theta'_m}{625} + \dfrac{50.66}{V_o}} \quad \ldots\ldots\ldots\ldots\ldots\ldots [9]$$

where

$\theta'_m$ = mean absolute temperature of air film

$V_0$ = velocity through clear area (measured at 70 deg.)

50 Therefore we have for the convection resistance from steam to air

$$R_\Sigma = \frac{1}{K_A} = 0.0447 \frac{\theta'_m}{625} + \frac{50.66}{V_o} \quad \ldots\ldots\ldots\ldots [10]$$

51 If we take 60 deg. fahr. or 520 deg. absolute as a fair average mean temperature of the air film, we will have

$$R_\Sigma = \frac{1}{K_A} = 0.0373 + \frac{50.66}{V_o} \quad \ldots\ldots\ldots\ldots\ldots [11]$$

52 It is noticeable that the combined resistance of the steam and air films is 100 times as great as the resistance of the combined steam and water films, and hence very probably more than 200 times as great as the water film alone.

53 We may take as the entire convection resistance between air and water, when there is no condensation

$$R_{\Sigma}=\frac{1}{K_{W}}+\frac{1}{K_{A}}=0.0002+0.0373+\frac{0.153}{V_{W}}+\frac{50.66}{V_{o}}\quad\ldots.[12]$$

$$R_{\Sigma}=\frac{1}{K_{\Sigma}}=0.0375+\frac{0.153}{V_{W}}+\frac{50.66}{V_{o}}\quad\ldots\ldots\ldots\ldots[13]$$

where

$V_W$ = velocity of water through cooling pipes in ft. per min.

$V_0$ = velocity of air through minimum clear area between pipes in ft. per min.

54 The heat transmission then between air and water when no condensation occurs for any initial and final temperatures will then be, in B.t.u. per hour,

$$H=K_{\Sigma}D_{m}$$

$$H=\frac{(\theta_{A_1}-\theta_{W_1})-(\theta_{A_2}-\theta_{W_2})}{\left(0.0375+\frac{0.153}{V_{W}}+\frac{50.66}{V_{o}}\right)\log_{e}\left(\frac{\theta_{A_1}-\theta_{W_1}}{\theta_{A_2}-\theta_{W_2}}\right)}\quad\ldots\ldots[14]$$

When $D$ is the mean temperature difference between steam and air, $(\theta_{A_1}-\theta_{W_1})$ is the initial temperature difference between air and water. The final temperature difference between air and water is $(\theta_{A_2}-\theta_{W_2})$. (See Appendix No. 2.)

### RATE OF TRANSMISSION BETWEEN AIR AND WATER WHERE CONDENSATION OCCURS

55 Whenever the relation between the water temperature and the temperature of the air is such that the film temperature is below the dewpoint, then condensation will occur. The air in the surface film will always be saturated at the temperature of the surface film, while the main body of the air passing through the heater may be considerably above the saturation point, even after considerable moisture has been condensed out from it, the final state of the air being simply the result of a mixture of air saturated at the mean film temperature with the main body of the air. For proof of this, see the discussion of the laws of convection in Pars. 62 to 75.

56 Actual tests with condensing coils, as well as the theory, both indicate that the resistance of the surface film of the air and the temperature of the surface film are in no way affected by the condensation of moisture. However, the rate of convection from the water to the conducting wall is proportionately affected by the increased

amount of heat transmitted, on account of condensation. As the effect of the rate of convection from water to the conducting wall is relatively slight, it may be neglected in approximate calculations, and the cooling effect upon the air will be approximately the same as though no moisture were condensed. The rate of heat transmission in a surface dehumidifier will be increased in proportion to the amount of heat given up by condensation. Proper allowance must of course be made for the increased rise in water temperature.

57 The total rate of heat transfer may be calculated more accurately by taking into account the increased rate of transmission from the conducting wall to the air as follows:

$$H = \frac{(\theta_A - \theta_W) \text{ mean}}{(1+m) R_{\Sigma W} + R_{\Sigma A}} \text{ (see Appendix No. 4)} \ldots\ldots [15]$$

$$H = \frac{(\theta_A - \theta_W) \text{ mean}}{\left[(1+m)\frac{0.153}{V_W}\right] + \left[0.0375 + \frac{50.66}{V_o}\right]} \ldots\ldots [16]$$

$$H = \frac{(\theta_{A_1} - \theta_{W_1}) - (\theta_{A_2} - \theta_{W_2})}{\left[\frac{(1+m)0.153}{V_W} + 0.375 + \frac{50.66}{V_o}\right] \log_e \left(\frac{\theta_{A_1} - \theta_{W_1}}{\theta_{A_2} - \theta_{W_2}}\right)} \ldots\ldots [17]$$

where

$$m = \frac{\Delta \text{ (latent heat per lb. of air)}}{\Delta \text{ (sensible heat per lb. of air)}}$$

## MOISTURE CONTENT OF AIR LEAVING SURFACE DEHUMIDIFIER

58 As we have previously shown, air leaving the surface dehumidifier need not necessarily be saturated, even though the moisture content be considerably reduced. Let $\theta_{A_1}$ be the initial air temperature and $\theta_{A_2}$ be the final air temperature. Let $W_1$ be the initial weight of water in a pound of pure air, and $W_2$ be the final weight of water contained in 1 lb. of pure air. Let $\theta'_m$ be the mean temperature of the surface film, for calculation of which see Appendix No. 2. Let $W'_m$ be the weight of water contained in one pound of pure air saturated at the mean film temperature. Then we will have

$$\theta_2 = (1 - X)\theta_1 + X\theta'_m \ldots\ldots [18]$$

$$W_2 = (1 - X) W_1 + XW'_m \ldots\ldots [19]$$

Hence eliminating X we will have

$$\frac{W_1 - W_2}{\theta_1 - \theta_2} = \frac{W_1 - W'_m}{\theta_1 - \theta'_m} \quad \text{[20]}$$

$$W_2 = W_1 = \frac{(W_1 - W'_m)\ (\theta_1 - \theta_2)}{\theta_1 - \theta'_m} \quad \text{[21]}$$

## RATE OF HEAT TRANSMISSION IN INDIRECT SURFACE AIR HEATERS AND DEHUMIDIFIERS

59 An essential element in air-conditioning apparatus is the indirect radiation necessary to warm the air after saturation in the humidifier. In systems where the air is required for ventilation only, and the heating is effected by separate radiation, as in many of the larger installations, it is necessary to use indirect radiation only for the purpose of warming the air from the dewpoint temperature to approximately room temperature. In the majority of installations, however, the air is heated by means of indirect radiation to the point required to maintain the proper room temperature.

60 The temperature to which this conditioned air must be heated evidently depends on the outdoor temperature and upon the temperature difference to be maintained between the room and the dewpoint of the air supply, as required by the humidity control. On this account data pertaining to the proper design of such an indirect heating surface are of especial importance. These data are also applied in air conditioning to the design of surface coolers, dehumidifiers, and interchangers.

61 The factors of importance in such a design are the relation of free area to heating surface; the rate of heat transmission for various velocities through the clear area, and various temperature differences between the air and heating medium; and the resistance of the heater to the passage of air. The following experimental and mathematical investigation was conducted for the purpose of establishing these relationships, as very little authoritative information is at present available on this subject.

### THEORY OF CONVECTION WITH FORCED CIRCULATION

62 The accompanying diagram, Fig. 29, presents a graphical representation of the process of the heat transfer from steam to air through conducting wall. Experimental investigation leads us to

conclude that the exterior of the conducting wall is covered with a surface film into which heat passes directly from the conducting wall, and whose resistance to the passage of heat is independent of the velocity of the convecting medium; but it is a direct function of the density and specific heat of that medium.

63 The total resistance of the surface film of the steam, of the conducting wall, and of the surface film of the conducting medium, may therefore be represented by a constant $R$, which is independent of the temperature difference between the steam and the convecting medium, and of the velocity of the latter.

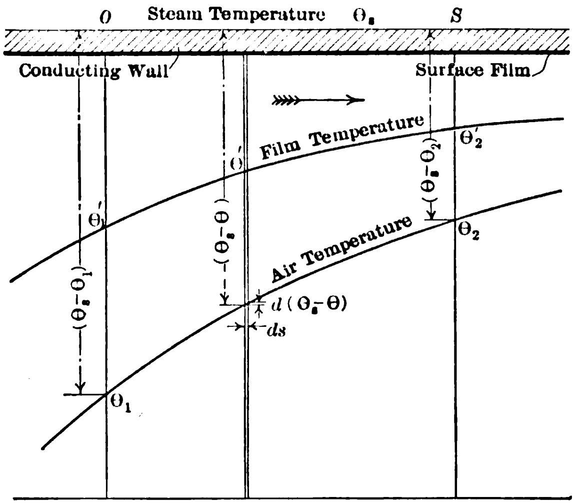



Fig. 29 Ideal Diagram illustrating the Theory of Heat Transmission

64 Experimental investigation also indicates that heat is transferred from the surface film to the main body of the convecting medium, that is to the air, entirely by displacement. Particles of air in the surface film are displaced by impact, due to the velocity of the air over the surface, and are thus mixed with the main body of the air. This displacement may be shown to be in direct proportion to the velocity. The rate of heat transfer from the surface film to the air is therefore directly proportional to the product of the velocity and temperature difference between the film and air.

65 Let $\theta_s$ represent the steam temperature, the distance $OS$ the extent of surface over which a unit of air passes progres-

sively. Let $\theta_1$ $\theta_2$ represent the progressive air temperatures with reference to the steam temperature $\theta_s$, and the line $\theta'_1 \theta'_2$ the corresponding surface film temperatures. Then $\theta_s - \theta$ represents the difference between air temperature and steam temperature at any instant, and $\theta s - \theta'$, the corresponding difference between the steam temperature and the film temperature.

66 The foregoing theory may then be stated mathematically as

$$\frac{dH}{dt} = \frac{1}{R}(\theta_s - \theta') \qquad [22]$$

where $\frac{dH}{dt}$ is the rate of transfer of heat per unit of surface through the resistance $R$ of the separating wall and surface films of steam and air. Assuming that this rate is proportional to the difference in temperature between the two films, from [22] we have

$$\theta^{1} = \theta_s - R\frac{dH}{dt} \qquad [23]$$

67 According to both theoretical considerations and experimental evidence $R$ probably varies inversely with the density of the air film. Hence with increased temperature of the surface film we would expect $R$ to be increased. This variation, however, for approximate calculations is negligible, although in exact calculations a correction must be made. This correction becomes important when the temperature range is great.

68 Assuming the number of particles from the surface film tobe directly proportional to the velocity, the rate of heat convection from the surface film is

$$\frac{dH}{dt} = \frac{C_p W V(\theta' - \theta)}{B} \qquad [24]$$

where $C_p$ is the specific heat of the air in the surface film, $W$ is the density of the air at the temperature $\theta_A$, $V$ the velocity in feet per minute through the clear area, and $B$ a constant to be determined experimentally, dependent upon the path of the air and upon the form and arrangement of the convecting surface.

69 From [24] we have

$$\theta' = \frac{B}{C_p W V}\frac{dH}{dt} + \theta \qquad [25]$$

Equating [23] and [25] we have

$$\left(\frac{B}{C_p WV} + R\right)\frac{dH}{dt} = \theta_s - \theta \text{ ..............[26]}$$

$$\frac{dH}{dt} = \frac{\theta_s - \theta}{R + \frac{B}{C_p WV}} \text{ ....................[27]}$$

70 Let $W_0$ and $V_0$ be the corresponding densities and velocities of the air at an absolute base temperature $\theta_0$ and let $\theta$ be the absolute temperature of the air corresponding to $W$ and $V$ then

$$WV = \left(\frac{W_0 \theta_0}{\theta}\right)\left(\frac{V_0 \theta}{\theta_0}\right) = W_0 V_0$$

Hence, substituting in [27] we have

$$\frac{dH}{dt} = \frac{\theta_s - \theta}{R + \frac{B}{C_p W_0 V_0}} \text{ ..................[28]}$$

which shows that the term $\frac{B}{C_p W_0 V^o}$ is unaffected by variation in temperature; and assuming $R$ constant, that $\frac{dH}{dt}$ is directly proportional to the difference in temperature between steam and air.

71 Therefore, let $K$ be the rate of transmission in B.t.u. per sq. ft. per hour per degree difference in temperature between the steam and air. Then

$$K = \frac{1}{R + \frac{B}{C_p W_0 V_0}} \text{ .....................[29]}$$

and

$$\frac{dH}{dt} = K(\theta_s - \theta) \text{ ....................[30]}$$

72 Let $H_s$ be the total heat transferred per hour from a surface $S$, then

$$H_s = K(\theta_s - \theta)S \text{ ....................[31]}$$

$$dH_s = K(\theta_s - \theta)dS \text{ ....................[32]}$$

Also

$$dH_s = -C_p G d(\theta_s - \theta) \text{ ................[33]}$$

where

$G$ = weight of air per hour passing over the surface $S$.

73 Equating [32] and [33] we have

$$K(\theta_s - \theta)\,dS = -C_pGd(\theta_s - \theta) \qquad [34]$$

Integrating between limits $(\theta_s - \theta_1)$ and $(\theta_s - \theta_2)$ and between $O$ and $S$, we have

$$\int_s^o KdS = -\int_{(\theta_s-\theta_2)}^{(\theta_s-\theta_1)} \frac{C_pGd(\theta_s - \theta)}{(\theta_s - \theta)} \qquad [35]$$

$$KS = C_pG \log_e \left(\frac{\theta_s - \theta_1}{\theta_s - \theta_2}\right) \qquad [36]$$

where

$A$ = clear area through heater having surface $S$
$V$ = velocity in ft. per min. through clear area
$W$ = density of air in lb. per cu. ft.

$$G = 60\ AWV = 60\ AW_oV_o$$

Hence

$$\log_e \left(\frac{\theta_s - \theta_1}{\theta_s - \theta_2}\right) = \frac{KS}{60C_pAW_oV_o} \qquad [37]$$

Changing this to common logarithms

$$\log \left(\frac{\theta_s - \theta_1}{\theta_s - \theta_2}\right) = \frac{KS}{(2.3026 \times 60)C_pAW_oV_o} \qquad [38]$$

74 From [29] we have

$$K = \frac{1}{R + \dfrac{B}{C_pW_oV_o}}$$

$$\log \left(\frac{\theta_s - \theta_1}{\theta_s - \theta_2}\right) = \frac{S}{(2.3026 \times 60)\,AC_pW_o\left(RV_o + \dfrac{B}{C_pW_o}\right)} \qquad [39]$$

$$= \frac{S}{(2.3026 \times 60)\ (RC_pQ + BA)} \qquad [40]$$

where $Q$ = cu. ft. of air per minute at standard temperature. This will also reduce to

$$\log \left(\frac{\theta_s - \theta_1}{\theta_s - \theta_2}\right) = \frac{f}{mV + n} \qquad [41]$$

where

$f=\frac{S}{A}$, $n$ is a constant, and $m$ is substantially a constant except as varied by change in the absolute temperature of the surface film.

## SURFACE FILM TEMPERATURE

75 From equation [23] we have for the surface film temperature

$$\theta' = \theta_s - R\frac{dH}{dt}$$

From equation [28]

$$\frac{dH}{dt} = \frac{\theta_s - \theta}{R + \frac{B}{C_p W_o V_o}}$$

Substituting this value in equation [23] we have

$$\theta' = \theta_s - R\left(\frac{\theta_s - \theta}{R + \frac{B}{C_p W_o V_o}}\right) \qquad [42]$$

Hence

$$\theta' = \theta_s - RK\,(\theta_s - \theta) \qquad [43]$$

and

$$R = \frac{1}{K}\left(\frac{\theta_s - \theta'}{\theta_s - \theta}\right) \qquad [44]$$

Also

$$\theta_s - \theta' = RK\,(\theta_s - \theta) \qquad [45]$$

i.e., the difference between the steam and film temperature is proportionate to the difference between the steam and air temperatures when $RK$ is constant, hence approximately so when $V_0$ is constant.

## EXPERIMENTAL DETERMINATION OF THE LAWS OF CONVECTION

76 We will now proceed to determine the constants in the foregoing equations and give the experimental evidence by which the above theory may be corroborated. Table 8 gives the observed and corrected results from ten heat transmission tests conducted upon

TABLE 8 LOG OF OBSERVED AND CORRECTED RESULTS FROM HEAT TRANSMISSION TESTS

| Test No. | 1 | | | 2 | | | 3 | | | 4 | | | 5 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Test Conditions | Reduced to Standard Conditions | Reduced to 8 Per Cent Correction Basis | Test Conditions | Reduced to Standard Conditions | Reduced to 8 Per Cent Correction Basis | Test Conditions | Reduced to Standard Conditions | Reduced to 8 Per Cent Correction Basis | Test Conditions | Reduced to Standard Conditions | Reduced to 8 Per Cent Correction Basis | Test Conditions | Reduced to Standard Conditions | Reduced to 8 Per Cent Correction Basis |
| Revolutions Per Minute | 80 | | | 120 | | | 160 | | | 200 | | | 240 | | |
| Barometer, In. | 29.46 | | | 29.40 | | | 29.45 | | | 29.47 | | | 29.43 | | |
| Velocity through Clear Area. Ft. per Min. | 335 | 276 | 254 | 453 | 375 | 345 | 594 | 499 | 459 | 738 | 626 | 576 | 950 | 805 | 741 |
| Initial Temperature of Air | 16.5 | 20.0 | | 20.0 | 20.0 | | 19.0 | 20.0 | | 16.5 | 20.0 | | 21.0 | 20.0 | |
| Final Temperature of Air | 174.4 | 183.4 | | 170.4 | 176.4 | | 162.5 | 167.6 | | 156.5 | 160.8 | | 155.0 | 157.1 | |
| Temperature Rise | 157.9 | 163.4 | | 150.4 | 156.4 | | 143.5 | 147.6 | | 140.0 | 140.8 | | 134.0 | 137.1 | |
| Total Air per Min. Cu. Ft. | 3440 | 2830 | 2604 | 4650 | 3850 | 3542 | 6100 | 5110 | 4702 | 7570 | 6420 | 5906 | 9750 | 8260 | 7600 |
| Total Air per Min. Lb. | 212 | 212 | 195 | 288 | 288 | 265 | 383 | 383 | 352 | 481 | 481 | 443 | 619 | 619 | 570 |
| Condensation per Section, Lb. per ½-Hr. Run 1st | 58.5 | 59.2 | | 66.4 | 68.3 | | 82.2 | 83.8 | | 97.0 | 97.8 | | 104.7 | 108.2 | |
| 2d | 45.3 | 46.2 | | 55.0 | 56.8 | | 69.7 | 71.5 | | 83.5 | 84.5 | | 91.4 | 94.3 | |
| 3d | 34.6 | 35.4 | | 43.4 | 45.0 | | 57.5 | 59.0 | | 69.2 | 70.1 | | 76.7 | 79.2 | |
| 4th | 28.6 | 29.4 | | 36.0 | 37.4 | | 49.1 | 50.5 | | 60.1 | 61.0 | | 66.3 | 68.6 | |
| 5th | 24.2 | 25.0 | | 30.9 | 32.2 | | 42.9 | 44.1 | | 53.1 | 54.0 | | 60.6 | 62.9 | |
| 6th | 17.3 | 18.0 | | 23.3 | 24.5 | | 33.8 | 35.0 | | 42.4 | 43.2 | | 49.9 | 51.9 | |
| 7th | 14.8 | 15.6 | | 19.6 | 20.7 | | 28.5 | 29.6 | | 36.1 | 36.9 | | 43.2 | 45.0 | |
| 8th | 12.2 | 12.7 | | 16.4 | 17.3 | | 24.1 | 25.0 | | 30.8 | 31.4 | | 37.6 | 39.1 | |
| Total Condensation ½ Hr. | | 241.5 | | | 302.2 | | | 398.5 | | | 478.9 | | | 549.2 | |
| Total Condensation 1 Hr. | | 483.0 | | | 604.4 | | | 797.0 | | | 957.8 | | | 1098.4 | |
| B.t.u. Delivered per Lb. of Condensation | | 977.0 | | | 979.4 | | | 982.3 | | | 979.0 | | | 976 1 | |
| B.t.u. per Sq. Ft. Heater per Hr. from the Steam | | 466.0 | | | 583.0 | | | 773.0 | | | 926.0 | | | 1058.0 | |
| B.t.u. per Sq. Ft. per Hr. absorbed by the Air | | 496.0 | 456 | | 644.0 | 592 | | 808.0 | 743 | | 967.0 | 890 | | 1214.0 | 1117.0 |

TABLE 8—Continued

| Test No. | 6 | | | 7 | | | 8 | | | 9 | | | 10 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Test Conditions | Reduced to Standard Conditions | Reduced to 8 Per Cent Correction Basis | Test Conditions | Reduced to Standard Conditions | Reduced to 8 Per Cent Correction Basis | Test Conditions | Reduced to Standard Conditions | Reduced to 8 Per Cent Correction Basis | Test Conditions | Reduced to Standard Conditions | Reduced to 8 Per Cent Correction Basis | Test Conditions | Reduced to Standard Conditions | Reduced to 8 Per cent Correction Basis |
| Revolutions Per Minute | 280 | | | 320 | | | 360 | | | 360 | | | 400 | | |
| Barometer, In. | 29.40 | | | 29.43 | | | 29.43 | | | 29.43 | | | 29.40 | | |
| Velocity through Clear Area, Ft. per Min. | 1067 | 911 | 838 | 1199 | 1027 | 945 | 1315 | 1135 | 1044 | 1345 | 1165 | 1072 | 1491 | 1286.0 | 1183 |
| Initial Temperature of Air | 20.5 | 20.0 | | 21.5 | 20.0 | | 20.6 | 20.0 | | 19.5 | 20.0 | | 19.8 | 20.0 | |
| Final Temperature of Air | 150.1 | 152.0 | | 148.6 | 149.8 | | 142.6 | 143.5 | | 143.6 | 145.4 | | 142.6 | 143.9 | |
| Temperature Rise | 129.6 | 132.0 | | 127.1 | 129.8 | | 122.0 | 123.5 | | 124.1 | 125.4 | | 122.8 | 123.9 | |
| Total Air per Min. — Cu. Ft. | 10950 | 9350 | 8602 | 12300 | 10520 | 9679 | 13500 | 11650 | 10720 | 13800 | 11950 | 10995 | 15300 | 13200.0 | 12145 |
| Total Air per Min. — Lb. | 701 | 701 | 645 | 789 | 789 | 726 | 873 | 873 | 803 | 895 | 895 | 823 | 989 | 989 | 910 |
| Condensation per Section, Lb. per ½-Hr. Run — 1st | 112.2 | 115.0 | | 130.6 | 134.5 | | 140.2 | 143.1 | | 136.2 | 139.1 | | 145.7 | 149.2 | |
| 2d | 107.0 | 110.0 | | 114.1 | 117.8 | | 113.0 | 116.0 | | 123.6 | 126.7 | | 135.1 | 138.6 | |
| 3d | 87.4 | 90.0 | | 97.6 | 101.0 | | 109.6 | 112.8 | | 107.1 | 109.8 | | 115.7 | 118.8 | |
| 4th | 76.9 | 79.3 | | 87.6 | 90.6 | | 99.1 | 102.0 | | 96.2 | 98.6 | | 103.8 | 106.4 | |
| 5th | 68.6 | 70.9 | | 78.1 | 80.8 | | 89.5 | 92.2 | | 86.5 | 88.7 | | 89.9 | 92.5 | |
| 6th | 57.4 | 59.4 | | 64.4 | 66.7 | | 74.1 | 76.4 | | 72.7 | 74.7 | | 80.1 | 82.5 | |
| 7th | 50.2 | 50.0 | | 57.5 | 59.7 | | 66.9 | 69.0 | | 66.1 | 68.0 | | 73.4 | 75.6 | |
| 8th | 43.6 | 45.2 | | 50.7 | 52.5 | | 59.9 | 61.8 | | 58.6 | 60.2 | | 64.1 | 66.0 | |
| Total Condensation — ½ Hr. | | 621.8 | | | 703.6 | | | 773.3 | | | 765.8 | | | 829.6 | |
| Total Condensation — 1 Hr. | | 1243.6 | | | 1407.2 | | | 1546.6 | | | 1531.6 | | | 1659.2 | |
| B.t.u. Delivered per Lb. of Condensation | | 977.1 | | | 968.9 | | | 972.2 | | | 970.3 | | | 975.1 | |
| B.t.u. per Sq. Ft. Heater per Hr. from the Steam | | 1200.0 | | | 1345.0 | | | 1483.0 | | | 1470.0 | | | 1595.0 | |
| B.t.u. per Sq. Ft. per Hr. absorbed by the Air | | 1322.0 | 1216 | | 1466.0 | 1349 | | 1546.0 | 1422 | | 1606 | 1477 | | 1753.0 | 1613 |

eight sections of fan system heaters each section being composed of four rows of 1-in. wrought-iron pipe, making a total depth of 32 rows of pipe. Details of the heater construction are shown in Fig. 30. For complete description of tests and corrections applied see Appendix No. 1.

