The Locomotive

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J. B. Pierce.

Joseph Bancroft Pierce.

It is with the deepest sorrow that we record the death of Joseph Bancroft Pierce, who had been secretary of the Hartford Steam Boiler Inspection and Insurance Company for nearly thirty-five years. He had been in poor health for several weeks, but the end was quite unexpected, for he had been confined to his home in Hartford for only four days when, on November 12, 1907, he died of pneumonia.

The story of Mr. Pierce's life is a simple one, devoid of incidents likely to stimulate the imagination, or even to attract more than passing notice from the world about him. It is the story of a genial, lovable gentleman, who was content to perform, each day, the task of that day, and who found his highest reward in the consciousness that the work that was done was done well.

Mr. Pierce was born October 13, 1835, in the town now known as Thomaston, Connecticut, but which, previous to 1875, formed a part of Plymouth, and was known as Plymouth Hollow. His parents were Hiram and Charlotte S. (Bancroft) Pierce. He was educated at Thomaston, where he attended the high school and academy.

About the time of his leaving the academy he was stricken with a serious pulmonary affection, and in 1854, at the age of nineteen, he came to Hartford for medical treatment, remaining in the city about a month. At the end of this period, his health being materially improved, he returned to Plymouth Hollow, where he worked for a time with the Seth Thomas Clock Company. In November, 1855, he took up his residence permanently in Hartford, entering the employ of Rogers Brothers, manufacturers of silver-plated ware. In the late spring or early summer of 1856 he left this position, and for two years thereafter he worked as bookkeeper in S. W. Griswold's shawl and mantilla store, which was situated on Main Street, opposite Church. In August, 1858, he returned to the silverware business, the name of the company having been changed in the meantime from Rogers Brothers to The Rogers Brothers Manufacturing Company. For a short time previous to 1860 he also worked as bookkeeper in a bank; and in 1860 he entered the insurance business for the first time, as bookkeeper for the North American Fire Insurance Company. Here he found his true field of activity, and his promotion was rapid. He was advanced from time to time, until, in 1868, he was made secretary of the company. He remained with the North American Fire Insurance Company until its extinction by the great Chicago fire of October, 1871, after which he entered the new National Fire Insurance Company as general agent, serving in this capacity until March, 1873.

On February 15, 1873, Mr. Pierce was elected secretary of the Hartford Steam Boiler Inspection and Insurance Company, the appointment dating from March 1, 1873; but while he became the secretary of the company on that date, he did not assume the active duties of the office until March 22. He first officiated as clerk of the board of directors of the company at the meeting held on May 13, 1873; and only two of the present fifteen members of the board have been present at its meetings for an equal length of time. He was himself elected a director on February 13, 1900.

On March 22, 1898, the twenty-fifth anniversary of his entering upon the actual work of the secretaryship, the officers and clerks of the Hartford Steam Boiler Inspection and Insurance Company presented him with a solid silver service, as a token of the regard that was felt for him by his intimate business associates; and on October 13, 1905, in recognition of his seventieth birthday, an informal reception was given to him at the home office, and he was presented with a beautiful bouquet of seventy roses.

Mr. Pierce was a republican in politics, but had never held any political office. Indeed, he was of so retiring a disposition that the publicity inseparable from such a position would have been exceedingly distasteful to him. He was a member of the Fourth Congregational Church of Hartford, and had been president of its board of trustees from the time the church was incorporated. He was, in fact, the leading layman in the church, and he had given great personal attention to the musical features of its services in particular, although his influence extended to all its departments. He was deeply interested in the mission work done by the institution now known as Warburton Chapel. He joined it in November, 1854, at which time it was known as the Union Sunday School, and occupied Washington Hall, on State Street. He became assistant superintendent of the organization about 1858 or 1859, and continued his active connection with it until October, 1880, when he withdrew from personal participation in the work, though his interest in it was always sustained. Here, as in the Fourth Church, he gave especial attention to the musical part of the services.

Mr. Pierce was universally admitted to be one of the highest authorities upon steam boiler inspection and insurance. He wrote nothing upon the subject, however, but was content to apply his knowledge solely to the advancement of the company with which he was identified. He was a man of strongly scientific tastes, and in earlier life he devoted much time to microscopic work, and particularly to the study of the various forms of animal and vegetable life that occur in the vicinity of Hartford. Indeed, his eyesight was somewhat affected from this cause at one time, though the impairment was not permanent. There can be little doubt but that his microscopic work, taken in connection with his other scientific tendencies, constituted one of the earliest bonds of friendship between himself and Mr. J. M. Allen, through whom Mr. Pierce became secretary. In later years he was forced to discontinue his microscopic work, but he maintained, to the last, the keenest interest in scientific progress along all lines, and he enjoyed nothing more than listening to an account of recent investigations in any field of knowledge whatever.