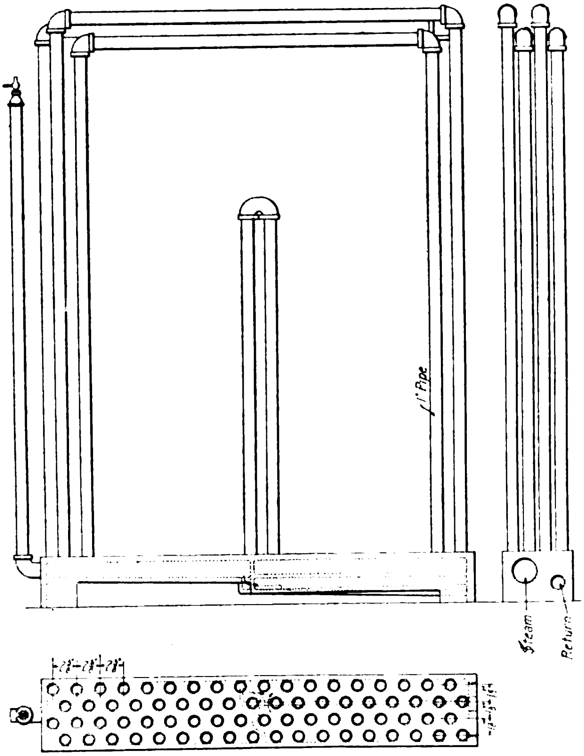



Fig. 30 Detail of Heater Construction

77 Curves shown in Fig. 31 are plotted from the values given in column 2 of each test in Table 8, which give air velocities through the clear area based on actual air measurements corrected to corresponding volume at 70 deg. fahr. and 29.92 in. barometric pressure. The lower curve gives the rate of heat transmission as determined from the condensation. The upper curve gives the corresponding values as determined from observed air measurements. These two curves show a uniform discrepancy of approximately 8 per cent, as indicated in Fig. 32. As both the temperature and condensation measurements

were made with considerable care, and since the per cent of error is substantially uniform at all velocities, it is evident that a systematic error was made of 8 per cent in the measurement of the air volume. This may be accounted for in large measure by the fact that no allowance was made for the coefficient of the discharge orifice. Accord-

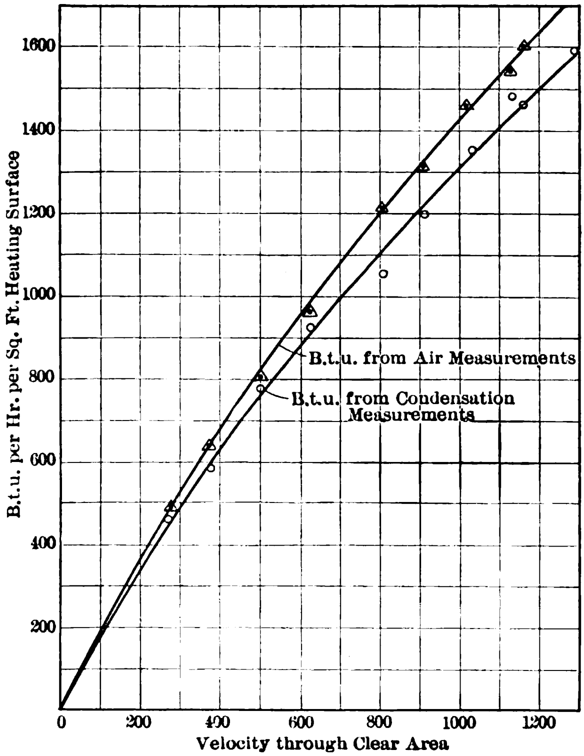



Fig. 31 Effect of Velocity upon Rate of Transmission from Original Air Measurements

ingly both the rate of transmission from the air measurements and the corresponding velocities have each been reduced 8 per cent.

78 From these corrected values and from the condensation, the combined curve shown in Fig. 33 has been plotted, showing a remarkably close agreement of both values, thus thoroughly establishing the true form of the curve.

## COEFFICIENT OF TRANSMISSION

79 From the above data we may calculate $K$, that is the rate of transmission per square foot per degree difference in temperature at the various velocities, providing we may assume, as in the foregoing theory, that the rate of transmission at any instant is proportionate to the temperature difference between the steam and air. To establish this relationship Table 9, containing the corrected test data on the individual sections, is given, and also Fig. 34 in which the transmission curves are plotted from the values in Table 9. These curves have been derived through the well-known systems of fairing,

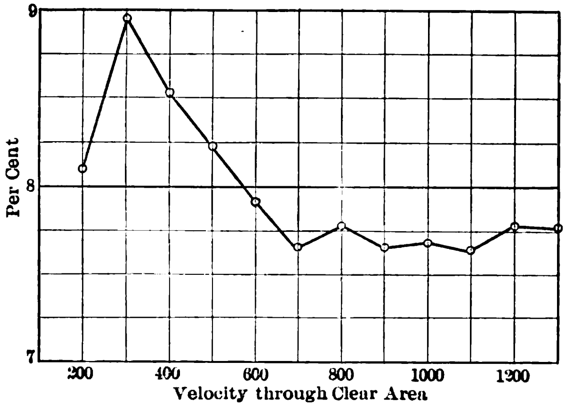



FIG. 32 PERCENTAGE OF ERROR IN AIR MEASUREMENTS AS COMPARED WITH CONDENSATION

and of cross and increment plotting, until they represent the most probable relationships to be determined experimentally.

80 From Fig. 34 the B.t.u. values given in the second column of Table 10 have been taken. Values exhibited here are taken at a velocity of 1000 ft. per min. through the clear area. While comparisons are given here for only one velocity, it should be understood that the same comparisons have been made at other velocities. Column 3 gives the temperature rise in each consecutive section, as computed from the experimental rate of transmission given in column 2, this relationship being expressed by the formula

$$\theta_2 - \theta_1 = \frac{H'S}{60\,C_p A W_o V_o}$$

where $H'$ = B.t.u. per hr. per sq. ft. The fourth column gives the computed temperature leaving the consecutive sections. From column 4, columns 5 and 6 are computed. Column 7 gives the ratio of the initial temperature difference between steam and air to the final temperature difference between the steam and air, for each consecutive section. From this comparison it will be seen that this ratio $\frac{\theta_s - \theta_1}{\theta_s - \theta_2}$ is substantially constant in all sections, for any one velocity, regardless of the variation in the entering temperature. If the rate of transmission per degree difference in temperature between steam and air was absolutely constant at any one velocity, it could be shown from equation [38] that the ratio of $\frac{\theta_s - \theta_1}{\theta_s - \theta_2}$ for any section as well as $\log \frac{\theta_s - \theta_1}{\theta_s - \theta_2}$ would also be absolutely constant, and conversely.

TABLE 9 B.T.U. PER SQ. FT. OF SURFACE PER HR., CALCULATED FROM CONDENSATION

| Section Number | Revolutions Per Minute | | | | | | | | | |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| | 80 | 120 | 160 | 200 | 240 | 280 | 320 | 360 | 360 | 400 |
| | Observed Velocities Corrected to Standard Conditions and Reduced 8 Per cent | | | | | | | | | |
| | 254 | 345 | 459 | 576 | 741 | 838 | 945 | 1044 | 1072 | 1193 |
| 1 | 912 | 1060 | 1278 | 1518 | 1670 | 1780 | 2029 | 2205 | 2130 | 2300 |
| 2 | 713 | 880 | 1110 | 1311 | 1458 | 1705 | 1800 | 1785 | 1938 | 2135 |
| 3 | 546 | 697 | 915 | 1089 | 1224 | 1397 | 1545 | 1735 | 1680 | 1830 |
| 4 | 453 | 579 | 783 | 944 | 1060 | 1229 | 1387 | 1570 | 1510 | 1640 |
| 5 | 386 | 499 | 685 | 836 | 971 | 1099 | 1238 | 1420 | 1358 | 1425 |
| 6 | 268 | 379 | 544 | 669 | 801 | 918 | 1020 | 1178 | 1143 | 1271 |
| 7 | 241 | 321 | 460 | 571 | 695 | 805 | 911 | 1063 | 1040 | 1165 |
| 8 | 196 | 267 | 388 | 486 | 604 | 700 | 801 | 950 | 920 | 1018 |

81 It will be seen, however, from column 8, that $\log \frac{\theta_s - \theta_1}{\theta_s - \theta_2}$ decreased regularly from the first to the last section. Column 9 gives the absolute film temperature as calculated from formula [43]. From this it will be seen that $\log \frac{\theta_s - \theta_1}{\theta_s - \theta_2}$, while varying inversely with the absolute film temperature, varies at a much less rapid rate. Column 12 gives the value of $K$, the factor of transmission, as calculated from the values in column 8 according to formula [36]. From the experimental constants, determined in the manner to be de-

scribed later, we are able to calculate the variations in the value of $R$, (according to formula [29]) as shown in column 13, from the values of $K$ as determined from the tests. In column 10 the variations in $R$ have been calculated on the assumption that the film resistance is directly proportional to the absolute film temperature. The sub-

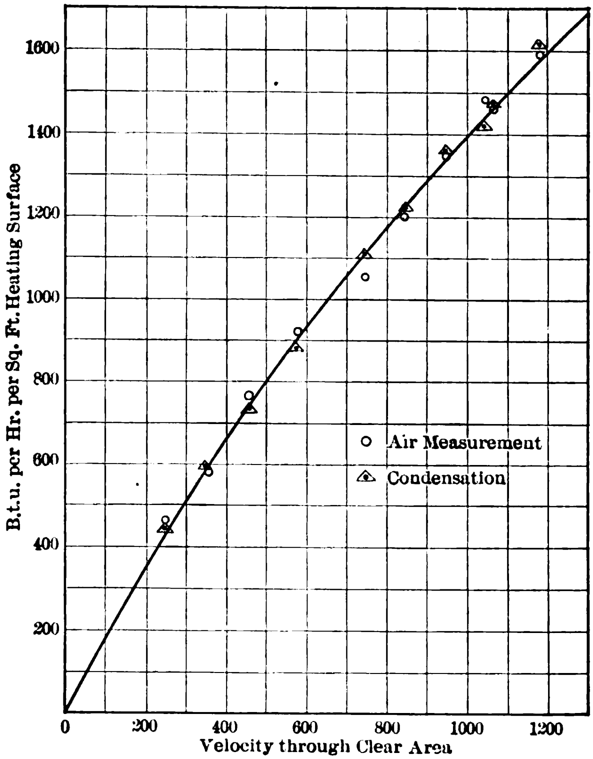



FIG. 33 COMBINED CURVE SHOWING RATE OF TRANSMISSION FROM CONDENSATION AND AIR MEASUREMENT CORRECTED FOR 8 PER CENT ERROR IN AIR MEASUREMENTS

stantial agreement of the values thus calculated, with the values of $R$ in column 13, as calculated from the tests, is thus conclusively demonstrated. In column 11 the value of $K$ has been calculated from formula [29], using the values of $R$ as calculated from the film temperature. The close agreement of these values of $K$ as calculated from the formula may be shown by comparison with the values of $K$ as determined from tests in column 12.

82 The same substantial agreement having been verified at other velocities, we are warranted in asserting that the value of $R$ varies directly as the calculated absolute film temperature, where $R$ is the resistance of the surface film to the transmission of heat. The value of $R$ as used in these calculations includes not only the resistance of the surface film of air, but also the surface film of steam and of the conducting wall. However, as has been proven by experiments in heat transmission from steam to water (see Fig. 28), this resistance is less than one per cent of the resistance of the air film. Therefore

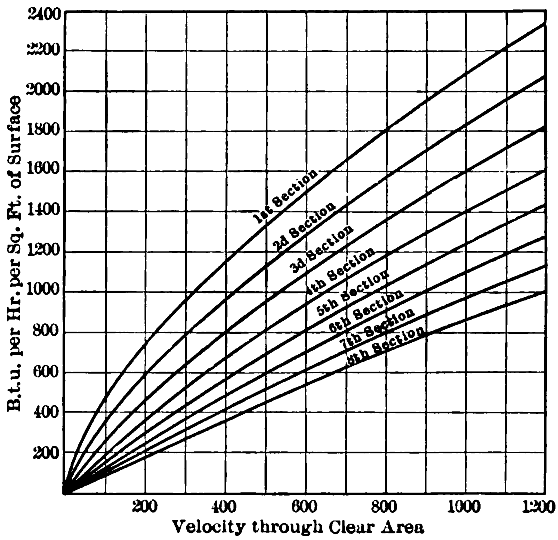



FIG. 34 RATE OF TRANSMISSION IN CONSECUTIVE SECTIONS OF HEATER AT VARIOUS VELOCITIES

we may take the entire resistance $R$ as varying directly as the absolute film temperature, with negligible error.

DETERMINATION OF THE VALUES $R$ AND $B$

83 As shown in the preceding paragraph, the absolute values of $R$ are dependent upon the film temperature, but in order to calculate this film temperature we must first know the approximate values of both $R$ and $K$. These values were first determined approximately for different velocities by assuming $R$ to be constant, that is $K$ to be constant, for any fixed velocity. $K$ may then be calculated directly from the values in Fig. 33 by means of equation [36], in which

$$K=\frac{C_pG}{S}\log_e\left(\frac{\theta_s-\theta_1}{\theta_s-\theta_2}\right)\quad\ldots\ldots\ldots\ldots\ldots\ldots[46]$$

where

$C_p$ = the specific heat of air

$G$ = the weight of air in lb. per hour passed through the heater

$S$ = the total sq. ft. of heating surface

84 From equation [29] we have

$$K=\frac{1}{R+\dfrac{B}{C_pW_oV_o}}$$

TABLE 10 SHOWING THE FILM RESISTANCE $R$ TO VARY AS THE ABSOLUTE FILM TEMPERATURE

VELOCITY THROUGH CLEAR AREA 1000 FT. PER MIN. $\theta_S$ = 227 DEG. FAHR. $\theta_1$ = 20 Deg. Fahr.

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Number of Section | B.t.u. per Sq. Ft. per Section | Temperature Rise per Section | Temperature of Air Leaving Section | Average Absolute Temperature in Each Section $\theta_A$ | Final Temperature Difference $\theta_S-\theta_2$ | Ratio of Leaving to Entering Temperature Difference $\frac{\theta_S-\theta_2}{\theta_S-\theta_1}$ | $\log\frac{\theta_S+\theta_1}{\theta_S-\theta_2}$ | Absolute Film Temperature $\theta'$ | $R$ Calculated from Film Temperature | $K$ Calculated from Formula | $K$ from Test | $R$ Calculated from Test |
| 1 | 2092 | 23.75 | 43.75 | 491.88 | 183.25 | 0.88528 | 0.05292 | 596.60 | 0.04267 | 10.72 | 10.74 | 0.04250 |
| 2 | 1838 | 20.88 | 64.63 | 535.07 | 162.37 | 0.88605 | 0.05254 | 615.78 | 0.04404 | 10.56 | 10.64 | 0.04333 |
| 3 | 1614 | 18.32 | 82.95 | 552.10 | 144.05 | 0.88725 | 0.05195 | 623.77 | 0.04461 | 10.55 | 10.55 | 0.04414 |
| 4 | 1418 | 16.10 | 99.05 | 567.10 | 127.95 | 0.88830 | 0.05144 | 630.79 | 0.04611 | 10.44 | 10.52 | 0.04438 |
| 5 | 1249 | 14.18 | 113.23 | 580.32 | 113.77 | 0.88910 | 0.05105 | 636.99 | 0.04555 | 10.39 | 10.36 | 0.04587 |
| 6 | 1104 | 12.53 | 125.76 | 592.03 | 101.24 | 0.88920 | 0.05100 | 642.48 | 0.04595 | 10.35 | 10.38 | 0.04565 |
| 7 | 981 | 11.14 | 136.90 | 602.47 | 90.10 | 0.89000 | 0.05061 | 647.37 | 0.04630 | 10.32 | 10.27 | 0.04668 |
| 8 | 878 | 9.97 | 146.87 | 611.86 | 80.13 | 0.88935 | 0.05093 | 651.77 | 0.04661 | 10.29 | 10.33 | 0.04615 |

from which we may deduce the resistance formula

$$\frac{1}{K}=R+\left(\frac{B}{C_pW_o}\right)\frac{1}{V_o}\quad\ldots\ldots\ldots\ldots\ldots\ldots[47]$$

in which $R$ is assumed to be a constant, $B$ is a constant to be determined, $C_pW_o$ is a known constant, $\frac{1}{V_o}$ is a known variable, and $\frac{1}{K}$ is the reciprocal of $K$ as calculated above, in equation [46].

85 By inspecting equation [47] we see that, if $R$ is assumed to be a constant, this is a straight line relationship. Therefore the approxi-

mate values of $R$ and $\frac{B}{C_p W_o}$ may be determined from the equation of a straight line drawn through the values of $\frac{1}{K}$ plotted to the corresponding values of $\frac{1}{V_o}$. Having determined the values in this manner we may now determine approximately the values of the mean absolute film temperatures at the different velocities using the average rates of transmission as shown in Fig. 33.

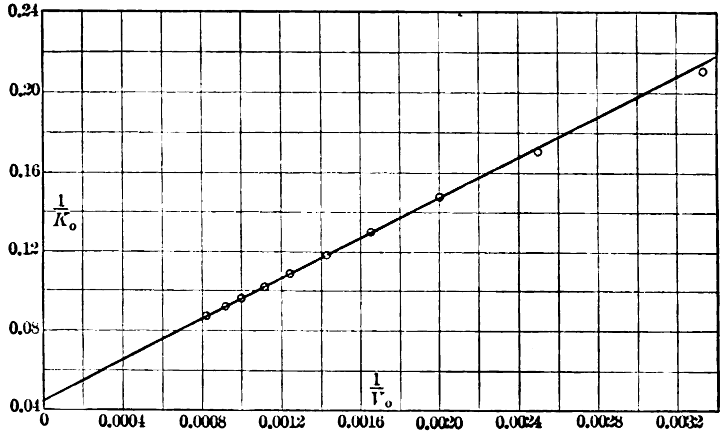



FIG. 35 CURVE SHOWING DERIVATION OF CONSTANTS IN RATIONAL CONVECTION FORMULA

$$\frac{1}{K_o} = R_o + \left(\frac{B}{C_p W_o}\right)\left(\frac{1}{V_o}\right) \quad \text{or} \quad K = \frac{1}{R_o + \frac{B}{C_p W_o V_o}}$$

86 The mean absolute film temperature may be determined by the formula

$$\theta'_m = \theta_s - RK(\theta_s - \theta)_m = \theta_s - RK \frac{(\theta_2 - \theta_1)}{\log_e \left(\frac{\theta_s - \theta_1}{\theta_s - \theta_2}\right)} \quad \ldots\ldots [48]$$

for the derivation of which see Appendix No. 2, where

$\theta'_m$ = mean absolute film temperature

$(\theta_s - \theta)_m$ = mean temperature difference between the steam and air

87 For eight sections of heater with the velocity of the air through the clear area of the heater, measured at 70 deg. fahr. at 1000 ft. per minute, we find a mean absolute film temperature of approximately

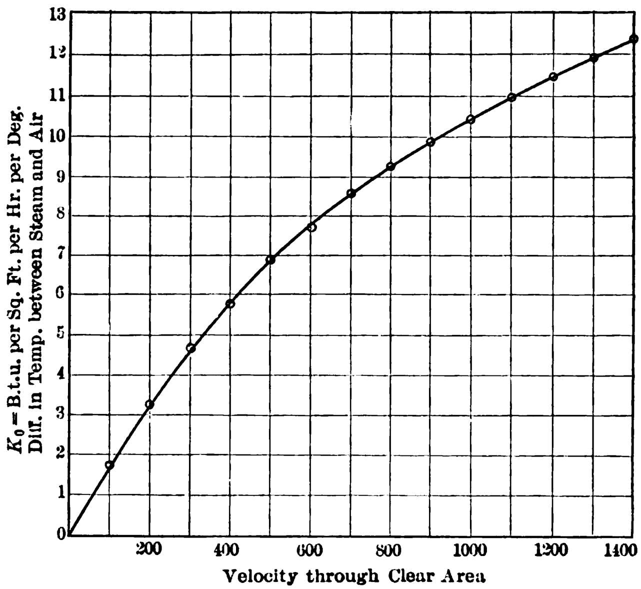



FIG. 36 RATE OF HEAT TRANSMISSION FOR VARIOUS VELOCITIES, VALUES OF $K_0$ FROM TEST CORRECTED TO FILM TEMPERATURE OF 625 DEG.

TABLE 11 COEFFICIENTS OF HEAT TRANSMISSION AT VARIOUS VELOCITIES

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $V$ | $\frac{1}{V}$ | $\frac{H}{S}$ = B.t.u. per Sq. Ft. | $\theta_2-\theta_1 = \frac{8\times\frac{H}{S}}{\frac{A\times 60\times V}{55.22\times S}}$ | $\theta_S-\theta_2$ | $K$ | $\frac{1}{K}$ | $(\theta_S-\theta)m$ | $K(\theta_S-\theta)m$ | $K$ | $\frac{1}{K_O}=\frac{1}{K}-K$ | $K_O$ from Test | $K_O$ Calculated from Formula |
| 200 | 0.0050 | 355 | 160.8 | 46.2 | 3.316 | 0.3015 | 107.0 | 355 | 0.00331 | 0.29819 | 3.354 | 3.356 |
| 300 | 0.00333 | 518 | 156.5 | 50.5 | 4.674 | 0.2140 | 111.0 | 520 | 0.00279 | 0.21121 | 4.735 | 4.689 |
| 400 | 0.0025 | 667 | 151.1 | 55.9 | 5.788 | 0.1730 | 115.4 | 667 | 0.002295 | 0.17071 | 5.858 | 5.838 |
| 500 | 0.0020 | 805 | 145.9 | 61.1 | 6.743 | 0.1480 | 119.6 | 806 | 0.001815 | 0.14619 | 6.841 | 6.845 |
| 600 | 0.001667 | 936 | 141.3 | 65.7 | 7.614 | 0.1310 | 123.0 | 933 | 0.00143 | 0.12957 | 7.718 | 7.746 |
| 700 | 0.00143 | 1060 | 137.2 | 69.8 | 8.412 | 0.1190 | 126.5 | 1067 | 0.001012 | 0.11799 | 8.476 | 8.540 |
| 800 | 0.00125 | 1178 | 133.4 | 73.6 | 9.146 | 0.1093 | 129.0 | 1180 | 0.000639 | 0.10866 | 9.204 | 9.251 |
| 900 | 0.00111 | 1290 | 129.9 | 77.2 | 9.823 | 0.1018 | 131.3 | 1290 | 0.000279 | 0.10152 | 9.850 | 9.896 |
| 1000 | 0.00100 | 1398 | 126.7 | 80.3 | 10.465 | 0.0956 | 133.5 | 1397 | −0.0000585 | 0.09566 | 10.455 | 10.490 |
| 1100 | 0.000909 | 1500 | 123.5 | 83.5 | 11.040 | 0.0905 | 136.0 | 1507 | −0.000418 | 0.09092 | 11.000 | 10.920 |
| 1200 | 0.000833 | 1599 | 120.8 | 86.3 | 11.610 | 0.0861 | 137.7 | 1600 | −0.000936 | 0.08704 | 11.490 | 11.400 |

625 deg. Therefore we have calculated the value of $R_o$ and all values of $K_o$ at different velocities for this assumed standard of film temperature. Having calculated the average values of $K$ for eight sections of heater and different velocities as described in the preceding paragraph, we may determine the value of $K_o$ for a film temperature of 625 deg. from the formula

$$K_o = K\left[1 + K_o R_o \left(\frac{\theta'_m - 625}{625}\right)\right] \qquad [49]$$

for derivation of which see Appendix No. 3.

88 These values as calculated from the tests are shown in column 12 of Table 11. In this table

$$X = R_o \left(\frac{\theta'_m - 625}{625}\right)$$

We now have the rates of transmission for different velocities corrected to a standard absolute film temperature of 625 deg. Therefore, if our theoretical relationships hold true

$$\frac{1}{K_o} = R_o + \left(\frac{B}{C_p W_o}\right)\frac{1}{V_o}$$

is the equation of a straight line, in which $R_o$ is the intercept at $\frac{1}{V_o} = 0$ and $\frac{B}{C_p W_o}$ is the slope. The plot of these values for different velocities as determined from the test curve Fig. 33 is shown in Fig. 35. It will be noticed from an inspection of Fig. 35 that these points do lie, with remarkable accuracy, in a straight line, thus showing the agreement of the test results with the rational formula

$$K_o = \frac{1}{R_o + \frac{B}{C_p W_o V_o}}$$

89 Substituting numerical values obtained from this plot we have

$$\frac{1}{K_o} = 0.0447 + \frac{50.66}{V_o} \qquad [50]$$

Hence

$$K_o = \frac{1}{0.0447 + \frac{50.66}{V_o}} \qquad [51]$$

Column 13, Table 11, shows the value of $K_o$ calculated from above formula, which may be compared with the values of $K_o$ calculated from test and given in column 12.

90 Fig. 36 gives the value of $K_o$ for different velocities, the curve being plotted from the formula and the points shown being the values determined directly from the test.

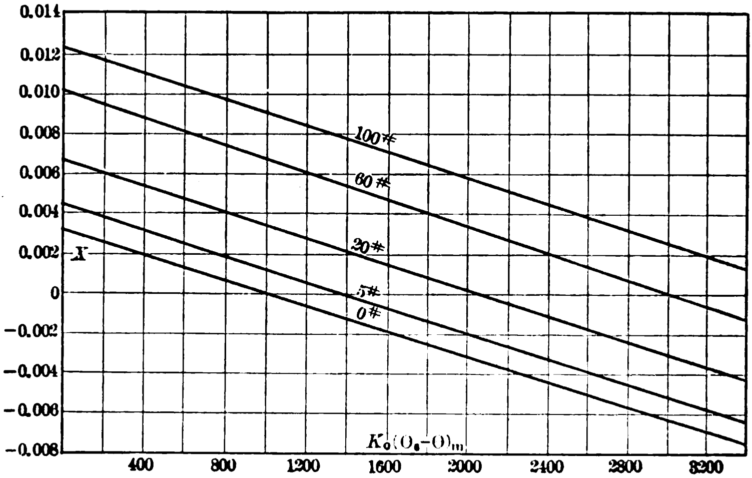



FIG. 37 RELATION BETWEEN $K_0(\theta_s - \theta)_m$ AND X AT DIFFERENT STEAM PRESSURES

## RATIONAL FORMULA FOR HEAT TRANSMISSION

91 We may now insert the above numerical values given in equation [51] in the rational formulae [38] to [41]. Substituting in equation [40] we have

$$\log_{10}\left(\frac{\theta_s - \theta_1}{\theta_s - \theta_2}\right) = \frac{S}{0.1119Q + 127A} \quad \text{[52]}$$

Substituting proper values in equation [41] we have

$$\log_{10}\left(\frac{\theta_s - \theta_1}{\theta_s - \theta_2}\right) = \frac{f}{0.1119\,V + 127} \quad \text{[53]}$$

also

$$\log_{10}\left(\frac{\theta_s - \theta_1}{\theta_s - \theta_2}\right) = \frac{0.3994fK}{V} \quad \text{[54]}$$

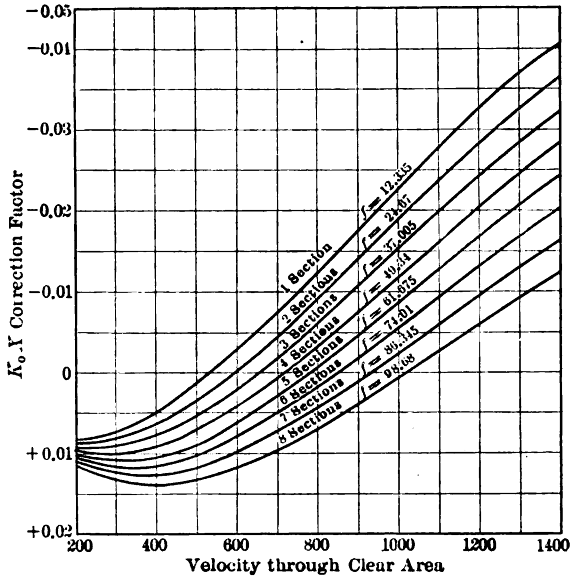



FIG. 38 CORRECTION FACTORS FOR COEFFICIENT OF HEAT TRANSMISSION

$$K = \frac{K_o}{1 + K_o X} \qquad \theta_s = 227 \text{ deg. fahr.} \qquad \theta_1 = 20 \text{ deg. fahr.}$$

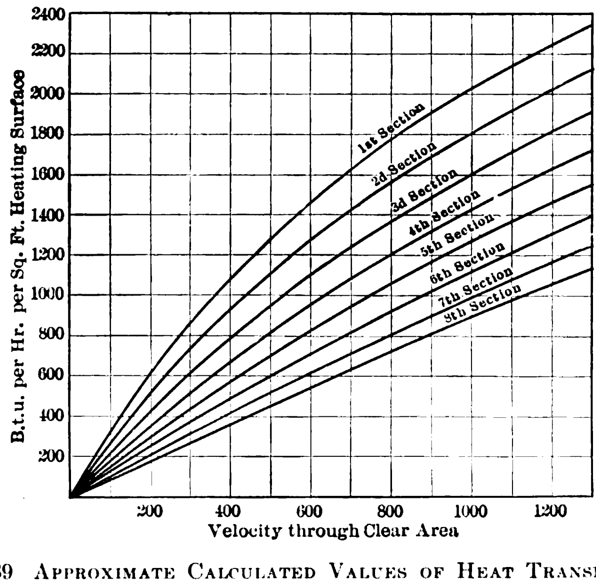



FIG. 39 APPROXIMATE CALCULATED VALUES OF HEAT TRANSMISSION

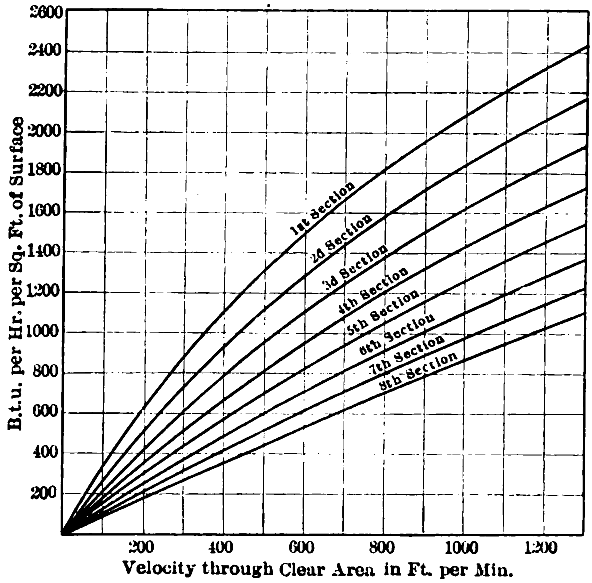



FIG. 40 CORRECTED CALCULATED VALUES OF HEAT TRANSMISSION

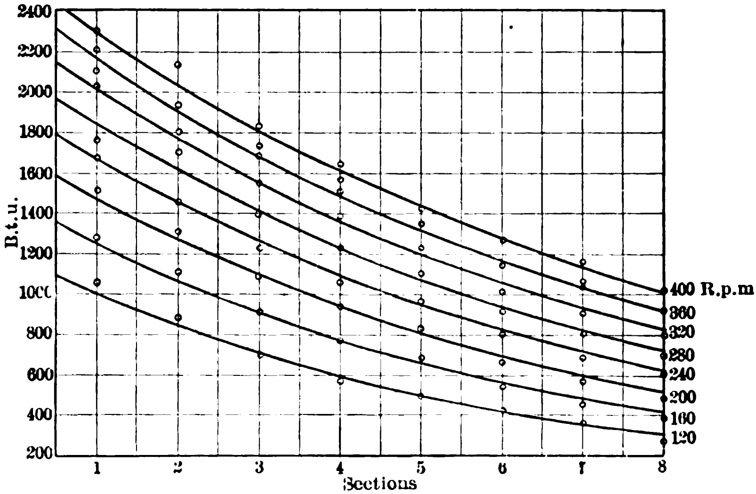



FIG. 41 COMPARISON OF CALCULATED VALUES WITH TEST RESULTS. LINES REPRESENT CALCULATED VALUES; POINTS REPRESENT TEST RESULTS

where

$\theta_s$ = steam temperature
$\theta_1$ = entering air temperature
$\theta_2$ = final air temperature
$f=\frac{S}{A}$ = ratio of total surface to clear area
$V$ = the velocity of air through clear area (at 70 deg.) in ft. per min.
$Q$ = cu. ft. air at 70 deg. fahr.

TABLE 12 CALCULATIONS FOR CORRECT VALUES OF FINAL TEMPERATURES AND HEAT TRANSMISSION

VELOCITY THROUGH CLEAR AREA 1000 FT. PER MIN. $\theta_S$=227 DEG. FAHR. $\theta_1$=20 DEG. FAHR.

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Number of Section | $f$ | Log of Approximate $\frac{\theta_S-\theta_1}{\theta_S-\theta_2}$ | $K_o X$ from Curve | $\frac{\text{Log}\frac{\theta_S-\theta_1}{\theta_S-\theta_2}}{1+K_o X}$ | $\frac{\theta_S-\theta_1}{\theta_S-\theta_2}$ Corrected | $\theta_S-\theta_2$ | Final Temperature | Total Temperature Rise | Average B.t.u. per Sq. Ft., Total | Temperature Increment in Section | Average B.t.u. per Sq. Ft. per Section |
| 1 | 12.335 | 0.05167 | −0.0224 | 0.05285 | 1.130 | 183.20 | 43.80 | 23.80 | 2096.4 | 23.80 | 2096.5 |
| 2 | 24.67 | 0.10334 | −0.0188 | 0.10534 | 1.2745 | 162.42 | 64.58 | 44.58 | 1963.5 | 20.78 | 1830.4 |
| 3 | 37.005 | 0.15501 | −0.0152 | 0.15739 | 1.4368 | 144.07 | 82.93 | 62.93 | 1840.8 | 18.35 | 1616.3 |
| 4 | 49.34 | 0.20668 | −0.0115 | 0.20909 | 1.6174 | 127.98 | 99.02 | 79.02 | 1740.0 | 16.09 | 1417.2 |
| 5 | 61.675 | 0.25835 | −0.0084 | 0.26052 | 1.8220 | 113.61 | 113.39 | 93.39 | 1645.5 | 14.37 | 1265.8 |
| 6 | 74.01 | 0.31002 | −0.00533 | 0.31168 | 2.0497 | 101.00 | 126.00 | 106.00 | 1556.0 | 12.61 | 1110.8 |
| 7 | 86.345 | 0.36169 | −0.00225 | 0.36250 | 2.304 | 89.85 | 137.15 | 117.15 | 1474.2 | 11.15 | 982.2 |
| 8 | 98.68 | 0.41336 | +0.00084 | 0.41301 | 2.5883 | 79.98 | 147.02 | 127.02 | 1398.5 | 9.87 | 869.4 |

92 The above formulae are correct for a mean film temperature of 625 deg. absolute. For approximate results, these formulae can be used without corrections. For more accurate results the factor 0.1119 must be corrected for the calculated absolute film temperature in each case. The full formula embodying this correction, where extreme accuracy is desired, is

$$f=(0.0001791V_o\theta_s+126.8)\cdot\log\left(\frac{\theta_s-\theta_1}{\theta_s-\theta_2}\right)-\frac{0.000003474\,V_o^2(\theta_s-\theta_1)}{0.0447\,V_o+50.66}\;.[55]$$

which can only be solved for $f$ when the initial and final temperature of the air are known. For ordinary calculations where we wish to solve for the initial and final temperatures where $f$ and $V$ are known, we first determine approximate values of $\theta_1$ and $\theta_2$ from equation [53]. We then solve for the mean temperature difference between

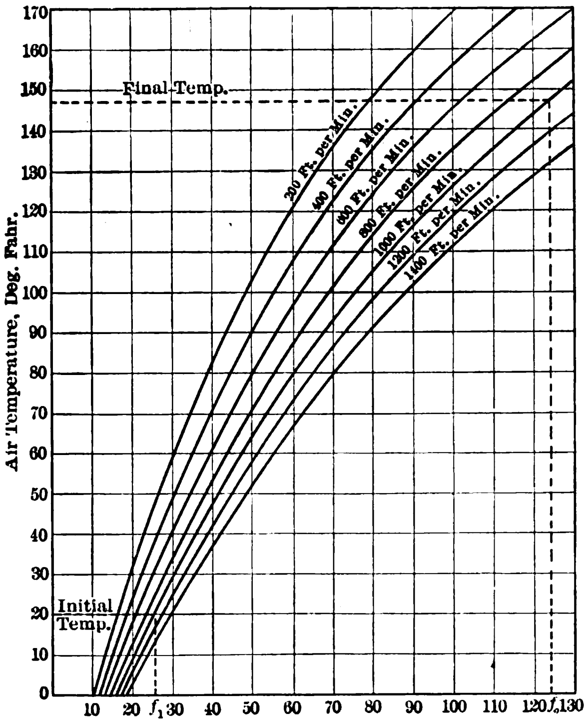



FIG. 42 RELATION BETWEEN HEATER SURFACE AND TEMPERATURES OF THE AIR AT VARIOUS VELOCITIES FOR WROUGHT-IRON PIPE HEATERS. STEAM PRESSURE = 5 LB.; STEAM TEMPERATURE = 227 DEG. FAHR.; AIR VELOCITY MEASURED AT 70 DEG. FAHR.

$$f = \frac{\text{total surface, sq. ft.}}{\text{clear area, sq. ft.}}$$

or

$$f = (0.000179\,V_0\theta_s + 126.8)\log\frac{\theta_s - \theta_1}{\theta_s - \theta_2} - (0.000003474\,V_0 K_0)(\theta_2 - \theta_1)$$

steam and air, using the above determined values of $\theta_1$ and $\theta_2$ in the formula

$$(\theta_s - \theta)_m = \frac{0.434\,(\theta_2 - \theta_1)}{\log_{10}\left(\frac{\theta_s - \theta_1}{\theta_s - \theta_2}\right)} \text{ (see Appendix No. 2) } \ldots\ldots\ldots [56]$$

93 Having determined $(\theta_s - \theta)_m$ we may then determine the value of X from the formula

$$X = 0.000071520\theta_s - 0.0447 - 0.0000032\, K_o\, (\theta_s - \theta)_m \ldots . [57]$$

or from Fig. 37 giving the values of X for the various values of $K_o(\theta_s - \theta)_m$. The correct value for $\theta_2$ will be given by the equation

$$\log \left(\frac{\theta_s - \theta_1}{\theta_s - \theta_2}\right) = \frac{0.3994\, f K_o}{V(1 + K_o X)} \text{ (see Appendix No. 3)} \ldots\ldots [58]$$

To simplify this correction for a series of calculations, curves may be constructed for the correction factor as shown in Fig. 38.

94 An example of such a calculation is given in Table 12. This should be compared with the results from tests given in Table 10, for the same conditions. Comparison of the following corresponding columns in each table is of interest:

| | TABLE 10 | | TABLE 12 |
|---|---|---|---|
| | Test Values | | Calculated Values |
| Compare column | 2 | with | 12 |
| Compare column | 3 | with | 11 |
| Compare column | 4 | with | 8 |
| Compare column | 6 | with | 7 |

95 Fig. 39 shows the approximate calculated values of heat transmission in the individual sections at various velocities, without correction for film temperature. Fig. 40 shows the same values corrected for film temperature. It is interesting to compare these results with Fig. 34, in which the corresponding test values are given. The agreement of the actual test results with the corresponding calculated values is still more strikingly shown in Fig. 41, in which the curves are accurately drawn in accordance with the corrected formula, while the plotted points represent the actual test values given in Table 8.

96 Fig. 42 shows graphically the relation between the heater surface and air temperature for various velocities through wrought-iron pipes heaters. The factor $f$ is the ratio of total surface to clear area and will vary with different number of heater sections, being equal to 98.68 for the eight sections tested. The values of $f$ as plotted were computed from formula [7], Appendix No. 4.

97 As an example of the use of Fig. 42, we will assume an initial or entering air temperature of 20 deg. fahr. with a velocity through

the clear area of 1000 ft. per min. Following the dotted line as shown, we find a value of $f_1 = 25.4$, and adding $f = 98.68$ for eight sections gives $f_2 = 124.08$. From $f_2 = 124.08$ follow the dotted line upward till it intersects the 1000 ft. per min. velocity and the across to a final or leaving temperature of 147 deg. fahr. An inspection of column 8 of Table 12 shows a final temperature obtained from the tests of 147.02 deg. fahr. This diagram may be used for any other value of temperature or surface, when the steam pressure is 5 lb. gage.

# APPENDIX No. 1

98 A series of ten tests was made in February 1906 for the purpose of checking the results obtained from similar tests made in 1902. As the results of these tests agreed so fully with those of the former tests, it was considered unnecessary to work them up in detail until the present time. A number of similar tests were also made at this time at various other steam pressures. As these merely substantiate the relationships here presented, it has been thought unnecessary to include them.

99 The tests were made on an indirect or fan system heater, consisting of eight sections each of four rows of 1-in. wrought-iron pipe. Details of the arrangement of the pipes and their distribution in the cast-iron base is shown in Fig. 30. Each section contained 126.6 sq. ft. of surface, and the clear area was 10.263 sq. ft. The air was drawn through the heater by a steel plate fan, and blown through a nozzle where the air measurements were made. The velocity of the air was measured by means of a pitot tube and a hook gage, the temperatures being carefully taken at the outlets with thermometers well protected from the effect of radiation. The pitot tube readings were taken at the outlet of the fan nozzle, a series of 64 readings having been taken over the area of the outlet, and the ratio of the average to the reading at the center carefully computed. During the test continuous readings were taken with the pitot tube fixed in the center of the orifice, which were afterwards corrected for the above ratio.

100 The pressure of the steam, as well as the speed of the fan engine, was kept constant throughout each test by two of the observers. The condensation from each section was weighed separately, and the temperatures carefully noted. Each section was provided with an air vent, and thoroughly blown out for about one hour before starting the test, and some steam was allowed to blow through during the entire test. A separator was placed in the steam line before the throttle, and a calorimeter was used to determine the quality of the steam as it entered the steam heater. A slight degree of superheat was observed during each test, and the proper allowance made in the calculation of the total heat of the steam. The saturation temperature of the steam was also taken before and after each test to check the steam gage, proper allowance being made for stem correction to the thermometer. Barometric readings were made during each test, and the steam pressure so regulated as to maintain an absolute pressure of 19.7 lb. on the heating coils. The steam gage was calibrated by means of a dead-weight tester before and after each test, due allowance being made for the barometric reading taken at the time.

101 In Table 8 will be found the principal data obtained. As already explained, the first column for each test contains the uncorrected observations, the second column these same readings corrected to standard conditions of 70 deg. fahr. and 29.92 in. barometer, while in the third column, as previously explained, a further correction is made for a systematic error of 8 per cent in

measuring the air. Proper allowance had been made for heat loss from the air by convection from the surface of the heater casing and fan housing, correction for this loss being added to the air temperature. Slight corrections were also made for condensation from such portions of the heater base and pipe connections as were exposed to the air of the room rather than to the air measured. This loss was found to amount to 78.4 B.t.u. per hr. per degree difference between the steam temperature and room temperature.

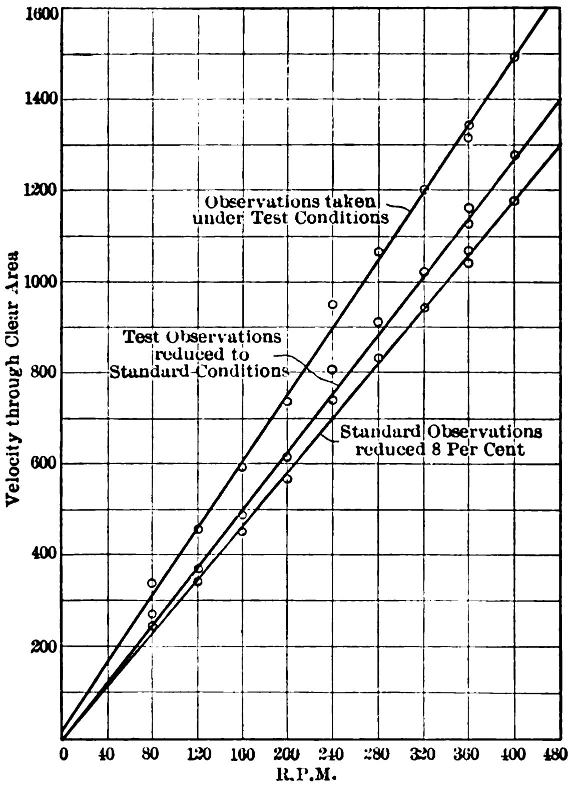



Fig. 43 Relation of Fan Speed to Velocity of Air through Heater

102 A further correction was also required to make allowance for the fact that the condensation left the heater at practically steam temperature, and a portion would flash into steam upon exposure to the atmosphere. After careful tests it was decided to add 1.5 per cent to the weight of condensation to cover this loss, as well as 1½ lb. per ½ hr. to cover the average loss due to evaporation from the tanks containing the condensation. A final correction was then made to reduce all the tests to a standard of 20 deg. for the temperature of the entering air. This was based on the fact that at any velocity the weight of the condensation practically varies directly as the temperature difference between the steam and entering air.

103 As previously stated, the speed of the fan was maintained constant during each test at the speeds shown in Table 8. The relation of the fan speed to the velocity through the clear area as computed from the air measurements, is shown in Fig. 43 plotted from the values in Table 8, barometric measurements being taken into consideration in computing the air measurements. It will be noted that the velocities recorded are fairly regular, with the exception of the tests made at 80 and 240 r.p.m.