It is impossible to convey any fair conception of Mr. Pierce's personal character to those who did not know him well. It would not be easy to exaggerate his kindness, nor his charity toward the faults and shortcomings of others; and no man could apply the principles of the Christian faith more conscientiously than he did, to the practical affairs of common life. He was unobtrusive to the last degree, and was of the select few who "meet in secret to plot charity to the poor." His known material gifts and benefactions were numerous and large; and it is certain that the unknown occasions on which he has extended a helping hand to the needy are past all reckoning. The world is better for his life, and his influence will long be felt, not only in obvious ways and places, but in many that are hidden and unsuspected.

On February 18, 1862, Mr. Pierce was married to Sophia A. Boardman, of Hartford, who died on January 18, 1904. He leaves an only daughter, Mrs. Arthur H. Merry, of Augusta, Georgia, two brothers, William J. and Edward H., of Hartford, and two sisters, Mrs. Charlotte S. Potter of Thomaston, and Mrs. E. T. Bradstreet of Meriden.

At a special meeting of the board of directors of the Hartford Steam Boiler Inspection and Insurance Company, held on November 14, 1907, the following minute was adopted, and a copy thereof, suitably engrossed, was transmitted to Mr. Pierce's family:

"In the death of Joseph Bancroft Pierce, the Hartford Steam Boiler Inspection and Insurance Company has lost an officer of great ability, who gave the best years of a noble life to the establishment of the company upon a secure foundation, and to the formation of sound precedents for its future guidance. He became Secretary of the company on March 1, 1873, and was elected a director on February 13, 1900.

"Mr. Pierce was quiet and unobtrusive, yet his influence was felt in every detail of the company's business. His life exemplified all the Christian virtues in the fullest measure. His character was simple and sincere, and his considerate bearing towards his office subordinates won for him a regard which ripened with the years into devoted affection.

"His associates on this board desire to testify their appreciation of the loss which the death of Mr. Pierce has occasioned to this company, and hereby direct the assistant secretary to send to the family of Mr. Pierce a copy of this minute."

A special service, in memory of Mr. Pierce, was held at the Fourth Congregational Church of Hartford, on November 17, the Sunday following his death. At this service the pastor, Rev. H. H. Kelsey, paid a touching and well merited tribute to Mr. Pierce's high character, and spoke feelingly of his services to the church, and of his influence upon the community in which he lived. Mr. L. B. Brainerd, President of the Hartford Steam Boiler Inspection and Insurance Company, also made a brief address, in which he dwelt upon Mr. Pierce's life as it was seen by a layman, and a fellow-officer of the company. We understand that both addresses are to be published in a memorial pamphlet, for distribution among Mr. Pierce's personal friends. We believe, however, that President Brainerd's remarks will be of interest to a wider circle than it will be possible to reach with the pamphlet alone, and hence we print them below.

President Brainerd's Remarks at the Memorial Service.

"It is not possible for me to speak of the life and work of my departed friend and associate, Mr. Pierce, as the work he performed and the life he lived richly deserve. Mr. Pierce was an exceptional man in many ways. He was a man who was willing to give his time and thought to the little things of life, content to serve in obscure and lowly places, unobserved, and to minister unto those who could do nothing for him in return. He was never too busy to receive and confer with a friend, nor in any haste to be free and return to the work in hand; but although he has been gone but a few days, you have been looking, and I have been looking, and we shall all look in vain, for a man qualified to take his place, and do the kind and the volume of work that he did, and do it as perfectly as he performed it. Nor did we think of him as a large man; but now that he has gone, Oh, how large the vacancy seems, and how hard it will be to fill acceptably the place that he occupied.

"He was a simple man, of gentle mien, and as he lived and walked without pomp or display, so he toiled and wrought without thought of applause; and the great world has taken little note of the many things that he has done, and of the services rendered by him that are imperishable, and that will exert an influence throughout eternity.

"It is hardly necessary for me, especially in this place and in the presence of his own people, to speak at length or in detail of his character, or of his various activities in the interest of humanity. You well know of the integrity and simplicity of his life, and of his abiding faith in the benevolence of his God, and of his determination to serve Him by the use of his talent and the means at his command. His sympathies were deep and responsive, and they went out as freely as the air toward the humble poor and the unfortunate. His means were freely dispensed to relieve the distress of the deserving needy. His voice was always raised in defense of the erring, and to encourage the straying ones back into the path of rectitude and usefulness. His hand was always extended in kindly assistance toward the man beneath him.

"And how often I have heard him speak of this church:— of its great mission, and of the work it is carrying forward, and of his solicitude for its future. I know something of the part he took in establishing and in maintaining the facilities for carrying on the work in which this church is especially engaged. We can see, all about us, the expression of many of his thoughts, and the completion of many of his plans. The very richness of their simplicity and stability fittingly typify the character of the man, and they are in striking accord with the melody of his great soul. These are the monuments that, by the life he lived, he erected unto himself; and they shall endure although he may perish. These are some of the things that he did; and these and others of like character are the only things that count when the value and usefulness of a man's life are to be measured.