# APPENDIX No. 2

## FORMULA FOR MEAN EFFECTIVE TEMPERATURE

104 Let $H$ be the total heat transferred, $S$ the total surface, $K$ the rate of heat transmission per degree difference in temperature, $(\theta_s - \theta)_m$ the mean effective temperature difference between the steam and air. Then we will have

$$H = K(\theta_s - \theta)_m S \qquad [1]$$

$$(\theta_s - \theta)_m = \frac{H}{KS} = \frac{C_p W(\theta_1 - \theta_2)}{KS} \qquad [2]$$

also

$$dH = (\theta_s - \theta)\,KdS \qquad [3]$$

105 Referring to Fig. 29 we have

$$dH = -C_p W d(\theta_s - \theta) \qquad [4]$$

where $W$ is the total pounds of air per hour passing over the surface $S$.

106 Equating [3] and [4] we have

$$(\theta_s - \theta)\,KdS = -C_p W d(\theta_s - \theta) \qquad [5]$$

$$K\int_s^o dS = -C_p W \int_{\theta_s - \theta_2}^{\theta_s - \theta_1} \frac{d(\theta_s - \theta)}{\theta_s - \theta} \qquad [6]$$

Integrating

$$KS = C_p W \log_e \frac{\theta_s - \theta_1}{\theta_s - \theta_2} \qquad [7]$$

Hence

$$(\theta_s - \theta)_m = \frac{\theta_2 - \theta_1}{\log_e\left(\dfrac{\theta_s - \theta_1}{\theta_s - \theta_2}\right)} \qquad [8]$$

$$(\theta_s - \theta)_m = \frac{(\theta_2 - \theta_1) - (\theta_s - \theta_2)}{\log_e\left(\dfrac{\theta_s - \theta_1}{\theta_s - \theta_2}\right)} \qquad [9]$$

107 From equation [45] we have

$$\theta_s - \theta' = RK(\theta_s - \theta)$$

or approximately

$$\theta_s - \theta' = R_0 K_0 (\theta_s - \theta) \qquad [10]$$

Hence

$$d(\theta_s - \theta') = RKd(\theta_s - \theta) \quad \text{[11]}$$

Therefore it follows from [10] and [11] that we will have the same relationship between $(\theta_s - \theta')$, $(\theta_s - \theta'_2)$ and $(\theta_s - \theta')_m$ as between $(\theta_s - \theta_1)$, $(\theta_s - \theta_2)$ and $(\theta_s - \theta)_m$ in equation [11]. Hence

$$(\theta_s - \theta')_m = \frac{(\theta_s - \theta'_1)\ (\theta_s - \theta'_2)}{\log_e \left(\dfrac{\theta_s - \theta'_1}{\theta_s - \theta'_2}\right)} \quad \text{[12]}$$

108 Substituting in [12] $R_0K_0(\theta_s - \theta_1)$ for $\theta_s - \theta'_1$ and $R_0K_0(\theta_s - \theta_2)$ for $\theta_s - \theta'_2$ we have

$$(\theta_s - \theta')_m = \frac{R_0K_0[(\theta_s - \theta_1) - (\theta_s - \theta_2)]}{\log_e \left(\dfrac{\theta_s - \theta_1}{\theta_s - \theta_2}\right)} \quad \text{[13]}$$

or

$$(\theta_s - \theta')_m = \frac{R_0K_0(\theta_2 - \theta_1)}{\log_e \left(\dfrac{\theta_s - \theta_1}{\theta_s - \theta_2}\right)} \quad \text{[14]}$$

or

$$\theta'_m = \theta_s - \frac{R_0K_0(\theta_2 - \theta_1)}{\log_e \left(\dfrac{\theta_s - \theta_1}{\theta_s - \theta_2}\right)} \quad \text{[15]}$$

# APPENDIX No. 3

## PROOF OF FORMULAE [49] AND [58]

$$K_0 = K\left[1 + K_0R_0\left(\frac{\theta'_m - 625}{625}\right)\right] \qquad [49]$$

109 It has been shown that the value of $R$ for a mean film temperature of 625 deg. is 0.0447, and that it varies directly as the absolute temperature. Hence

$$R = \frac{R_0\theta'_m}{625} = \frac{0.0447\,\theta'_m}{625} \qquad [1]$$

Hence

$$\frac{1}{K} = \frac{R_0\theta'_m}{625} + \frac{50.66}{V} \qquad [2]$$

$$= \frac{1}{K_0} + R_0\left(\frac{\theta'_m - 625}{625}\right) \qquad [3]$$

$$K_0 = K + KK_0R_0\left(\frac{\theta'_m - 625}{625}\right) \qquad [4]$$

$$= K\left[1 + K_0R_0\left(\frac{\theta'_m - 625}{625}\right)\right] \qquad [5]$$

110 Let

$$X = R_0\left(\frac{\theta'_m - 625}{625}\right) \qquad [6]$$

Then

$$K_0 = K(1 + XK_0) \qquad [7]$$

$$K = \frac{K_0}{1 + XK_0} \qquad [8]$$

111 We have from equation [54]

$$\log_{10}\left(\frac{\theta_s - \theta_1}{\theta_s - \theta_2}\right) = \frac{0.3994\,f\,K}{V} \qquad [9]$$

Hence substituting the above value of $K$ we have

$$\log\left(\frac{\theta_s - \theta_1}{\theta_s - \theta_2}\right) = \frac{0.3994\,fK_0}{V(1 + K_0X)} \qquad [58]$$

112 From equation [6] we have $X = R\left(\frac{\theta'_m - 625}{625}\right)$. From equation [48] we have $\theta'_m = \theta_s - RK(\theta_s - \theta)_m$. Hence

$$\theta'_m = \theta_s - R_o K_o (\theta_s - \theta)_m \text{ (approximately)} \qquad [10]$$

Substituting this value of $\theta'_m$ in equation [6] we have

$$X = R_o \left[\frac{\theta_s - R_o K_o (\theta_s - \theta)_m - 625}{625}\right] \qquad [11]$$

113 Substituting numerical values previously determined

$$X = 0.0447 \left[\frac{\theta_s - 0.0447\, K_o (\theta_s - \theta)_m - 625}{625}\right] \qquad [12]$$

Hence

$$X = 0.00007152\,\theta_s - 0.0447 - 0.0000032\, K_o (\theta_s - \theta)_m \qquad [13]$$

# APPENDIX No. 4

## PROOF OF EQUATION [55]

114 From equation [54] we have

$$\log\left(\frac{\theta_s - \theta_1}{\theta_s - \theta_2}\right) = \frac{0.3994\, f\, K}{V} \qquad \text{[1]}$$

and from equation [2], Appendix No. 3

$$\frac{1}{K} = \frac{0.0447\,\theta'_m}{625} + \frac{50.66}{V} \qquad \text{[2]}$$

115 From equation [15] Appendix No. 2

$$\theta'_m = \theta_s - 0.434 \times 0.0447\, K_o \left(\frac{\theta_s - \theta_1}{\log_{10}\left(\frac{\theta_s - \theta_1}{\theta_s - \theta_2}\right)}\right) \qquad \text{[3]}$$

Hence

$$\frac{1}{K} = \frac{0.0447\,\theta_s}{625} - \frac{0.0447 \times 0.434 \times 0.0447}{625} K_o \left(\frac{\theta_2 - \theta_1}{\log_{10}\left(\frac{\theta_s - \theta_1}{\theta_s - \theta_1}\right)}\right) + \frac{50.66}{V} \qquad \text{[4]}$$

$$= 0.00007152\,\theta_s - 0.0000013875\, K_o \left(\frac{\theta_2 - \theta_1}{\log_{10}\left(\frac{\theta_s - \theta_1}{\theta_s - \theta_2}\right)}\right) + \frac{50.66}{V} \qquad \text{[5]}$$

$$\frac{0.3994\, f}{V} = \left(0.00007152\,\theta_s + \frac{50.66}{V}\right)\log_{10}\left(\frac{\theta_s - \theta_1}{\theta_s - \theta_2}\right) - 0.0000013875\, K_o(\theta_2 - \theta_1) \qquad \text{[6]}$$

or

$$f = (0.0001791\, V_o\,\theta_s + 126.8)\log_{10}\left(\frac{\theta_s - \theta_1}{\theta_s - \theta_2}\right) - (0.000003474\, V_o\, K_o)\,(\theta_2 - \theta_1) \qquad \text{[7]}$$

$$= (0.0001791\, V_o\,\theta_s + 126.8)\log_{10}\left(\frac{\theta_s - \theta_1}{\theta_s - \theta_2}\right) - \frac{0.000003474\, V^2 (\theta_2 - \theta_1)}{0.0447\, V_o + 50.66} \qquad \text{[8]}$$

# TESTS OF A SAND-BLASTING MACHINE

By Wm. T. Magruder

## ABSTRACT OF PAPER

The paper gives the records and results of quantitative tests of a sand-blasting machine under the actual conditions of commercial practice. The rough surfaces of pieces of cast-iron, which had been cast in one mold, were blasted by air, from which the moisture had been separated, with dried and screened new Cape May grit by a Pangborn sand-blasting machine, and with the sand valve wide open. The quantity of air used was measured by a pitotmeter; the quantities of iron removed, of sand used, and of sand consumed, were measured for each test. The air pressure was varied from 20 lb. to 70 lb. The angle between the surface of the test bar and the nozzle was varied from 30 to 90 deg. The distance from the nozzle to the test bar was varied from 4 to 10 in.

The results show that (*a*) for distance of 8 in. and angle of 45 deg., the equivalent amount of free air delivered per minute, the iron removed, the sand discharged, the sand used up, per 100 cu. ft. of free air flowing per minute, vary directly with the pressure; the amount of usable sand remaining and the amount of sand discharged per pound of iron removed vary inversely with the pressure; (*b*) for 60 lb. pressure and 8 in. distance, the largest amount of iron was removed and the least amount of sand was required to do it, when the angle between the nozzle and the work was from 45 to 60 deg.; (*c*) for 60 lb. pressure and 45 deg. between the nozzle and the work, the largest amount of iron was removed and the least amount of sand was required to do it, when the distance was 6 in.; (*d*) the sand used varies with the directness of the blast; and (*e*) inversely with the distance from the test bar.

# TESTS OF A SAND-BLASTING MACHINE

By Wm. T. Magruder. Columbus, Ohio

Member of the Society

This paper gives the records, results and conclusions of a series of quantitative tests of a sand-blasting machine, under the actual conditions of commercial practice, which were made by David H. Ebinger and Robert A. Frevert, of Columbus, under the direction of the author as their thesis for the degree of mechanical engineer from The Ohio State University in 1910. As it was evident that a complete solution of the problem of securing quantitative results under such conditions was impossible in the time available, certain of the variables which present themselves in such a problem were assumed to be constant: (*a*) the material to be sand-blasted; (*b*) the character of its surface; (*c*) the air-pressure best to use with each of these materials and conditions; (*d*) the size of nozzle for different classes of work; (*e*) the angle to the surface of the work at which the nozzle should be held; (*f*) the distance from the work at which the nozzle should be held; (*g*) size, sharpness, kind, character, uniformity of size, and cleanliness of the sand, and the number of times it has been previously used for sand-blasting; (*h*) the relative dryness of the sand and of the compressed air of the blast; (*i*) the proportion of sand to air; (*j*) differences in commercial machines.

2 The conditions of this set of tests were as follows:

*a* The material was pieces of cast-iron which had been broken as test bars for transverse tests. They were 2 in. by 4 in. in cross-section and from 15 to 25 in. long. They had been cast diagonally on edge in one mold from one ladle of machinery iron.

*b* Their rough surfaces were as uniform as were the bars themselves.

*c* A new nozzle, $\frac{5}{16}$ in. in diameter, was used for each test. To remove any unevenness of the interior surface of the

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nozzles, and to bring them all exactly to the same condition, sand was blown through each for 2 minutes previous to starting the tests. No tests have yet been made with other sizes of nozzles.

*d* The sand used was a No. 3-J Cape May grit, new, hard, sharp, clean, free from clay, and was such as is commonly used by the trade. It was obtained from a large storage bin in the works. It was thoroughly dried in a Pangborn No. 1, Type M, sand dryer, shortly before being used. Great care was taken to avoid overheating it and

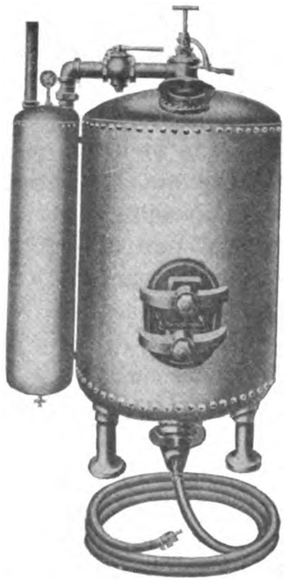

FIG. 1 SAND-BLASTING MACHINE

so destroying its strength and cohesion. The sand was then passed through a No. 8 mesh screen. After use in the machine, it was weighed, sifted, reweighed, and discarded. New sand was used for each test.

*e* The sand was dried as above described. The compressed air was passed through a separator to relieve it of moisture from the atmosphere and oil from the compressor.

*f* No attempt was made to regulate and adjust the proportion of air to sand. All tests were run with the regulating valve wide open.

*g* No comparisons were made of the operations or results from different machines on the market.

3 Upon the three remaining variables, the air pressure, the angle between the surface of the work and the nozzle, and its distance from the work, the quantitative experiments were made.

## EQUIPMENT

4 The regular equipment of the D. A. Ebinger Sanitary Manufacturing Company at Columbus, Ohio, was used for these tests. It

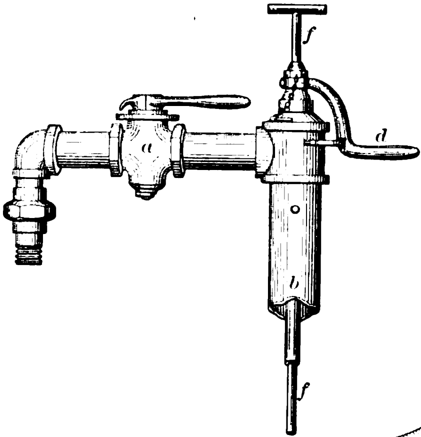


Fig. 2 Regulating and Controlling Valves

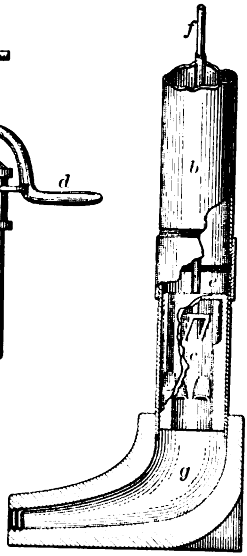


Fig. 3 Mixing Chamber for Air and Sand

had been recently installed for use in sand-blasting cast-iron ware before enamelling. It consisted of one No. 8, Type C, sand-blasting machine, made by the Thomas W. Pangborn Company, Jersey City, N. J., having a sand capacity of 4000 lb. per charge. It was provided with a moisture separator, pneumatic sand separator, dust catcher, and exhaust fan. The air was compressed by a Fairbanks, Morse & Company air compressor, having a capacity of 138 cu. ft. of free air per minute, and driven by an opposed gas engine of 25 h.p. capacity.

5 Fig. 1 shows the machine and Fig. 2 the regulating and controlling valves. Fig. 3 shows the mixing chamber for the air and sand. Fig. 4 shows a plan of the rooms and apparatus. Fig. 5 shows the sand-blasting box and sand-catcher. Fig. 6 shows a photograph of the machine, blasting room and apparatus. Table 1 gives the record of the tests and the results. Figs. 7 to 9 graphically show the results obtained.

## OPERATION OF THE MACHINE

6 The compressed air, coming from the compressor, enters the moisture and oil separator at the left of the machine, passes through

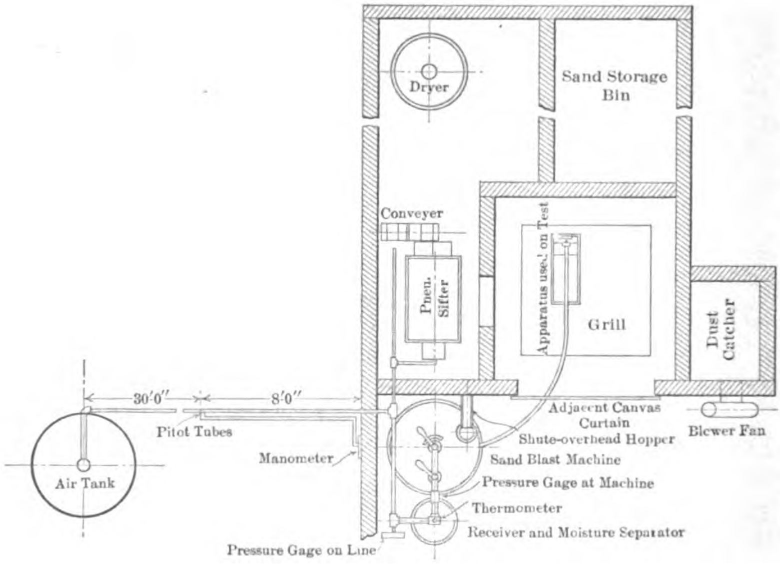


Fig. 4 Location and Arrangement of Apparatus

the air regulator *a*, which has an indicator-handle working over a graduated disc, enters and passes down through the cylinder *b*, inside the machine, then through the air ports in the piston *c*, and engages the entering sand. The ports in the top of the cylinder, one of which is shown, deliver the air to the sand chamber, so as to maintain equal pressure above the sand and to assist in insuring uniform flow. The sand-controller handle, *d*, moves on a quadrant, having limit stops for its off and on full positions. This handle permits the piston *c* to be rotated in its casing *e*, thereby opening, regulating and closing the sand ports by a single control. The stirrer and handle *f* connect with its fork which operates inside of the piston and mixing chamber for dislodging caked sand that may form under certain conditions. Ports, elliptical in shape, are located in opposite sides of both the piston *c* and the casing *e*, and are inclined downwards, so starting the flow of the sand by gravity. The rotation of the piston by the controller handle regulates the opening of the ports and the flow of sand. The sand on leaving the ports is met by the air coming through the ports in the piston. They cross each other from opposite sides into the mixing chamber *g*. By this cross flow, a swirl-

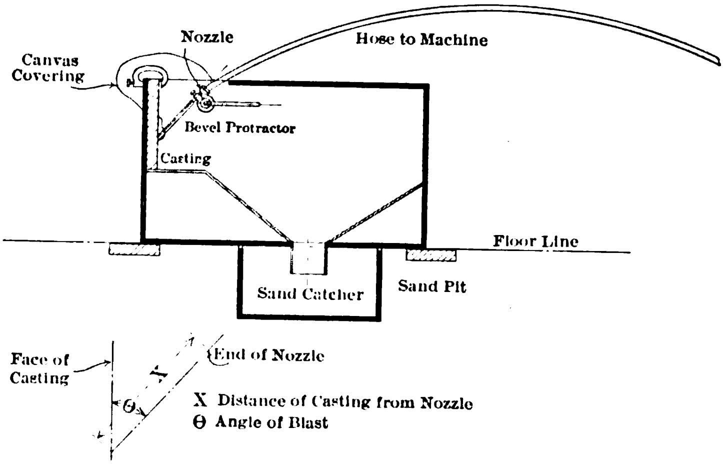


Fig. 5 Sand-Blasting Box and Sand Catcher

ing motion is produced and a thorough mixture of the sand and air is obtained in the rear part of the mixing chamber. The mixture is carried forward by the air pressure from the rear part, 2½ in. in diameter, to the hose connection where it is ¾ in. in diameter, thence through the hose to the nozzle, whence it is projected upon the casting to be sand-blasted.

## MEASUREMENT OF THE AIR

7 The air used was measured by a pitotmeter placed horizontally in a run of straight 1½-in. standard welded pipe in the main air line, and located at a distance from any fitting. The opening,

$\frac{1}{8}$ in. in diameter, of the dynamic tube faced the current of air from the receiver tank. The end of the static tube was trimmed off flush with the interior of the pipe. The tubes were connected by $\frac{1}{8}$-in. pipes to the ends of a water manometer. The difference in the levels of the liquid in the two legs of the manometer indicated the difference between the dynamic and static pressures, and is a measure of the velocity head in inches of water. From the formula, $v^2 = 2gh$, the velocity of the air in the pipe was calculated. Deducting the area of the dynamic tip from the area of the opening in the pipe, gave the net area of the air pipe. The coefficient of discharge was taken as 0.91. To remove the moisture that collected in the tubes, valves were placed in each of the tubes above the manometer, and pet cocks

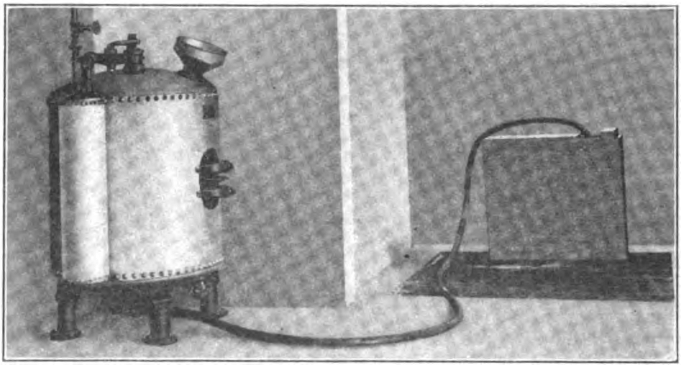

Fig. 6 View of Machine and Apparatus in Blasting Room

placed in the tubes directly above the valves. This arrangement permitted the blowing out of each tube before taking a reading of the pitotmeter. The temperature of the air in the line was taken just before it entered the stop valve at the machine. Calibrated pressure gages in the line and at the machine gave the desired pressures.

## MEASUREMENT OF THE SAND

8 To collect the sand used during each test and also to control the blast, a closed box with a hopper bottom and a shelf at one end to support the test bar was prepared, as is shown in Fig. 5. The sand discharged during a test was collected in the hopper, removed, and weighed as total sand used. It was then sifted, and again weighed, thus giving by difference the amount of sand rendered useless by the

test, and the amount of sand that might be used again in commercial practice. It was not again used in these tests.

## MEASUREMENT OF THE IRON REMOVED

9 The test bar was held in a vertical position in the sand-blasting box. Before and after blasting, it was carefully weighed on a plat-

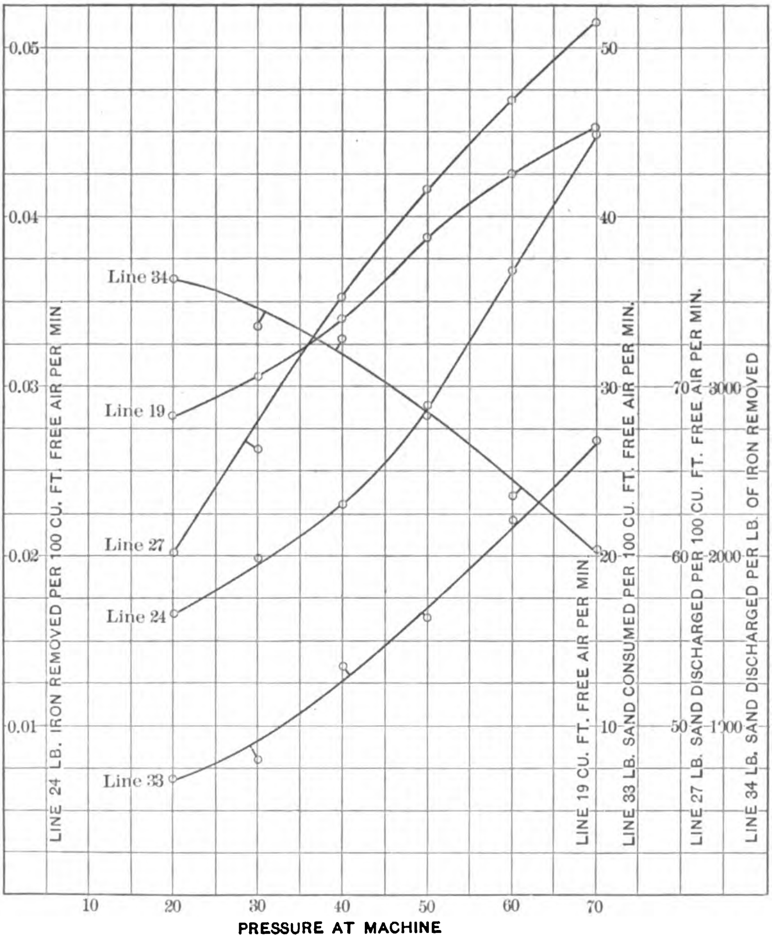


FIG. 7 RESULTS OF TESTS IN RELATION TO AIR PRESSURE AT MACHINE

form scale of 250 lb. capacity by quarter ounces. The scale was carefully balanced before each weighing.

## METHOD OF MAKING THE TESTS

10 In each test the new nozzle was first brought to a uniform condition by discharging a blast of sand and air through it for 2 minutes under a constant blast pressure. The test bar was weighed and placed in position in the closed hopper box. The nozzle was then set by scale for its distance from the test bar and by bevel protractor for its angle with the surface of the test bar. The air regulator *a* was kept wide open during the tests. The desired air pressure in the

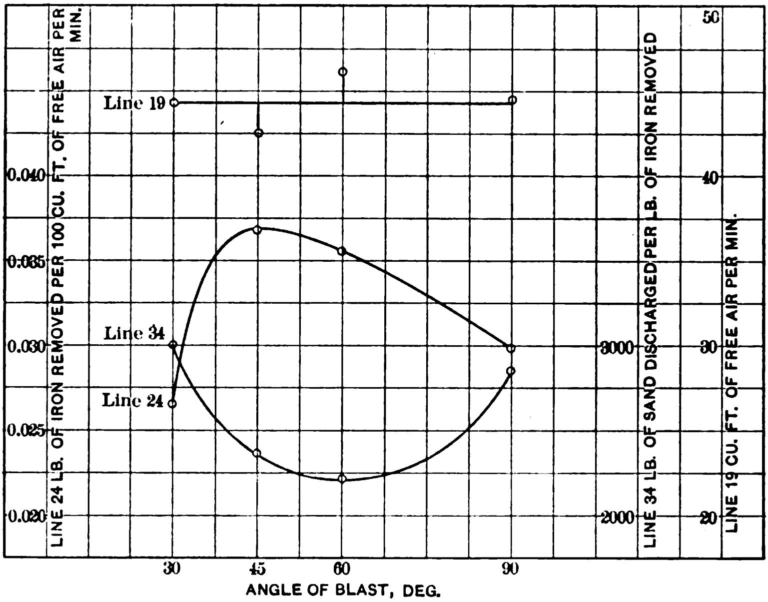


Fig. 8 Results of Tests in Relation to Angle of Blast

machine was secured and maintained constant by adjusting the stop valve in the supply pipe to the moisture separator. After starting the air blast and carefully adjusting the valve to maintain a constant pressure at the machine, the sand-controller handle *d* was moved to its open position at the instant of starting, thus allowing sand to flow into the mixing chamber and be forced by the blast of air out through the nozzle and against the test piece. Readings of the temperature and pressures of the air on the main line and at the machine were taken at regular intervals of about 2 minutes. In closing down the machine at the end of a test, the sand valve was first closed and then the air valve; the test bar was weighed, and the difference of the two weights gave the amount of iron removed; the sand discharged was weighed, sifted and again weighed.

### VARIABLES OF THE TESTS

11 Starting at 20 lb. corrected pressure at the machine on the first test, and increasing by 10 lb. up to and including 70 lb. pres-

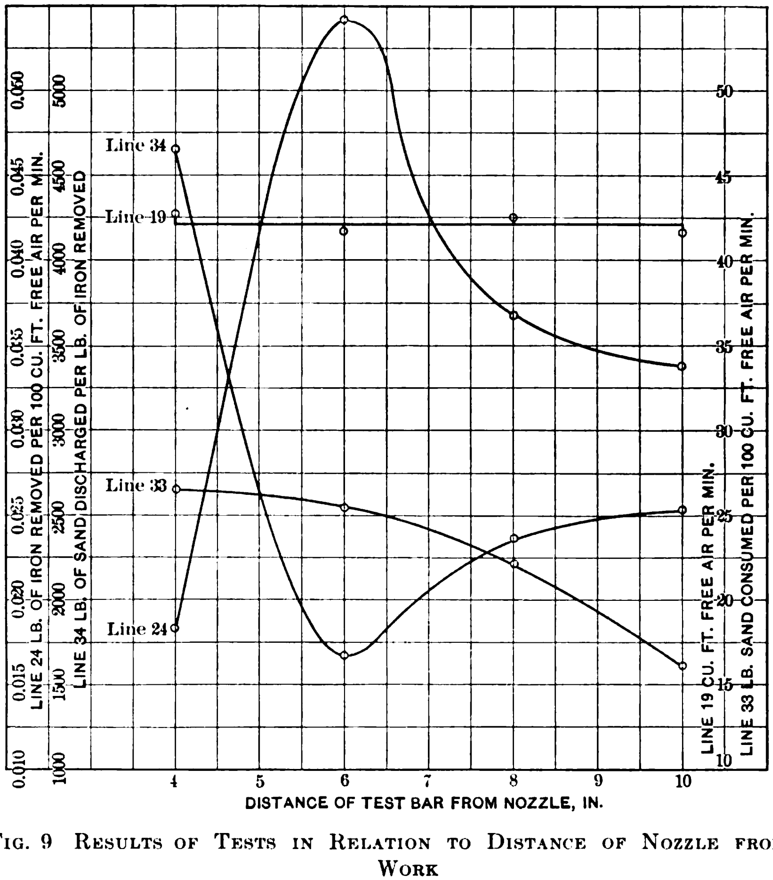


FIG. 9 RESULTS OF TESTS IN RELATION TO DISTANCE OF NOZZLE FROM WORK

sure, the variation in the effectiveness of the blast due to increase of pressure was obtained, with the nozzle set at 45 deg. and at 8 in. from the test bar.

12 In the second series of tests, a constant pressure of 60 lb. was

TABLE 1 TESTS OF SAND-BLASTING MACHINE.

| | | Pressure Variable | | | | | |
|---|---|---|---|---|---|---|---|
| 1 | Number of test | 1 | 2 | 3 | 4 | 5 | 6 |
| 2 | Diameter of nozzle, in | $\frac{5}{16}$ | $\frac{5}{16}$ | $\frac{5}{16}$ | $\frac{5}{16}$ | $\frac{5}{16}$ | $\frac{5}{16}$ |
| 3 | Angle of blast, deg | 45 | 45 | 45 | 45 | 45 | 45 |
| 4 | Distance of nozzle from casting, in | 8 | 8 | 8 | 8 | 8 | 8 |
| 5 | Length of run, min | 15 | 13 | 20 | 20 | 10 | 10 |
| 6 | Air pressure at sand-blasting machine, lb. | 20 | 30 | 40 | 50 | 60 | 70 |
| 7 | Air pressure in line, lb., corrected | 78.4 | 75.0 | 76.1 | 75.0 | 75.0 | 76.5 |
| 8 | Barometric pressure, in. mercury | 29.08 | 29.13 | 29.35 | 29.35 | 29.30 | 28.80 |
| 9 | Temperature of air, deg. fahr | 77.6 | 85.1 | 82.00 | 83.20 | 87.50 | 80.40 |
| 10 | Pitotmeter reading, in. water | 0.056 | 0.070 | 0.085 | 0.112 | 0.135 | 0.150 |
| 11 | Velocity head, ft. water | 0.0047 | 0.0058 | 0.0071 | 0.0093 | 0.0113 | 0.0125 |
| 12 | Volume as free air of 1 cu. ft. of compressed air under actual conditions | 5.796 | 5.508 | 5.607 | 5.527 | 5.483 | 5.648 |
| 13 | Weight of 1 cu. ft. of water at temperature of air in line | 62.25 | 62.18 | 62.21 | 62.20 | 62.16 | 62.23 |
| 14 | Weight of 1 cu. ft. air at actual pressure and temperature | 0.4679 | 0.4446 | 0.4526 | 0.4462 | 0.4427 | 0.4560 |
| 15 | Head of compressed air equivalent to 1 ft. of head of water | 133.0 | 139.9 | 137.4 | 139.4 | 140.4 | 136.5 |
| 16 | Velocity head, ft. air | 0.6253 | 0.8111 | 0.9758 | 1.296 | 1.567 | 1.706 |
| 17 | Velocity in air line, ft. per sec | 6.342 | 7.223 | 7.922 | 9.132 | 10.10 | 10.47 |
| 18 | Cu. ft. compressed air per min. at line pressure and temperature | 4.866 | 5.543 | 6.079 | 7.007 | 7.752 | 8.038 |
| 19 | Equivalent free air, cu. ft. per min | 28.21 | 30.53 | 34.09 | 38.73 | 42.51 | 45.40 |
| 20 | Weight of test bar before blasting, lb | 44.5469 | 41.3906 | 36.4531 | 41.6094 | 41.3125 | 28.7031 |
| 21 | Weight of test bar after blasting, lb | 44.4765 | 41.3125 | 36.2969 | 41.3906 | 41.1563 | 28.5000 |
| 22 | Iron removed, lb | 0.0704 | 0.0781 | 0.1562 | 0.2188 | 0.1562 | 0.2031 |
| 23 | Iron removed, lb. per min | 0.00469 | 0.00601 | 0.00781 | 0.01094 | 0.01562 | 0.02031 |
| 24 | Iron removed, lb. per 100 cu. ft. of free air flowing per min | 0.01663 | 0.01969 | 0.02291 | 0.02825 | 0.03675 | 0.04473 |
| 25 | Sand discharged, lb | 255.0 | 262.0 | 512.0 | 631.0 | 369.0 | 415.0 |
| 26 | Sand discharged, lb. per min | 17.0 | 20.2 | 25.6 | 31.5 | 36.9 | 41.5 |
| 27 | Sand discharged, lb. per 100 cu. ft. of free air flowing per min | 60.27 | 66.19 | 75.10 | 81.34 | 86.81 | 91.41 |
| 28 | Usable sand remaining, lb | 226.0 | 230.0 | 420.0 | 504.0 | 275.0 | 293.0 |
| 29 | Usable sand remaining, lb. per min | 15.1 | 17.7 | 21.0 | 25.2 | 27.5 | 29.3 |
| 30 | Usable sand remaining, per cent | 88.6 | 87.8 | 82.0 | 80.0 | 74.5 | 70.6 |
| 31 | Sand consumed, lb | 29.0 | 32.0 | 92.0 | 127.0 | 94.0 | 122.0 |
| 32 | Sand consumed, lb. per min | 1.93 | 2.46 | 4.60 | 6.35 | 9.40 | 12.20 |
| 33 | Sand consumed, lb. per 100 cu. ft. of free air flowing per min | 6.843 | 8.059 | 13.50 | 16.40 | 22.11 | 26.87 |
| 34 | Sand discharged per lb. of iron removed, lb | 3625.0 | 3361.0 | 3278.0 | 2879.0 | 2362.0 | 2043.0 |

Lines 6 and 7 give corrected gage readings.

Line 12 is obtained from the characteristic equation for perfect gases $V_1 = \frac{492}{14.7} \times \frac{P}{T}$, by taking the absolute pressures and temperatures corresponding to the readings given on Lines 7 and 9.

Line 13 is taken from p. 688 of Kent's Pocket Book for the temperatures given on Line 9.

Line 14 = Line 12 × weight of 1 cu. ft. free air.

$$\text{Line 15} = \frac{\text{Line 13}}{\text{Line 11}}$$

Line 16 = Line 15 × Line 11

$$\text{Line 17} = 8.02 \sqrt{\text{Line 16}}$$

Line 18 = Line 17 × net area of pipe in sq. ft. × coefficient of discharge × 60

Line 19 = Line 18 × Line 12

$$\text{Line 23} = \frac{\text{Line 22}}{\text{Line 5}}$$

$$\text{Line 24} = \frac{100\ (\text{Line 23})}{\text{Line 19}}$$

COLLECTED DATA AND CALCULATED RESULTS

| Angle Variable | | | | Distance Variable | | | | |
|---|---|---|---|---|---|---|---|---|
| 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 7A |
| ☆ | ☆ | ☆ | ☆ | ☆ | ☆ | ☆ | ☆ | ☆ |
| 30 | 45 | 60 | 90 | 45 | 45 | 45 | 45 | 30 |
| 8 | 8 | 8 | 8 | 4 | 6 | 8 | 10 | 8 |
| 8 | 10 | 10 | 10 | 10 | 9 | 10 | 10 | 10 |
| 60 | 60 | 60 | 60 | 60 | 60 | 60 | 60 | 60 |
| 78.1 | 75.0 | 77.0 | 79.0 | 78.4 | 77.7 | 75.0 | 77.0 | 77.8 |
| 29.13 | 29.30 | 29.20 | 29.20 | 29.08 | 29.30 | 29.30 | 29.08 | 29.30 |
| 81.60 | 87.50 | 78.10 | 80.15 | 78.97 | 89.66 | 87.50 | 77.94 | 79.44 |
| 0.140 | 0.135 | 0.154 | 0.140 | 0.130 | 0.127 | 0.135 | 0.125 | 0.208 |
| 0.0117 | 0.0113 | 0.0128 | 0.0117 | 0.0108 | 0.0106 | 0.0113 | 0.0104 | 0.0173 |
| 5.735 | 5.483 | 5.704 | 5.806 | 5.781 | 5.626 | 5.483 | 5.705 | 5.739 |
| 62.21 | 62.16 | 62.25 | 62.23 | 62.24 | 62.13 | 62.16 | 62.25 | 62.24 |
| 0.4630 | 0.4427 | 0.4604 | 0.4687 | 0.4667 | 0.4542 | 0.4427 | 0.4606 | 0.4633 |
| 134.4 | 140.4 | 135.2 | 132.8 | 133.04 | 136.8 | 140.4 | 135.2 | 134.3 |
| 1.572 | 1.587 | 1.730 | 1.553 | 1.440 | 1.450 | 1.587 | 1.406 | 2.324 |
| 10.06 | 10.10 | 10.55 | 9.996 | 9.625 | 9.657 | 10.10 | 9.508 | 12.23 |
| 7.717 | 7.752 | 8.096 | 7.670 | 7.386 | 7.411 | 7.752 | 7.296 | 9.382 |
| 44.25 | 42.51 | 46.18 | 44.53 | 42.70 | 41.69 | 42.51 | 41.63 | 53.84 |
| 36.5313 | 41.3125 | 51.6172 | 30.8437 | 44.2656 | 41.1250 | 41.3125 | 44.4062 | 41.4219 |
| 36.4375 | 41.1563 | 51.4531 | 30.7109 | 44.1875 | 40.9219 | 41.1563 | 44.2656 | 41.3125 |
| 0.0938 | 0.1562 | 0.1641 | 0.1328 | 0.0781 | 0.2031 | 0.1562 | 0.1406 | 0.1094 |
| 0.0117 | 0.01562 | 0.01641 | 0.01328 | 0.00781 | 0.02257 | 0.01562 | 0.01406 | 0.01094 |
| 0.02644 | 0.03675 | 0.03554 | 0.02982 | 0.01829 | 0.05413 | 0.03675 | 0.03378 | 0.0203 |
| 281.0 | 369.0 | 364.0 | 378.0 | 361.0 | 341.0 | 369.0 | 356.0 | 243.0 |
| 35.1 | 36.9 | 36.4 | 37.8 | 36.1 | 37.9 | 36.9 | 35.6 | 24.3 |
| 79.32 | 86.81 | 78.83 | 84.88 | 84.55 | 90.90 | 86.81 | 85.52 | 45.13 |
| 218.0 | 275.0 | 268.0 | 279.0 | 248.0 | 246.0 | 275.0 | 289.0 | 180.0 |
| 27.3 | 27.5 | 26.8 | 27.9 | 24.8 | 27.3 | 27.5 | 28.9 | 18.0 |
| 77.58 | 74.5 | 73.6 | 73.8 | 68.7 | 72.1 | 74.5 | 81.2 | 74.1 |
| 63.0 | 94.0 | 96.0 | 99.0 | 113.0 | 95.0 | 94.0 | 67.0 | 63.0 |
| 7.875 | 9.4 | 9.6 | 9.9 | 11.3 | 10.6 | 9.4 | 6.7 | 6.30 |
| 17.80 | 22.11 | 20.79 | 22.23 | 26.46 | 25.42 | 22.11 | 16.09 | 11.70 |
| 3000.0 | 2362.0 | 2218.0 | 2846.0 | 4642.0 | 1679.0 | 2362.0 | 2532.0 | 2221.0 |

$$\text{Line 26} = \frac{\text{Line 25}}{\text{Line 5}}$$

$$\text{Line 27} = \frac{100\,(\text{Line 26})}{\text{Line 19}}$$

$$\text{Line 29} = \frac{\text{Line 28}}{\text{Line 5}}$$

$$\text{Line 30} = \frac{\text{Line 29}}{\text{Line 26}}$$

$$\text{Line 32} = \frac{\text{Line 31}}{\text{Line 5}}$$

$$\text{Line 33} = \frac{100\,(\text{Line 32})}{\text{Line 19}}$$

$$\text{Line 34} = \frac{\text{Line 27}}{\text{Line 24}}$$

maintained at the machine, and the nozzle set at 8 in. from the test bar. The angle was varied from 30 to 90 deg. The effectiveness of these angles of blast was in this way obtained.

13 In the third series of tests, the distance of the nozzle from the test piece was varied, the angle being set at 45 deg. and the air pressure maintained constant at 60 lb.

## OBSERVATIONS

14 It was noted that with no sand flowing, the quantity of air flowing approximated the theoretical discharge for the nozzle. On turning on the sand, the quantity of air flowing immediately decreased; and when the sand was "on full," the amount of air discharged was only 40 to 50 per cent of the original quantity.

15 With constant air pressure and with the sand-controller lever in its "on full" position, on account of the variation in the openings of the sand and air ports of the machine, about 30 tests were required to be made in order to get even fairly concordant results for the pounds of sand discharged per 100 cu. ft. of free air flowing per minute, as shown on Line 27, Table 1. For constant pressure, variations in the pitotmeter readings were due to the variations in the sand flowing. As the quantity of sand decreased, the velocity and quantity of air increased, but the quantity of sand discharged per pound of iron removed also decreased. This can be seen by comparing the readings on Line 34 for tests 7 and 7*A*. It would seem that further experiments might prove that at other angles than 30 deg., and at other distances than 8 in., and at other pressures than 60 lb., less sand would be used per pound of iron removed if the sand-regulating valve was not open so much. This would make the energy of the individual grain of sand greater and its blasting effect larger. Furthermore, there would be less piling up of the sand on the surface being sand-blasted.

## RESULTS

16 From these quantitative experiments on a cast-iron test bar for these three variables, within the limits used, the results as given in Table 1 and graphically shown in Figs. 7, 8 and 9, are as follows:

*a* For a constant distance of 8 in., and at a constant angle of 45 deg., between the nozzle and the test bar, the equivalent amount of free air delivered per minute, the iron removed, the sand discharged, and the sand used up per

100 cu. ft. of free air flowing per minute, vary directly with the pressure; the per cent of usable sand remaining, and the amount of sand discharged per lb. of iron removed vary inversely with the air pressure in the machine. (See Lines 19, 24, 27, 33, 30, and 34, Fig. 7.)

*b* With a constant pressure of 60 lb. in the machine, and a fixed distance of 8 in. from the nozzle to the test bar, the largest amount of metal was removed, and the least amount of sand was required to do it, when the angle between the nozzle and the surface of the work was from 40 to 60 deg. (See Lines 24 and 34, Fig. 8.)

*c* With a constant pressure of 60 lb. in the machine and a constant angle of 45 deg. between the nozzle and the surface of the test bar, the largest amount of metal was removed, and the least amount of sand was required to do it, when the distance from the nozzle to the work was about 6 in. (See Lines 24 and 34, Fig. 9.)

*d* With a constant pressure of 60 lb. and a fixed distance of 8 in. from the nozzle to the test bar, the amount of sand used up varies as the directness of the blast. (See Line 33, Table 1.)

*e* With a constant pressure of 60 lb., and a constant angle of 45 deg. between the nozzle and the test bar, the amount of sand used up varies inversely with the distance of the nozzle from the test bar. (See Line 33, Fig. 9.)

*f* For a constant angle of 45 deg., and a fixed distance of 8 in. between the nozzle and the test bar, twice as much metal was removed at 56 lb. pressure as at 20 lb.; at 64 lb. as at 30 lb.; and at 72 lb. pressure as at 40 lb. (See Line 24, Fig. 7.)

*g* With a constant pressure of 60 lb., and a constant distance of 8 in. between the nozzle and the test bar, over 20 per cent more metal was removed with the nozzle held at 45 deg. than at 90 deg. to the test bar.

*h* With a constant pressure of 60 lb., and a constant angle of 45 deg. between the nozzle and the test bar, 60 per cent more metal was removed when the nozzle was held at 6 in. than at 10 in. from the test bar.

## CONCLUSION

17 Unless it can be shown that the extra cost of compressing 100 cu. ft. of free air per hour to a pressure of 70 or 80 lb. per sq. in. exceeds the cost to compress it to 30 or 40 lb. by the cost of an hour of labor (25 cents), the higher pressures, delivered at an angle of about 45 deg., and at a distance of about 6 in. from the work, are to be preferred for the sand-blasting of cast iron.

# STANDARD CROSS-SECTIONS

By H. de B. Parsons, New York

Member of the Society

The advantage of a uniform method for cross-sectioning drawings so as to indicate graphically the materials, is so obvious that it needs no argument. For some years the tendency has been in this direction, with the result that many materials are represented on drawings by substantially uniform methods of cross-sectioning.

2 The author suggests that this Society promote this question of the use of uniform methods for indicating materials on engineering plans, and to this end supplements this paper with a sheet of typical standard cross-section designs (Fig. 1).

3 Communications were sent by the author to engineers, manufacturers, engineering societies and others having occasion to make cross-sectional drawings, in the United States, England, France and Germany, asking that they submit the standards, if any, used by them. The replies were given to the writer's assistant, Mr. David C. Johnson, who tabulated them and prepared the accompanying sheet of standard sections (Fig. 1), so that they might agree so far as possible with the standards now in use.

4 It is not practical to indicate every material by standard cross-sectioning, because there are so many alloys and materials of like nature which can always best be defined by lettering on the drawing.

5 The author believes that such a standard form as the one submitted would meet all requirements and create uniformity in practice which would be very desirable. Many have adopted standards of their own, but it would seem to be better if the same standards were used by all.

The American Society of Mechanical Engineers, 29 West 39th Street, New York. All papers are subject to revision.

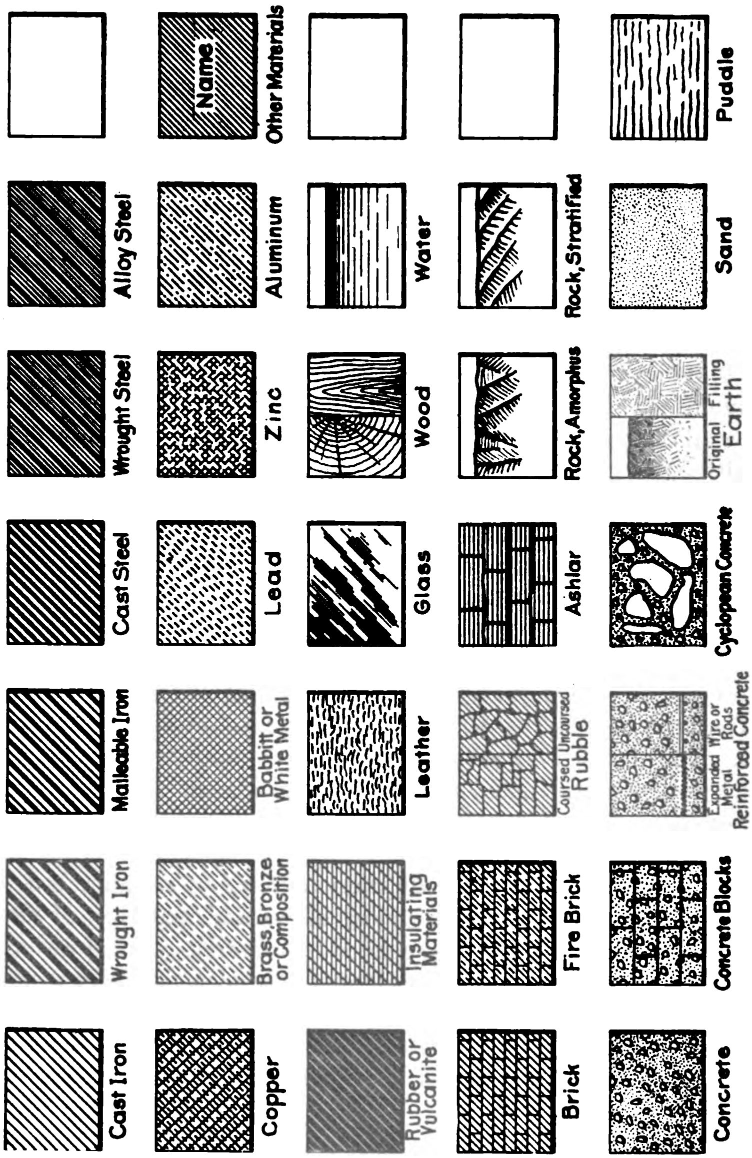


FIG. 1 TYPICAL STANDARD CROSS-SECTIONS

# GAS POWER SECTION

## PRELIMINARY REPORT OF LITERATURE COMMITTEE

## (XII)

### ARTICLES IN PERIODICALS[1]

DIESEL ENGINE, 335-B.H.P. *The Engineer (London), October 27, 1911.* ½ p., 1 fig. *bfB.*

Describes a 4-cylinder, 4-cycle engine, 335 maximum b.h.p. at 220 r.p.m., 15 in. cylinder, 22 in. stroke, built by Williams & Robinson.

DIESEL ENGINES FOR SEA-GOING VESSELS, J. T. Milton. *Journal American Society Naval Engineers, August 1911.* 27 pp., 9 curves.

Read before the 52d session of the Institute of Naval Architects, April 6, 1911.

GAS ENGINES: THEIR DESIGN AND APPLICATION, E. N. Percy. *International Marine Engineering, November, 1911.* 2 pp., 1 table.

Continued from October International Marine Engineering.

GASGENERATOR, EIN NEUER AMERIKANISCHER. *Der Praktische Maschinen-konstrukteur, August 31, 1911.* 2 pp., 2 figs. *bC.*

Describes the gas producer made by the Gibbs Gas Engine Co., Atlanta, Ga.

GASTURBINEN, ÜBER, P. Langer. *Stahl und Eisen, October 19, 1911.* 5 pp., 6 figs., 3 curves. *bdef.*

Article on gas turbines.

GAZOGÈNE POUR CHARBONS BITUMINEUX. *Le Mois Scientifique et Industrielle, August 1911.* 1 p., 3 figs.

Bituminous coal gas producer. Extract from The Practical Engineer, London, May 26, 1911.

GAZOGÈNES; LEUR HISTOIRE, LEUR RENDEMENT, M. Dowson. *Le Mois Scientifique et Industrielle, August 1911.* 6 figs., 4 tables. *df.*

Gas producers; their history and operation. Extract from Engineering, May 5, 1911.

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[1] Opinions expressed are those of the reviewer not of the Society. Articles are classified as *a* comparative; *b* descriptive; *c* experimental; *d* historical; *e* mathematical; *f* practical. A rating is occasionally given by the reviewer, as *A*, *B*, *C*. The first installment was given in The Journal for May 1910.

D'HYDROCARBURES DANS LES GARAGES D'OMNIBUS AUTOMOBILE SYSTÈME MARTINI ET HUNEKE, ETABLISSEMENT DES DEPOTS, M. A. Mariage. *Journal Société des Ingénieurs Civils de France, August 1911.* 28 pp., 7 figs., 2 tables.

Description and plans of the fire-proof storage houses for gasolene of the Paris Automobile Omnibus Co.

INTERNAL-COMBUSTION ENGINE, A NEW. *The Iron Age, October 12, 1911.* 1 p., 2 figs. *b.*

New type of 4-cylinder, 4-cycle, water-cooled gasolene motor.

INTERNAL-COMBUSTION ENGINE FOR NAVAL PURPOSES, THE. *The Engineer (London), October 27, 1911.* 1 p. *adfA.*

Article sets forth what has been done towards finally replacing the steam engine with the oil engine on shipboard.

MOTEUR À COMBUSTION INTERNE PERFECTIONNE À DEUX TEMPS. *Le Mois Scientifique et Industrielle, August 1911.* 21 pp., 6 figs.

Improved 2-cycle, internal-combustion engine. Extract from The Engineer, (London) May 19, 1911.

MOTEURS À PÉTROLE. *Revue de Mécanique, September 30, 1911.* 19½ pp., 70 figs., 1 table, 1 curve. *b.*

Brief accounts of various oil engines are represented by patent records.

MOTEUR DIESEL À GRANDE VITESSE, RECHERCHES, THERMODYNAMIQUES SUR LE, M. Seileger. *Revue de Mécanique, September 30, 1911.* 17 pp., 3 figs., 9 tables, 7 curves. *A.*

Describes thermodynamic researches of 300-h.p. Diesel engine.

OIL ENGINES, MODERN DIESEL, F. Schubeler. *Journal American Society of Naval Engineers, August 1911.* 14 pp.

Before the Zurich meeting of The Institution of Mechanical Engineers, July 1911.

PRODUCER GAS CANAL TUGBOAT, A. *Power, October 17, 1911.* 2 pp., 3 figs. *b.*

Describes boat and its power equipment.

PRODUCER GAS, TWO MARINE INSTALLATIONS OF, C. B. Page. *Transactions Society of Naval Architects and Marine Engineers, Vol. 18, p. 219.* 7 pp., 4 figs., 1 curve.

Before the Society of Naval Architects and Marine Engineers.

ROHOELMOTOREN NEUERE, Ch. Pohlmann. *Dinglers Polytechnisches Journal, October 7, 14, 21, 28, 1911.* 21 pp., 34 figs., 6 tables, 8 curves. A.

Description, design, tests and construction of new crude oil motors.

SCHIFFS DIESELMOTOR IN RUSSLAND, DER VIERTAKT, R. MURAUER. *Zeitschrift des Vereines deutscher Ingenieure, September 30, 1911.* 5½ pp., 12 figs., 2 tables. *bf.*

The 4-cycle marine Diesel engine in Russia.

SUCTION GAS ENGINES AND PRODUCERS, W. A. Tookey. *Engineering, October 6, 1911.* 3½ pp., 6 tables, 6 curves. *ac.*

Comparison of test performances with results obtained in daily operation, and notes on working costs for fuel, oil, labor, etc.

TEER ZUM BETRIEBE VON DIESELMOTOREN, VERWENDUNG VON, W. Allner-Denan. *Journal für Gas and Wasserversorgung, October 21, 1911.* 6 pp., 4 tables, 6 curves.

The use of tar in Diesel engines.

TORFGASKRAFTANLAGE AUF DER OST DEUTSCHEN AUSSTELLUNG POSEN, 1911, DIE. *Dinglers Polytechnisches Journal, October 28, 1911.* 3 pp., 5 figs. *A.*

Description of a peat gas producer and peat gas engine.

VALVE GEAR, THE JENCKES. *The Iron Age, October 12, 1911.* 2 pp. 2 figs. *b.*

A Corliss type gear for gas engines.

WIRTSCHAFTLICHKEIT DER GLEICHDRUCK-GAS-UND-GAS-DAMPF-TURBINEN, J. Nadrowski. *Die Turbine, October 5, 1911.* 3½ pp., 20 curves. *e.*

Contribution to the question of the economy of constant-pressure turbines and of gas-steam turbines.

# GENERAL NOTES

## NATIONAL SOCIETY FOR THE PROMOTION OF INDUSTRIAL EDUCATION

The annual convention of the National Society for the Promotion of Industrial Education was held in Cincinnati, Ohio, November 2–4. The general topic discussed on the first day of the convention was Cincinnati's Experience in Industrial Education, and among the papers presented were: Coöperative plan of the University of Cincinnati, Prof. Herman Schneider; Vocational Plans in the High School, P. A. Johnston; Part-Time School for Apprentices, J. H. Renshaw; The Ohio Mechanic's Institute, J. L. Shearer. The subjects presented the second day were: What Types of Continuation Schools are Most Needed in American Conditions, What can be done for the Factory Worker Through Industrial Education, Industrial Education Necessary to the Economical Development of the United States, and Should Trade Schools for Youths above Sixteen Years of Age be Provided at Public Expense. These subjects were discussed by many prominent in the educational and industrial field.

## AMERICAN ROAD BUILDERS' ASSOCIATION

The annual convention of the American Good Roads Congress and the American Road Builders' Association was held at Rochester, N. Y., November 14–17. The papers read were: Highway Administration, J. A. Bensel; Adaptability of Roads and Pavements to Local Conditions, Nelson P. Lewis; Probems of Construction, W. W. Crosby, Mem.Am.Soc.M.E.; Problems of the Contractor, C. A. Crane; and Maintenance of Roads and Pavements, James Owen, Mem.Am.Soc.M.E. An illustrated lecture was also given which included the subjects, European Roads, A. H. Blanchard; American Roads, P. D. Sargent; New York Roads, by a representative of the New York State Commission of Highways.

## THE SOCIETY OF NAVAL ARCHITECTS AND MARINE ENGINEERS

The annual meeting of the Society of Naval Architects and Marine Engineers was held in the Engineering Societies' Building, New York, November 16–17. The subjects presented included the following: On the Maximum Dimensions of Ships, Sir William H. White, Hon. Mem.Am.Soc.M.E.; Dock Facilities of New York City; Present Facilities and Proposed Improvements and Enlargements, W. J. Barney; Some Model Basin Investigations of the Influence of Forms of Ships upon Their Resistance, D. W. Taylor; The Resistance of Some Types of Merchant Vessels in Shallow Water, H. C. Sadler; Panama Canal and American Commerce, Lewis Nixon; Experiments on the Froude, Prof. C. H. Peabody; The Effects of Waves upon a Taffrail Log, Prof.

H. A. Everett; The Raising of the Dry Dock Dewey, L. S. Adams; The Best Arrangements for Combined Reciprocating and Turbine Engines on Steamships, G. W. Dickie, Mem.Am.Soc.M.E.; Various Arrangements of Turbine Propulsive Machinery, E. H. B. Anderson; Ship Calculations, Derivation and Analysis of Methods, T. G. Roberts; Economy in the Use of Fuel Oil for Harbor Vessels, C. A. McAllister; The Marine Terminal of the Grand Trunk Pacific Railway, W. T. Donnelly, Mem.Am.Soc.M.E.; Cargo Transference at Steamship Terminals, H. McL. Harding; Heavy-Oil Engines for Marine Propulsion, G. C. Davidson; Automatic Record of Propeller Action in an Electrically Propelled Vessel, W. L. R. Emmet, Mem.Am.Soc.M.E.; Some Applications of the Principles of Naval Architecture of Aeronautics, William McEntee.

## THE AMERICAN INSTITUTE OF MINING ENGINEERS

The December meeting of the New York Section of the American Institute of Mining Engineers to be held in the Engineering Societies' Building, New York, at a date not yet determined, will be devoted to an account of the Institute's recent visit to Japan, by members who participated.

## NOVA SCOTIA SOCIETY OF ENGINEERS

The annual meeting of the Nova Scotia Society of Engineers was held in Halifax, November 15–16. Papers on the following subjects were read and discussed: Development of Electric Power at the Pit Mouth, P. A. Freeman; History of Roads in Nova Scotia, J. W. MacKenzie; Notes on Cement and Concrete Work, H. C. Burchell.

## AMERICAN SOCIETY OF CIVIL ENGINEERS

At a meeting of the American Society of Civil Engineers on November 1, papers on A Reinforced Concrete Stand-Pipe, and Retrogression in the Tensile Strength of Concrete, were read. On November 15, Some of the Properties of Oil Mixed Portland Cement Mortar, and A Reinforced Concrete Bridge across the Almendares River, Havana, Cuba, were read and discussed.

## PERSONALS

H. P. Ahrnke, lately associated with Barrett Manufacturing Co., New York, has accepted a position with the Dairy Machinery and Construction Co., Derby, Conn.

Charles B. Barnes, formerly connected with Holabird & Roche, Chicago, Ill., has entered the service of the Western Electric Co., as assistant works engineer of the Hawthorne Station, Chicago, Ill.

George H. Benton, formerly manager of the valve department of the Fairbanks Co. of New York, has accepted the Presidency and Managership of the Benton Valve Co., New York.

Sydney Bevin has become associated with the Matheson Automobile Co., Wilkes Barre, Pa.

J. G. Bower, formerly sales agent of the Pressed Steel Car Co., Chicago, Ill., has become identified with Hale & Kilburn Co. of the same city.

C. D. Chasteney has resigned his position as sales manager of the De Laval Steam Turbine Co., Trenton, N. J., having acquired an interest in the Turbine Equipment Co., New York, which company represents the De Laval Steam Turbine Co. in New York State, parts of New Jersey and Connecticut.

Howard B. Clark resigned as member of the firm of Flaherty & Clark on June 1st and is now Eastern representative for the McNaull-Boiler Manufacturing Co. of Toledo, O., manufacturers of water tube boilers.

Dwight S. Cole has opened an office in the Ashton Building, Grand Rapids, Mich., as a consulting engineer and mechanical expert and expects to pay particular attention to steam power plants.

Fred. B Corey has accepted a position with the Union Switch and Signal Co., Swissvale, Pa. He was formerly identified with the General Electric Co., Schenectady, N. Y.

Claude E. Cox has been appointed resident manager of the research department of the General Motors Co., Detroit, Mich. Mr. Cox was until recently engineer and factory manager of the H. E. Wilcox Motor Car Co., Minneapolis, Minn.

Horace W. De Ved has severed his connection with the Westchester Lighting Co., Mt. Vernon, N. Y., to accept the position of superintendent of distribution with the N. Y. & Queens Electric Light and Power Co., Long Island City, N. Y.

John A. Doane has been appointed manager of the Worcester Piston Ring and Machine Works, Worcester, Mass. Mr. Doane was recently in the employ of the American Optical Co., Southbridge, Mass., in the capacity of superintendent of machine shops.

S. A. Donaldson has left the employ of Westinghouse, Church Kerr & Co., New York, to accept a position with the New Jersey Zinc Co., at their Palmerton, Pa. plant.

Robert Noyes Fairbanks has become identified with Dutilh-Smith, McMillan & Co., London, England. He was until recently manager of the Fairbanks Co., London, England.

David C. Fenner has resigned his position of sales manager of the Alden Sampson Manufacturing Co., New York, and has joined the forces of the Saurer Motor Co., New York.

E. W. Hamilton has entered the employ of Harvey Hubbell, Inc., Bridgeport, Conn., in the capacity of mechanical engineer.

Robt. T. Hazelton, until recently superintendent of the Bridgeford Machine Tool Works, Rochester, N. Y., has accepted a position with the Cincinnati Milling Machine Co., Cincinnati, O.

R. S. King, formerly associated with the civil engineering department of the Indiana Steel Co., Gary, Ind., has become connected with the engineering department of Fairbanks, Morse & Co. of Chicago, Ill., having charge of a coaling station being erected by them for the Chicago Great Western Railroad at Des Moines, Ia.

Milton Kraemer, formerly connected with the A. & F. Brown Co., New York, has become associate consulting engineer of the U. S. Gold Dredging and Rubber Co. of Ecquador, South America, with offices in New York.

W. Edward Lindsay, has assumed the duties of consulting engineer of the United Cork and Seal Co., Millis, Mass. Mr. Lindsay was until recently secretary and treasurer of the American Welding Co., Carbondale, Pa.

James H. MacLauchlan has severed his connection with the American Cement Engineering Co., Yorktown, Va., and has opened offices in Baltimore, Md., to conduct business under the firm name of J. H. MacLauchlan Engineering Co.

Robt. C. Monteagle has accepted a position with the Lockwood Manufacturing Co., East Boston, Mass., in the capacity of assistant manager and engineer. He was lately connected with the Atlantic Works, of the same city, as chief engineer.

Albert B. Moore, until recently associated with Woodman & Moore, Chicago, Ill., has been appointed treasurer and general manager of the Shedd Electric Co., Inc., Roselle Park, N. J.

C. J. Morrison, who has been holding the position of manager of the department of effective organization of Suffern & Son, New York, has been made manager of the engineering department of that firm.

Charles C. Phelps has severed his connection with the Ferguson Publishing Co., New York, as editor of Steam and is now with Stevens Institute of Technology, Hoboken, N. J., having accepted the position of manager of Castle Stevens which was recently acquired from the Stevens family to serve as a student commons and dormitory and headquarters for the Alumni and Faculty of the Institute. Mr. Phelps will also fill the offices of secretary of Stevens Alumni Association and editor of the Stevens Indicator.

S. B. Redfield, formerly associate editor of the American Machinist is now engineer of tests for the Ingeısoll-Rand Co., Phillipsburg, N. J.

Wm. B. Sturgis has become connected with the E. I. de Pont de Nemours Powder Co., Wilmington, Del. Mr. Sturgis was, until recently, superintendent of the Dover White Marble Co., Wingdale, Duchess Co., N. Y.

George E. Titcomb has entered the employ of the McMyler Interstate Co., as Eastern branch sales manager, with headquarters in New York. He was formerly vice-president of the J. M. Dodge Co., Philadelphia, Pa.

George E. Williamson has resigned as engineer of works of the Union Metallic Cartridge Co., Bridgeport, Conn., to become chief engineer of the Strathmore Paper Co., Mittineague, Mass.

Chas. D. Young, formerly assistant engineer of motive power of the Pennsylvania Lines West of Pittsburgh, has been appointed engineer of tests of the same company, with headquarters in Altoona, Pa.

# ACCESSIONS TO THE LIBRARY

## With Comments by the Librarian

This list includes only accessions to the library of this Society. Lists of accessions to the libraries of the A. I. E. E. and A. I. M. E. can be secured on request from Calvin W. Rice, Secretary, Am.Soc.M.E.

American Ceramic Society. Transactions, Vol. 13. *Columbus, 1911.* Gift of the society.

American Institute of Consulting Engineers. Constitution and By-Laws, 1911.

Bearings and Their Lubrication, L. P. Alford. *New York, American Machinist, 1911.* Gift of the author.

The first book on the subject and of particular importance at the present time because of the modern tendency to high-speed shafts and spindles and friction-reducing forms of bearings.

Congreso Cientifico (First Pan-American). Ciencias Económicas y Sociales, Vol. 3. *Santiago de Chile, 1911.*

———Ciencias Pedagógicas y Filosofia, Vol. 1. *Santiago de Chile, 1911.* Gift of the congress.

Dénivellations de la Voie et Oscillations des Véhicules des Chemins de Fer, Georges Marié. Pt. 1. *Paris, Dunod & Pinat, 1911.*

Handbook on the Gas Engine, H. Haeder. Translated from the German and edited by W. M. Huskisson. *New York, McGraw Hill Book Co., 1911.*

The book is designed for engine builders, engineers, and engineering students, and is absolutely free of descriptive matter. The treatment is entirely mechanical and mathematical, differing in that respect from Diederich's translation of Güldner's manual published last year. The translator has added a large number of useful tables in the appendix, as well as a description of the Humphrey pump. The volume is a distinct contribution to the literature in English on the subject.

Leather for Bookbinding, Report of the Committee on. Edited for the Society of Arts and Worshipful Company of Leathersellers by Viscount Cobham. *London, 1905.* Gift of the society.

Limites de Flexibilité des Ressorts et Limites de Vitesse du Matériel des Chemins de Fer, Georges Marié. *Paris, Dunod & Pinat, 1911.*

Louisville and Nashville Railroad Company. 16th Annual Report, 1911. *Louisville, 1911.* Gift of Miss Helen Craig.

Mitteilungen über Forschungsarbeiten auf dem Gebiete des Ingenieurwesens. Pts. 10-13, 17-18, 20-106. *Berlin, 1903-1911.*

Modern Science Club of Greater New York. Year Book, May 1907. *1907.*

Municipal Electric Light Commissioners of Chicopee, Mass., Report to, C. W. Whiting. *Chicopee, 1911.* Gift of the author.

National Association of Railway Commissioners. Proceedings of 23rd Annual Convention, 1911. Gift of the association.

NATIONAL CONSERVATION CONGRESS, ADDRESSES AND PROCEEDINGS OF THE SECOND, 1910. *Washington, 1911.*

NEW ORLEANS SEWAGE AND WATER BOARD, 22ND, 23RD, SEMI-ANNUAL REPORT OF, *New Orleans, 1910–1911.* Gift of the board.

NIAGARA RIVER AND VICINITY (Map), 1901. Gift of Miss H. S. Welling.

NORWICH UNIVERSITY. Catalogue, 85th–92d year. *1903–1910.* Gift of the university.

———Roster of the Graduates and Past Cadets, 1819–1907. *Bradford, 1907.* Gift of the university.

PEI YANG UNIVERSITY. 4th Catalogue, 1910. *Tientsin, 1911.* Gift of the university.

PENNSYLVANIA STATE COLLEGE. General Catalogue, 1910–1911. *State College, 1911.*

———School of Engineering Announcement, 1911–1912. *State College, 1911.* Gift of the college.

POWER AND PLOW, L. W. Ellis and E. A. Rumely. *GardenCity, N. Y., Doubleday, Page & Co., 1911.* Gift of the authors.

This is probably the first work written on power plowing, and should be of especial interest for that reason. The treatment is elementary, but thorough. Although the investigation and study have had the support of a company making gasolene power engines for traction and general farm use, all reference to their product has been eliminated. The work is almost a necessity to those who are contemplating the use of power in soil cultivation, and contains much historical matter not easily found elsewhere. A two-page bibliography is given.

PRELIMINARY REPORTS ON THE DISPOSAL OF NEW YORK'S SEWAGE. Metropolitan Sewage Commission of New York, 1911.

PROBLEMS IN RAILWAY REGULATION, H. S. Haines. *New York, Macmillan Co., 1911.* Gift of the author.

This work is in a sense a continuation of the author's Restrictive Railway Legislation and his Railway Corporations as Public Servants. Its purpose, as stated in the preface, is to follow the course of railway regulation in this country, to consider the various ways in which the railways have affected the public welfare, and to offer some suggestions for future regulation. The author, a well-known railway authority and ex-president of the American Railway Association, has presented a work without bias, and singularly free from political argument. The appendix contains some very useful tables, notably the classification of the various subsidiary companies of the Interborough Metropolitan System and the index is unusually useful.

SCIENTIFIC AMERICAN. Vol. 38, (except title page); vol. 39, (except no. 1, and pp. 27–31, 45–46, and title page); vol. 40; vol. 41 (except no. 17); vols. 42–43; vol. 44 (except no. 6); vols. 45–46; vol. 47, (except nos. 17 and 19); vols. 48–50; vols. 51–53 (except title page); vols. 54–58; vol. 59 (except no. 10); vols. 60–61; vol. 62 (except no. 6 and title page); vols. 63–67; vols. 68–76 (except title pages); vols. 77–80; vol. 81 (except no. 21); vols. 82–83; vol. 84, lacks no. 24; vols. 85–86 (except title pages); vol. 87 (except no. 16 and title page), vol. 88 (except title page); vols. 89–91; vol. 92 (except title page); vol. 93 (except no. 1 and title page); vol. 94 (except no. 15); vols. 95–98; vol. 99 (except nos. 16, 23); vol. 100 (except no. 3); vol. 101. *New York, 1878–1909.* Gift of Miss H. S. Welling.

SCIENTIFIC AMERICAN SUPPLEMENT. Vols. 5–12; vol. 13 (except no. 319); vols. 14–25; vol. 26 (except no. 668); vols. 27–30; vol. 31 (except pp. 12503–4); vol. 32; vol. 33 (except nos. 840, 849); vols. 34–36; vol. 37 (except no. 951); vols. 38–44; vol. 45 (except no. 1172); vols. 46–50; vol. 51 (except no. 1328);

vols. 52–55; vol. 56 (except nos. 1437, 1447); vols. 57–59; vol. 60 (except no. 1539 and title page); vols. 61–63; vol. 64 (except no. 1651); vols. 65–68. *New York, 1878–1909.* Gift of Miss H. S. Welling.

———Catalogue of valuable papers contained in Supplement 1876–1902. Gift of Miss H. S. Welling.

TESTING OF MOTIVE POWER ENGINES, R. Royds. *London-New York, Longmans, Green & Co., 1911.*

**The author is lecturer on motive power engineering in the Glasgow and West of Scotland Technical College, and the book is intended for practical use by engineering students. It covers not only engines proper, but gas producers, refrigerating apparatus, fans and blowers, water turbines and pumps, and gives examples and forms for laboratory use.**

TRACK ELEVATION WITHIN THE CORPORATE LIMITS OF THE CITY OF CHICAGO, January 1909–June 1911. Compiled by Track Elevation Department of the City of Chicago. *Chicago.* Gift of the Commissioner of Track Elevation.

UNITED STATES PATENT OFFICE. Alphabetical Lists of Patentees and Inventions for quarter ending December 31, 1885. Gift of Capt. H. L. Prince.

WESTMINSTER COLLEGE. Catalogue, 1911. *Fulton, Mo., 1911.* Gift of the college.

ZEITSCHRIFT DES VEREINES DEUTSCHER INGENIEURE. Vol. 1; vol. 2, nos. 1–8, 11–12; vol. 3, nos. 1–2, 5–12. *Berlin, 1857–1859.*

## EXCHANGES

INSTITUTION OF CIVIL ENGINEERS OF IRELAND. Transactions, vol. 37. *Dublin, 1911.*

INSTITUTION OF NAVAL ARCHITECTS. Transactions, vol. 53, pt. 1. *London, 1911.*

NORTHEAST COAST INSTITUTION OF ENGINEERS AND SHIPBUILDERS. Transactions, vol. 27. *Newcastle-upon-Tyne, 1911.*

## TRADE CATALOGUES

GARDNER MACHINE CO., *Beloit, Wis.* Milling and grinding machines, 6 pp.

GENERAL ELECTRIC CO., *Schenectady, N. Y.* Bull. no. 4857, switchboard and high tension relays for alternating and direct current, 32 pp.; Bull. no. 4876, small plant direct current switchboards, 11 pp.; Bull. no. 4878, cloth pinions, 6 pp.; Bull. no. 4879, direct-current instruments, types D-7 and D-8, 12 pp.; Bull. no. 4882 enclosed flame arc lamps, 4 pp.; Bull. no. 4883, Curtis steam turbine generators, 50 pp.; Bull. no. 4884, lighting of iron and steel works, 39 pp.

HESS-BRIGHT MFG. CO., *Philadelphia, Pa.* Ball bearings in circular saws and jointing machines, 3 pp.

INGERSOLL-RAND CO., *New York.* Class N-E-1, air compressors, 12 pp.; Class N-F-1, air compressors, 12 pp.

MODEL HEATING CO., *Philadelphia, Pa.* Model boilers and radiators, 24 pp.

SHERWOOD MFG. CO., *Buffalo, N. Y.*, Steam and gasolene engine appliances, 62 pp.

UNDERFEED STOKER CO. OF AMERICA, *Chicago, Ill.* Publicity Magazine, October 1911, devoted to the interests of the Jones stoker, 16 pp.

# EMPLOYMENT BULLETIN

**The Society considers it a special obligation and pleasant duty to be the medium of securing better positions for its members. The Secretary gives this his personal attention and is most anxious to receive requests both for positions and for men available. Notices are not repeated except upon special request. Copy for the Bulletin must be in hand before the 12th of the month. The list of men available is made up of members of the Society and these are on file in the Society office together with names of other good men not members of the Society, who are capable of filling responsible positions. Information will be sent upon application.**

## POSITIONS AVAILABLE

**For the following kindly send application to the Society and we will forward.**

0125 Manager for firm manufacturing high-grade ball bearings desires assistant capable of handling office correspondence and sales propositions. Good opportunity for advancement for energetic and capable young man Location New York.

0126 Philadelphia concern desires two or three men capable of demonstrating the qualities of their product in the shops of customers; must have actual experience in shop work and with qualifications necessary for a salesman.

0127 Iron and steel chemist for New Jersey concern.

0128 Young mechanical engineer capable of taking charge of laying out details of cement machinery, involving structural steel work, installation of boilers, turbines, grinding machinery, etc. Position will pay $125 to $150 a month to start with good possibilities for promotion for right man. Location Middle West.

0129 Professorship at Northwestern University, salary $2700; appointee to take permanent charge in September 1912 of instruction in thermodynamics and engines and temporary charge of instruction in hydraulics. Communicate with John F. Hayford, Director, Evanston, Ill.

0130 Attention is called to Examination Order No. 288 for a mechanical engineer at a salary of $2500. Address application to Superintendent U. S. Naval Academy, Annapolis, Md., before Friday, December 15, 1911. Copies of the Order can be secured at office of the Society.

0131 Instructor in engineering mechanics to begin work in February. Salary $1100 to $1300 for college year. Prefer young mechanical engineer of two or three years' experience with good college record and who would like to teach. Location Michigan.

0132 Professor of mechanical engineering for Michigan college; salary $2500 to $2700. First requisite, character and abstemious habits, second, ability to teach well and inspire students. Must have capability for administration and if possible aptitude for original investigations.

MEN AVAILABLE

317 Experienced mechanical engineer desires engagement for part time; has specialized in hydraulics and power-house work.

318 Experienced superintendent, design and management in shop and field, desires to locate in Philadelphia or vicinity.

319 Member; technical education, with broad experience as master mechanic of different kinds of rolling mills and steel works, steam engineering and modern machine-shop practice, competent to take a position of traveling and introducing machinery.

320 Junior member, available January 15; age 27, eight years' experience in shop, drafting, purchasing and construction work; past three years mechanical engineer for holding company of public utilities on design, construction, economical operation, extensions, valuations, etc., desires position preferably offering opportunity for identification with business of manufacturing, consulting or contracting engineers, by later investment.

321 Member; technical education, seven years' experience as chief draftsman and superintendent of large engine company; at present construction engineer for large irrigation company.

322 Junior; technical education and training; testing department large electrical concern, operating and managing pumping station, drafting and designing; at present employed as draftsman and designer by hydro-electric company; would like to make connection as testing engineer in large manufacturing plant or as manager or assistant manager of power plant.

323 Mechanical engineer and expert, over 25 years' experience in designing, manufacturing and installation of special fine machinery, tools and specialties.

324 Associate; over 15 years' experience as draftsman, squad foreman, chief draftsman and checker on blast furnaces, steel, rolling, pipe and tube mills, coke ovens and chemical apparatus, open for engagement, preferably as assistant or chief draftsman, or assistant superintendent.

325 Associate; 18 years' experience in designing and building automatic machinery; also established a system for this class of work; 39 years of age; desires position as superintendent or assistant manager; at present employed.

326 Student member; recent technical graduate; practical experience in open-hearth steel plant, desires to locate with efficiency engineer or concern where there are possibilities for advancement.

327 Mechanical and structural engineer, with liberal experience in charge of drafting room, on design of furnaces and rolling mills; desires position as chief draftsman.

328 Mechanical engineer, technical graduate, Junior member; desires position in sales or purchasing department of industrial establishment. Experienced; can give references.

329 Member, superintendent, wide experience and familiar with modern machine-shop practice, expert on tools and methods for increasing production and reducing costs.

330 Member, mechanical engineer, technical graduate, six years' teaching experience, and four years' commercial experience, desires position as professor of mechanical engineering, or designing engineering or superintendent in commercial work. Experienced in design of steam and gas engines and hydraulic machinery, also teaching experience in machine design, shop work, steam engineering, hydraulics, mechanical laboratory, and industrial administration. At present employed.

331 Technical graduate with exceptional commercial experience with large central station and now in complete charge of New England business of mechanical draft concern, including handling of salesmen, desires position as assistant to sales manager.

## CHANGES IN MEMBERSHIP

### CHANGES IN ADDRESS

ADAMS, Kilburn E. (Junior, 1908), Mech. Engr., Boston & Albany R. R., Rm. 372, South Sta., Boston, and *for mail,* 1019 Washington St., Newtonville, Mass.

AHRNKE, H. P. (Junior, 1902), Dairy Mchy. & Constr. Co., Derby, Conn.

ALLISON, John Franklin (Junior, 1910), Clemson Agri. College, Clemson College, S. C.

ARMSTRONG, Walter J. (Junior, 1907), Mech. Engr., Jeffrey Mfg. Co., and *for mail,* 900 Neil Ave., Columbus, O.

ARMSTRONG, Wm. M. (Junior, 1894), Corrugated Bar Co., 402 Mutual Life Bldg., Buffalo, N. Y.

ATKINS, David Fowler (1907), 727 Custom House Bldg., New York, N. Y.

BACON, John Lord (1899; 1909), 1101 Am. Natl. Bank Bldg., San Diego, Cal.

BAENDER, Fred. Geo. (Junior, 1909), 1745 Seminary Ave., Fruitvale, Cal.

BAGG, Samuel F. (1896), Dist. Agt., The Fidelity & Casualty Co., Savings Bank Bldg., Troy, N. Y.

BAILEY, Frederic W. (Junior, 1901), Skaneateles, N. Y.

BALDWIN, Abram T. (1899: 1902), Life Member; V. P. and Treas., Precision Instrument Co., 49 Larned St. W., Detroit, and *for mail,* Washington Rd. and Maumee Blvd., Grosse Pointe, Mich.

BANNON, Leo Matthew (Junior, 1908), 32 Bagley St., Central Falls, R. I.

BARNES, Charles B. (1905; 1908), Asst. Wks. Engr., West. Elec. Co., Hawthorne Sta., Chicago, and *for mail,* 333 N. Harvey Ave., Oak Park, Ill.

BERG, Hart O. (1898; 1903), Engr., 72, Victoria St., Westminster, S. W., London, England, and *for mail,* 32 Ave. Des Champs-Elysées, Paris, France.

BEVIN, Sydney (Junior, 1909), Matheson Automobile Co., Wilkes-Barre, and *for mail,* Welles Ave., Forty Fort, Wilkes-Barre, Pa.

BIXBY, Genl. William H. (1888), Life Member; U. S. Engr., 735 Southern Bldg., Washington, D. C.

BLENCOWE, John (1900), 723 Edgemont Blvd., Los Angeles, Cal.

BOWER, J. G. (Associate, 1903), Hale & Kilburn Co., 605 McCormick Bldg., Chicago, Ill.

BRAY, Thos. Jos. (1898), Pres., Republic Iron & Steel Co., and 524 Wick Ave., Youngstown, O.

BUSHNELL, Leonard T. (Junior, 1906), Secy. and Treas., Rockwood Sprinkler Co., 208 Columbia St., Seattle, Wash.

BUTCHER, Joseph J. (1892), 33 Union Ave., South Framingham, Mass.

CHADWICK, Lee S. (1899; 1909), Bantam, Conn.

CHASTENEY, Charles D. (Junior, 1904), Turbine Equip. Co., 30 Church St., New York, N. Y.

CLARK, Howard B. (1910), East. Rep., The McNaull-Boiler Mfg. Co. of Toledo, O., 50 Lefferts Pl., Brooklyn, N. Y.

COMSTOCK, Charles Warren (Associate, 1906), Ins., 504 N. E. Bldg., Cleveland, O.

COOPER, Geo. S. (1909), Mech. Engr., Buckeye Eng. Co., Salem, O.

CORBETT, Chas. H. (1884), Manager, 1901–1904; V. P., Continental Iron Wks., and *for mail*, 147 Lefferts Pl., Brooklyn, N. Y.

COREY, Fred Brainard (1894; 1900), Union Switch & Signal Co., Swissvale, and *for mail*, 245 Maple Ave., Edgewood Park, Pa.

COX, Claude E. (Associate, 1907), Res. Mgr., Research Dept., Genl. Motors Co., and *for mail*, 120 Medbury Ave., Detroit, Mich.

DAHLSTRAND, Hans (1910), Mech. Engr., Steam Turbine Engrg. Dept., Allis-Chalmers Co., and *for mail*, 247 18th St., Milwaukee, Wis.

DARBY, John (1907), Con. and Designing Engr., 7 E. 42nd St., New York, N. Y., and *for mail*, 111 Summit Ave., Summit, N. J.

DEAN, Edmund Willard (1905), Duplex Ptg. Press Co., Battle Creek, Mich.

DE VED, Horace W. (Junior, 1908), Supt. of Distribution, N. Y. & Queens Elec. Light & Power Co., 244 Jackson Ave., Long Island City, and 140 Broadway, Flushing, N. Y.

DOANE, John Appleton (1910), Mgr., Worcester Piston Wing & Mch. Wks. 22 Commercial St., Worcester, Mass.

DONALDSON, Stuart A. (Junior, 1909), Mech. Dept., New Jersey Zinc Co., Palmerton, Pa.

DUNN, Charles (1897), 480 E. 19th St., Brooklyn, N. Y.

FAIRBANKS, Robert Noyes (Associate, 1895), Dutilh-Smith, McMillan & Co., 29 Great St. Helens, E. C., London, England.

FARRELL, W. Elliston (1900), Treadwell Engrg. Co., Easton, Pa.

FENNER, David C. (1906) Saurer Motor Co., 411 W. 55th St., New York, N. Y., and *for mail*, 705 Ravine Rd., Plainfield, N. J.

FESSENDEN, Chas. Horace (Junior, 1909), Instr. Mech. Egnrg., Univ. of Mich., 333 New Engrg. Bldg., and 727 Forest Ave., Ann Arbor, Mich.

FESSENDEN, Edwin A. (Junior, 1908), Asst. Prof. Mech. Engrg., Univ. of Mo., and *for mail*, 1331 Ross St., Columbia, Mo.

FORSYTH, William (1883), Manager, 1888–1891; Mech. Engr., Railway Age Gazette, 417 S. Dearborn St., and Windermere Hotel, Chicago, Ill.

GIBSON, Arthur (1892), Cons. Engr., P. O. Box. 35, Nome, Alaska.

GINGRICH, Charles Sumner (Junior, 1900), The Cincinnati Milling Mch. Co., Cincinnati, and *for mail*, 24 Landon Court, Avondale, Cincinnati, O.

GLEASON, Gilbert Howe (Junior, 1906), 12 Pearl St., Boston, Mass.

GRAVER, Alexander M. (Junior, 1908), Mech. Engr., Wm. Graver Tank Wks., East Chicago, Ind., and 436 W. 72nd St., Chicago, Ill.

GREER, Thomas W. (1902), Ch. Engr., Wilbraham-Green Blower Co. Pottstown, and *for mail*, 3465 Frankford Ave., Philadelphia, Pa.

GREGER, Henrik (Junior, 1904), Asst. Engr., Fred. M. Prescott Steam Pump Co., Milwaukee, Wis.

HADFIELD, Sir Robert Abbott, F.R.S., (1907), Chairman and Managing Dir., Hadfield Co., and *for mail*, Parkhead House, nr. Sheffield, also, Reform Club, Pall Mall, London, England.

HAMERSTADT, William D. (Junior, 1907), Engr., The Rockwood Mfg. Co., and *for mail*, 3209 Central Ave., Indianapolis, Ind.

HAMILTON, Edward Waterman (Junior, 1905), Mech. Engr., Harvey Hubbell, Inc., and *for mail,* 99 Lenox Ave., Bridgeport, Conn.

HAZELTON, Robert T. (Junior, 1909), Cincinnati Milling Mch. Co., Cincinnati, O.

HECHT, Julius Lawrence (1907), Mech. Engr., North Shore Elec. Co., 137 S. La Salle St., Chicago, and 2022 Harrison St., Evanston, Ill.

HEINEN, Emil Jennings (Associate, 1910), Ch. Mech. Estimator, Minneapolis Steel & Mchy. Co., and *for mail,* 3146 Longfellow Ave., Minneapolis, Minn.

HENES, Harry W. (Junior, 1909), A. Bolter's Sons, Rm. 612, 118 N. La Salle St., Chicago, Ill.

HIGGINS, Albert W. (Associate, 1906), present address unknown.

HODGINS, George S. (1908), 565 W. 139th St., New York, N. Y.

HUBBARD, Allen (1910), Cons. Engr., 88 Pearl St., Boston, Mass.

HYDE, Charles E. (1885), Marine Engr. and Naval Arch., 424 W. 20th St., New York, N. Y.

JAQUES, Wm. H. (1893), Hotel Puritan, 390 Commonwealth Ave., Boston Mass.

JOHNSON, Arthur E. (1890; 1892), Life Member; Designer, Ordnance Office, War Dept., Washington, D. C.

JOHNSON, Paul F. (1905), 628 Shepard Ave., Milwaukee, Wis.

JONES, W. Clyde (Junior, 1892), Lawyer, Genl. and Pat. Law, Rm. 1610, 105 W. Monroe St., Chicago, Ill., and 2 Rector St., New York, N. Y.

JUNKERSFELD, Peter (1910), Asst. to Second V. P., Commonwealth Edison Co., and *for mail,* 120 W. Adams St., Chicago, Ill.

KING, Roy Stevenson (1904; 1910), Engrg. Dept., Fairbanks Morse & Co. of Chicago, Ill., 1706 S. W., 9th St., Des Moines, Ia.

KOENIG, Adolph G. (Associate, 1909), Member of Firm, Mortensen & Co., 114-116 E. 28th St., New York, N. Y., and 43 Eldorado Pl., Weehawken, N. J.

KRAEMER, Milton (Junior, 1910), Assoc. Cons. Engr., U. S. Gold Dredging & Rubber Co. of Ecquador, S. A., 39 Liberty St., and *for mail,* 65 Park Ave., New York, N. Y.

LAMAR, Philip Rucker (1911), The So. Cotton Oil Co., Savannah Bank & Trust Co. Bldg., Savannah, Ga.

LARKIN, William H., Jr. (1904), Exec. Engr., C. W. Hunt Co., and *for mail,* 106 Bement Ave., West New Brighton, S. I., N. Y.

LEACH, William J., Jr. (1905), 7 Peabody St., Newton, Mass.

LEE, Ernest Eugene (Associate, 1908), Supt. of Erection, Dept of Constr. and Engrg., Isthmian Canal Com., Culebra, C. Z., Panama, C. A.

LEES, Ernest J. (1907), Pres. Lees-Bradner Co., 6210 Carnegie Ave., and *for mail,* 10,829 Superior Ave., Cleveland, O.

LEWIS, Joseph E. (Junior, 1899), Treas., Bush Mfg. Co., Hartford, Conn., and *for mail,* 222 N. Carey St., Baltimore, Md.

LIBBY, Malcolm M. (1902; 1905; 1909), Canadian Fairbanks Co., 28 W. Front St., Toronto, Ont., and *for mail,* Box 235, Edmonton, Alberta, Canada.

LINDSAY, W. Edward (1895), Cons. Engr., United Cork & Seal Co., Millis, and Box 21, Needham, Mass.

LOWE, Henry Leland (Junior, 1903), 37 Brady St., Detroit, Mich.

McDEWELL, Horatio S. (Junior, 1908), Gas Eng. Erecting Engr., Allis-Chalmers Co., Milwaukee, Wis., and *for mail,* 94 Addington Rd., Brookline, Mass.

McGWIRE, Charles H. (1909), 2828 Lafayette St., Denver, Colo.
MacGREGOR, Walter (1906), 236 S. Oak Park Ave., Oak Park, Ill.
MacLAUCHLAN, James H. (1907), J. H. MacLauchlan Engrg. Co., 205 W. Lombard St., Baltimore, Md.
MICHEL, Arthur Eugene (1906; Associate, 1908), Adv. Engr., Park Row Bldg. 21 Park Row, New York, N. Y.
MILLETT, Kenneth Ballard (Junior, 1908), Fairview St., Willimantic, Conn.
MIX, Edgar W. (1903), Mgr. European Div., Genl. Motors Export Co., 12 Blvd. des Invalides, Paris, France.
MOLÉ, Harvey E. (1901), Lenz & Molé, Rm. 1301, 55 Liberty St., New York, N. Y.
MONTEAGLE, Robt. Chas. (1904), Asst. Mgr. and Engr., The Lockwood Mfg. Co., East Boston, and *for mail*, 283 Highland Ave., West Newton, Mass.
MOORE, Albert B. (1903), Treas. and Genl. Mgr., Shedd Elec. Co., Inc., Roselle Park, and *for mail*, 145 Fourth Ave., E. Roselle, N. J.
MORRISON, Clarke J. (1909), Mgr. Engrg. Dept., Suffern & Son, 165 Broadway, New York, N. Y., and *for mail*, 191 N. Walnut St., East Orange, N. J.
MORSE, Arthur Holmes (1911), Mech. Engr. and Asst. Supt., The Baldwin Co., and *for mail*, 2202 Highland Ave., Cincinnati, O.
MORSE, Chas M. (1884), Ch. Engr., Buffalo Engrg. Co., 5 Beekman St., New York, N. Y.
NEWCOMB, Robert E. (Junior, 1907), Mech. Engr., Deane Steam Pump Co., and *for mail*, 229 Chestnut St., Holyoke, Mass.
NEWELL, William (Junior, 1907), Mech. Engr., Bureau of Factory Inspc., N. Y. State Dept. of Labor, 381 Fourth Ave., and 104 E. 54th St., New York, N. Y.
PARKER, John (1909), Mch. Designer, Brown & Sharpe Mfg. Co., Providence, and *for mail*, 1061 Narragansett Blvd., Edgewood, R. I.
PHELPS, Charles C. (Junior, 1909), Mgr. Castle Stevens, Stevens Inst. of Tech., and *for mail*, The Castle, Castle Point, Hoboken, N. J.
POMEROY, L. R. (1890; 1909), Cons. Engr., 246 Berkeley Ave., Orange, N.J.
RAMSAY, Herbert Hartley (Junior, 1910), Asst. Engr. with John Hays Hammond and Harris Hammond, 71 Broadway, and *for mail*, 15 E. 48th St., New York, N. Y.
RAYMOND, Herbert Emmons (Junior, 1906), Mech. Engr., Missisquoi Pulp Co., Sheldon Springs, Vt.
RIEGE, Rudolph (1911), 26 Gramercy Park, New York, N. Y.
ROBB, D. W. (1888), Pres., Robb Engrg. Co., Ltd., South Framingham, Mass.
ROBINSON, Garland P. (1902; 1909), Asst. Ch. Inspr., Interstate Commerce Com., First Natl. Bank Bldg., Columbus, O.
ROGERS, Robert W. (Junior, 1908), Asst. Engr. of Tests, Erie R. R., and *for mail*, 676 Baldwin St., Meadville, Pa.
ROUX, Paul (Associate, 1890), 9 rue des Bluets, Paris, France.
RUPP, M. E. (Junior, 1909), Mech. Engr., Stanley G. Flagg & Co., 1421 Chestnut St., Philadelphia, Pa., and *for mail*, 303 E. 4th St., New York, N. Y.
SANDO, Will J. (1899), Manager, 1908–1911; Cons. Engr., 67 Waldeck St., Dorchester, Mass.
SCHLESINGER, Georg, (1905), Prof. Engrg., Tech. Hochschule, Charlottenburg, 2, Berlinerstr. 171, Germany.

SCOTT, Clarence N. (1902), Cons. Engr., 1102 Carter Bldg., Houston, Tex.
SEARLE, Wilbur C. (Junior, 1909), Heald Mch. Co., and *for mail*, 178 Russell St., Worcester, Mass.
SHOUDY, Wm. Allen (Junior, 1903), Baltimore Copper Smelting & Rolling Co., Baltimore, and 19 Murymount Rd., Roland Park, Md.
SMEAD, William H. (Junior, 1906), Supt. Htg. and Equip. Dept., The Samuel Austin & Son Co., 6408 Euclid Ave., Cleveland, O.
SMITH, Charles P. (Junior, 1888), Lower Pacific Mills, and *for mail*, 11 Byron Ave., Lawrence, Mass.
SPENCER, Frank C. (Associate, 1908), West. Elec. Co., Hawthorne, and *for mail*, 1724 Washington Blvd., Chicago, Ill.
STONE, Mason A., Jr., (Junior, 1907), The Griscom Spencer Co., 90 West St. New York, and *for mail*, Clinton and Prospect Aves., New Brighton, S. I., N. Y.
STURGIS, Wm. Bayard (Junior, 1909), E. I. du Pont de Nemours Powder Co., Wilmington, Del.
SUMNER, Eliot (1910), King St., Northumberland, Pa.
SVENSSON, Johan Alfred (1909), Ingle Mch. Co., 371 St. Paul St., and 246 Park Ave., Rochester, N. Y.
THOMAS, Jay G. (Junior, 1906), Engrg. Dept., Westinghouse Mch. Co., East Pittsburgh, and *for mail*, 844 Rebecca Ave., Wilkinsburg, Pa.
THUMAN, Frederic (1900), Life Member; Ch. Engr., Humphreys & Glasgow, 36–38 Victoria St., Westminster, London, S. W., and 31 Campden Hill Court, London, W., England.
TITCOMB, George E. (1908), East Branch Sales Mgr., The McMyler Interstate Co., Rm. 1756, 50 Church St., New York, and 51 Hamilton Ave., New Rochelle, N. Y.
VAN TRUMP, Charles R. (1893; 1898), Life Member; 305 W. 8th St., Wilmington, Del.
VON PHUL, William (1907), Engr. in Charge, So. Properties, Ford, Bacon & Davis, Liverpool, London & Globe Bldg., and *for mail*, 496 Audubon St., New Orleans, La.
WEEKS, Paul (Junior, 1905), Mech. Engr., 216 Central Bldg., 6th and Main Sts., Los Angeles, Cal.
WHITE, James A. (Junior, 1900), Wks. Mgr., Worcester Pressed Steel Co., and *for mail*, 12 Clearview Ave., Worcester, Mass.
WILCOX, C. C. (Junior, 1905), Asst. to Cons. Elec. Engr., Hodenpyl, Hardy & Co., 1004 Majestic Bldg., and 463 Hamilton Ave., Detroit, Mich.
WILDER, Stuart (Associate, 1904), Asst. Eng., Westchester Ltg. Co., Mt. Vernon, N. Y.
WILSON, J. Fred (1891), Ret. Mfr., R. F. D., Box 69, Westboro, Mass.
WILLIAMSON, George E. (Junior, 1906), Ch. Engr., Strathmore Paper Co., Mittineague, and *for mail*, 141 Pineywoods Ave., Springfield, Mass.
WOLDENBERG, I. (Junior, 1903), Mgr., Ingersoll-Rand Co., m. b. H., Oststrasse 128–132, and Sternstrasse 20a, Düsseldorf, Germany.
YOUNG, Chas D. (1902; 1910), Engr. of Tests, Pa. R. R., Altoona, Pa.
YOUNG, E. R. (Junior, 1900), 553 Mifflin Ave., Wilkinsburg, Pa.

### NEW MEMBERS

ALMQUIST, Karl (1911), Ch. Draftsman, A. S. Cameron Steam Pump Wks., foot E. 23rd St., and *for mail*, 408 W. 150th St., New York, N. Y.

McINTOSH, Walter S. (Associate, 1911), Asst. Supt., S. A. Woods Mch. Co., Boston, and *for mail*, 29 Westover St., West Roxbury, Mass.

### DEATHS

BULKLEY, Henry W., November 7, 1911.
JOHNSON, Henry James, October 8, 1911.
MORRISON, Hugh Stockdell, August 3d, 1911.

# COMING MEETINGS

## November–December

**Advance notices of annual and semi-annual meetings of engineering societies are regularly published under this heading and secretaries or members of societies whose meetings are of interest to engineers are invited to send such notices for publication. They should be in the editor's hands by the 15th of the month preceding the meeting. When the titles of papers read at monthly meetings are furnished they will also be published.**

AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE
December 27–January 3, annual meeting, Washington, D. C. Secy., L. O. Howard, Smithsonian Institution.

AMERICAN CHEMICAL SOCIETY
December 27–30, annual meeting, Washington, D. C. Secy., C. L. Parsons, Durham, N. H.

AMERICAN INSTITUTE OF ARCHITECTS
December 12–14, annual convention, Washington, D. C. Secy., Glenn Brown, The Octagon.

AMERICAN INSTITUTE OF CHEMICAL ENGINEERS
December 20–22, annual meeting, Washington, D. C. Secy., J. C. Olsen, Polytechnic Institute, Brooklyn, N. Y.

AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS
December 8, monthly meeting, New York. Acting Secy., F. L. Hutchinson, 29 W. 39th St.

AMERICAN PUBLIC HEALTH ASSOCIATION
December 4–9, annual meeting, Havana, Cuba. Secy., W. C. Woodward, Washington, D. C.

AMERICAN SOCIETY FOR MUNICIPAL IMPROVEMENTS
December 11–13, annual meeting, Waldorf-Astoria, New York. Secy., A. P. Folwell, 239 W. 39th St.

AMERICAN SOCIETY OF AGRICULTURAL ENGINEERS
December 27–29, annual meeting, St. Paul, Minn. Secy., J. B. Davidson, Ames, Iowa.

AMERICAN SOCIETY OF ENGINEERING CONTRACTORS
January 9, annual meeting, New York. Secy., J. R. Wemlinger, 13 Park Row.

AMERICAN SOCIETY OF HEATING AND VENTILATING ENGINEERS
January 23–25, annual meeting, New York. Secy., W. W. Macon, 29 W. 39th St.

AMERICAN SOCIETY OF REFRIGERATING ENGINEERS
December 4, annual meeting, New York. Secy., W. H. Ross, 154 Nassau St.

ASSOCIATION OF AMERICAN PORTLAND CEMENT MANUFACTURERS
December 11–13, annual meeting, New York. Secy., P. H. Wilson, Land Title Bldg., Philadelphia, Pa.

ENGINEERS CLUB OF ST. LOUIS
December 6, annual business meeting, 3817 Olive St., St. Louis, Mo. Secy., W. W. Herner.

NATIONAL ASSOCIATION OF BRASS MANUFACTURERS
December 13–14, annual meeting, New York. Secy., W. M. Webster, 64 W. Randolph St., Chicago, Ill.

NATIONAL GAS AND GASOLINE ENGINE TRADES ASSOCIATION
December 5–8, annual meeting, Hotel Hollenden, Cleveland, O. Secy., A. Stritmatter, 224 E. 7th Ave., Cincinnati.

NATIONAL IRRIGATION CONGRESS
December 5–9, Chicago, Ill. Secy., Arthut Hooker, 830 Commercial National Bank Bldg., Chicago, Ill.

NEW ENGLAND WATER WORKS ASSOCIATION
January 10, annual meeting, Hotel Brunswick, Boston, Mass. Secy., Williard Kent, Narragansett Pier, R. I.

WOOD PRESERVERS' ASSOCIATION
January 16–18, annual meeting, Chicago, Ill. Secy., F. J. Angier, Mount Royal Station, Baltimore, Md.

## MEETINGS IN THE ENGINEERING SOCIETIES BUILDING

| Date | Society | Secretary | Time |
|---|---|---|---|
| December | | | |
| 5–8 | American Society of Mechanical Engineers | C. W. Rice | All day |
| 7 | Blue Room Engineering Society | W. D. Sprague | 8.15 p.m. |
| 8 | American Institute of Electrical Engineers | F. L. Hutchinson (Acting Secy.) | 8.15 p.m. |
| 14 | Illuminating Engineering Society | P. S. Millar | 8.00 p.m. |
| 15 | New York Railroad Club | H. D. Vought | 8.15 p.m. |
| 19 | New York Telephone Society | T. H. Lawrence | 8.15 pm. |
| 27 | Municipal Engineers of New York | C. D. Pollock | 8.15 p.m. |
| January | | | |
| 4 | Blue Room Engineering Society | W. D. Sprague | 8.00 p.m. |
| 9 | American Society of Mechanical Engineers | C. W. Rice | 8.15 p.m. |
| 11 | Illuminating Engineering Society | P. S. Millar | 8.15 p.m. |
| 12 | American Institute of Electrical Engineers | F. L. Hutchinson (Acting Secy.) | 8.00 p.m. |
| 16 | New York Telephone Society | T. H. Lawrence | 8.15 p.m. |
| 19 | New York Railroad Club | H. D. Vought | 8.15 p.m. |
| 23–25 | American Society of Heating and Ventilating Engineers | W. W. Macon | All day |
| 24 | Municipal Engineers of New York | C. D. Pollock | 8.15 p.m. |

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*Meetings*
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Note—Numbers in parentheses indicate number of years the member has yet to serve.

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## SPECIAL COMMITTEES

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*Sub-Committee on Steam of Research Committee*

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*Constitution and By-Laws*

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*Engineering Standards*

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*Standardization of Catalogues*

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San Francisco, Cal.
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*Committee to Formulae Standard Specifications for the Construction of Steam Boilers and other Pressure Vessels and for Care of Same in Service*

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C. H. MEINHOLTZ
R. C. CARPENTER
W. H. BOEHM
R. HAMMOND

NOTE—Numbers in parentheses indicate number of years the member has yet to serve.

## SPECIAL COMMITTEES

*(Continued)*

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D. M. BATES
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H. H. VAUGHAN

## MEETINGS OF THE SOCIETY

### *The Committee on Meetings*

L. R. POMEROY (1), *Chmn.*
C. E. LUCKE (2)
C. J. H. WOODBURY (5)
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### *Meetings of the Society in Boston*

I. N. HOLLIS, *Chmn.*
I. E. MOULTROP, *Secy.*
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### *Meetings of the Society in New York*

W. RAUTENSTRAUCH, *Chmn*
F. A. WALDRON. *Secy.*
R. V. WRIGHT
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### *Meetings of the Society in St. Louis*

E. L. OHLE, *Chmn.*
F. E. BAUSCH, *Secy.*
J. HUNTER
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### *Meetings of the Society in San Francisco*

A. M. HUNT, *Chmn.*
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### *Meetings of the Society in Philadelphia*

T. C. McBRIDE, *Chmn.*
D. R. YARNALL, *Secy.*
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### *Meetings of the Society in New Haven*

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### SUB-COMMITTEES ON

### *Textiles*

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DANIEL M. BATES, Wilmington, Del.
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EDW. W. FRANCE, Philadelphia, Pa.
EDWARD F. GREENE, Boston, Mass.
FRANKLIN W. HOBBS, Boston, Mass.
C. R. MAKEPEACE, Providence, R. I.
C. H. MANNING, Manchester, N. H.
HENRY F. MANSFIELD, Utica, N. Y.

EDWARD W. THOMAS, *Secy*, Lowell, Mass.

Note—Numbers in parentheses indicate the number of years the member has yet to serve.

## MEETINGS OF THE SOCIETY

*(Continued)*

### *Cement*

W. R. DUNN, *Chmn.*
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# THE JOURNAL

## THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS

DECEMBER 1911

85 CENTS A COPY $3 A YEAR

ANNUAL MEETING, NEW YORK, DECEMBER 5-8.
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# THE JOURNAL
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## CONTENTS



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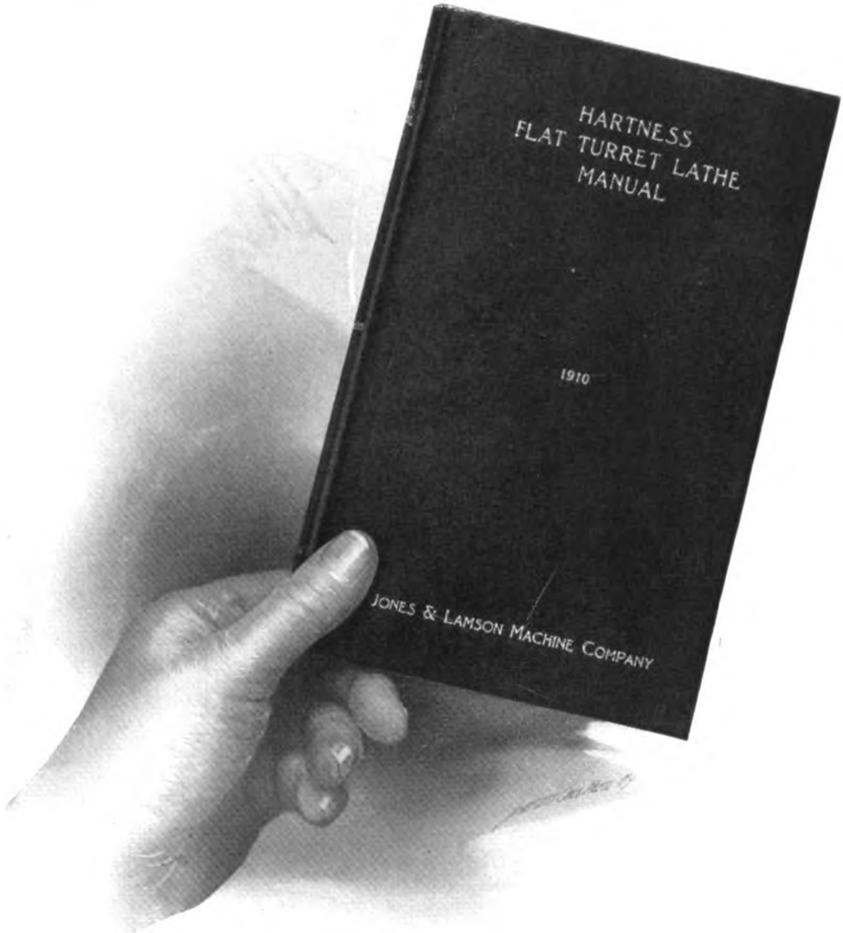
The Society as a body is not responsible for the statements of facts or opinions advanced in papers or discussions. C55.

# This Book is for the Operator

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# The Best is None Too Good

an extract from the report of D. A Morris, Metallurgist, read at a meeting of the Sales Representatives of the Nelson Valve Company : : : : Philadelphia

A Professor of Mechanical Engineering in one of our leading universities once said in the course of his lectures, "What is *good enough* is best." It made a great hit and was quoted continually about the campus. It sounds all right; it certainly looks as if things which are *good enough* must be the best, taking all things into consideration.

Since coming to this plant, however, I have had occasion to think over this phrase many times. When I first came here I had little to do and I saw many things which set me to thinking. Only the best materials were being used for our Bronze and Iron mixtures; Lake Copper instead of the cheaper brands; Straits Tin, which is the best that can be procured, and the best brands of Refined Spelter and Lead. In the Iron Foundry, 2X Iron and Selected Machinery Scrap were used, while nothing but the best coke, namely: 72-hour Connellsville, was used in the cupola. Only the best castings passed from the foundry to the Machine Shop. Very often the defect was so slight that it could be detected only by the closest inspection. In the Machine Shop again castings were scrapped because of some slight flaw showing up in the machining and finally, when these thoroughly inspected valves were put under the hydraulic test, others were thrown out, if the slightest sweat developed.

The thought came to me that if "What is good enough is best," why could not cheaper materials be used in our Bronze and Iron mixtures? Other valve concerns used them and their valves were being sold. Secondly, would not some of those valves thrown out in the Iron Foundry and in the Machine Shop stand the test just as well as those which had passed inspection; and finally, would not many of the valves which developed only the slightest sweats under these severe hydraulic tests answer all practical purposes. They might have; but I soon found that Mr. Mason's policy, and therefore the policy of this Company, was not "What is good enough is best" but "The best is none too good." Theoretically, "What is good enough is best" is all right, but how is one to determine what is good enough? Our way is to use the best and be on the safe side.

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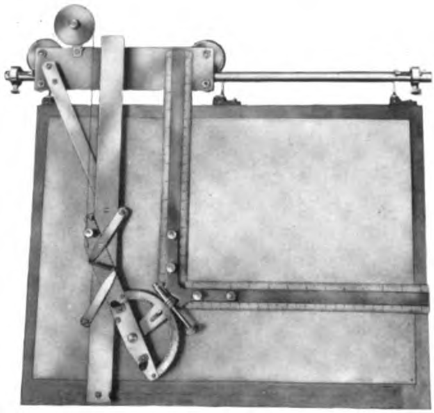

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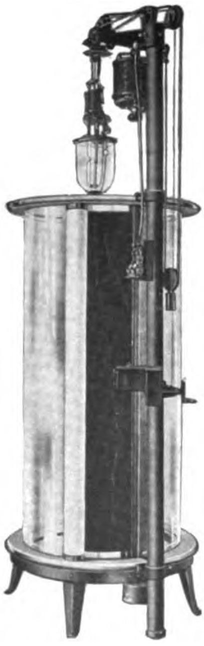

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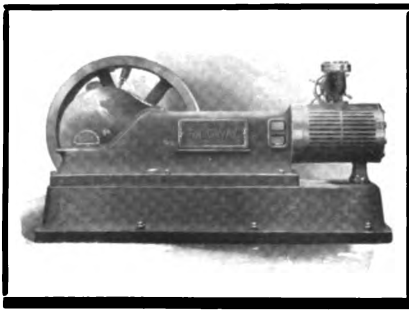

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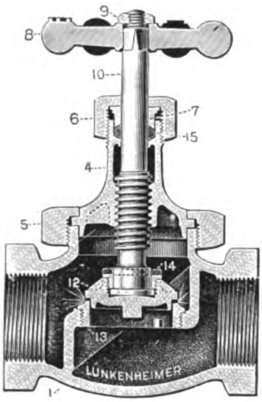


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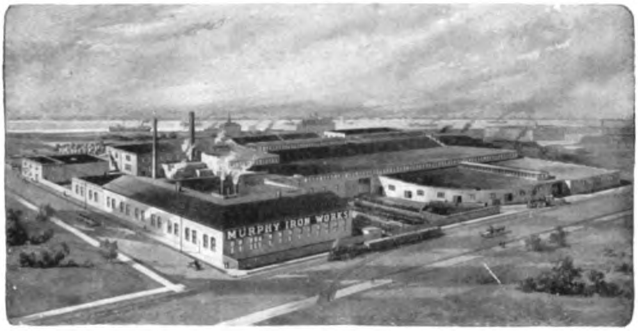


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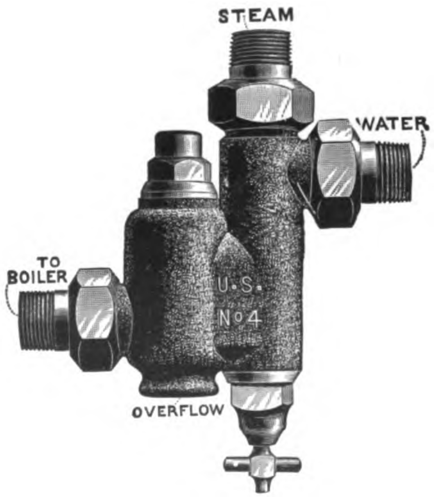


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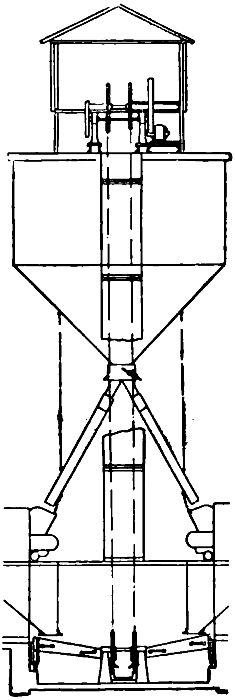

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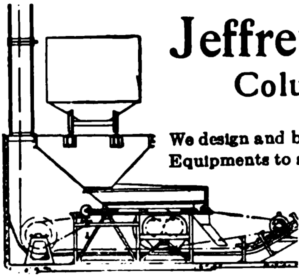

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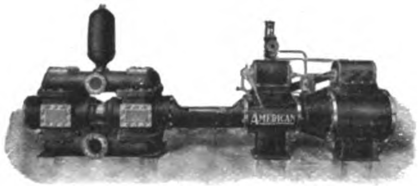


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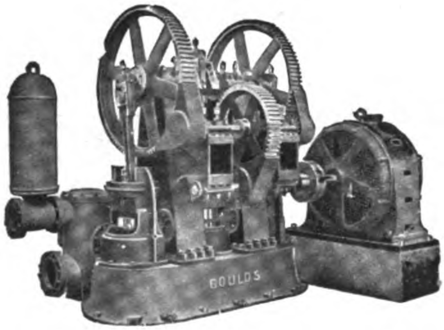


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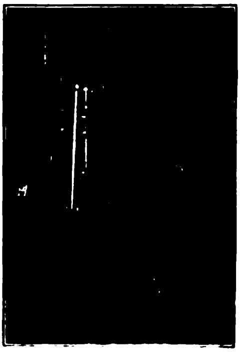

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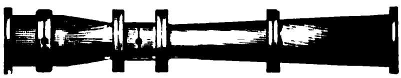

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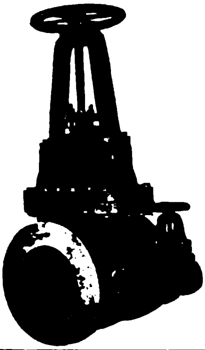

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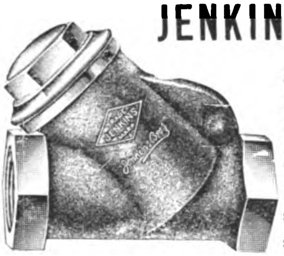

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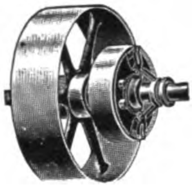





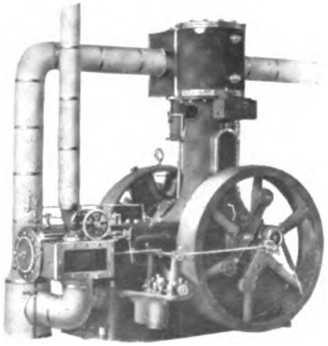

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