"I desire to say a word concerning his every-day life,— concerning his life as it was seen by his associates. He came into the service of the company with which he was connected at the time of his death, early in 1873, in the zenith of his strength and power. He fully justified the confidence in which, without prior connection therewith, or experience in its particular line, he was offered the secretaryship of the company, which position he filled at the time of his death. During the nearly thirty-five years of continuous service, he has given the company the best of all he possessed. Every duty has been carefully and conscientiously discharged; every corporate act has received the impress of his sterling integrity; in every decision there were inherent the elements of justice and equity. Although filling a position vested with the right of command, he never exercised that right as one in authority, but always in a manner so considerate that seemingly all were at once placed on an equality. His name and the history of his life can never be dissociated from that of the company he served so long and so faithfully. As his years advanced and his strength waned, the company grew; and it will ever stand as a monument to his devotion, to his ability, and to his integrity. Others may sit in his chair and appropriate to themselves his title, but they will not succeed him. In a broad sense, no man will ever succeed Mr. Pierce. The foundations that he assisted in laying, the business that he assisted in establishing, the labor that he performed so well and so perfectly, will abide; and the most that remains for others to do is to take up the work where he laid it down, and carry it on as he would carry it on

"I desire to personally testify to his faithfulness and loyalty, and to the great value and influence of his life upon myself and upon his other associates. He was always ready to assist those below him, and he was never jealous of those above him in authority. He was a man of perfect poise, never greatly elated, never unduly depressed, always calm and under self-control in an emergency; and all his emotions seemed adjusted to a dead level.

"In the death of Joseph Bancroft Pierce more than an ordinary loss has been sustained, more than an ordinary man has fallen, more than an ordinary record of deeds well and faithfully performed has passed on for review and for reward; and we can rest assured that a place of high honor will be assigned to him among those who have wrought most valiantly for the Master."

Boiler Explosions.

AUGUST, 1907.

(266.) — The boiler of a Pennsylvania railroad freight locomotive exploded, August 1, in the yards at Urbana, Ohio. Engineer L. W. Chamberlain, fireman P. F. Weisner, and brakeman C. A. Stewart were instantly killed.

(267.) — A tube ruptured, August 2, in a water-tube boiler at the blast furnace of the Thomas Furnace Co., Milwaukee, Wis.

(268.) — The boiler of a threshing outfit blew up, August 2, on a farm just west of Coshocton, Ohio. W. D. Palmer and George Best were seriously injured.

(269.) — A slight boiler explosion occurred, August 3, at the restaurant of the Horn & Hardart Baking Co., Philadelphia, Pa.

(270.) — On August 3 a boiler ruptured in the plant of the Beatrice Creamery Co., Lincoln, Neb.

(271.) — A tube ruptured, August 4, in a water-tube boiler at the plant of the Kosmos Portland Cement Co., Kosmosdale, Ky.

(272.) — The boiler of a Santa Fe freight locomotive exploded, August 5, near El Toro, Cal. Fireman R. O. O'Connell was killed instantly, and conductor Frank Phillips died on the following day. Engineer G. P. Luce was also terribly burned.

(273.) — The boiler of a shifting locomotive exploded, August 7, in the yards of the Reading railway, at Bridgeport, Pa. Engineer Harry Smith and fireman Emil George were severely injured.

(274.) — On August 7 a tube ruptured in a water-tube boiler at the compressor plant of the Cleveland Stone Co., North Amherst, Ohio. Peter Stouvik, fireman, was slightly injured.

(275.) — A boiler exploded, August 8, in the Sandoval & Carillo sawmill, near Mora, N. M. Maximilano Martinez was instantly killed, and two other men were injured.

(276.) — A tube ruptured, August 10, in a water-tube boiler at the power house of the Louisville Railway Co., Campbell and Jacob Sts., Louisville, Ky. Richard Turnstile was badly scalded.

(277.) — A boiler exploded, August 12, in the Merriam & Humquist grain elevator, Omaha, Neb. One end of the elevator was blown out.

(278.) — A cast-iron steam pipe, located between the boiler and the first stop valve, exploded, August 14, in the plant of the Grand Rapids Railway Co., Grand Rapids, Mich.

(279.) — A boiler exploded, August 14, in a laundry at Dubuque, Iowa. Fire followed, and the total loss was heavy.

(280.) — On August 14 a boiler exploded in Shaffer's shingle mill, at Dadeville, Ala. Thomas McCarty and William Graves were instantly killed, and McCarty's wife was seriously injured.

(281.) — The boiler of locomotive No. 2686, of the Southern Pacific railway, exploded, August 15, near the shops at Tucson, Ariz. C. H. Varney was fatally injured, and Charles Gomez, E. L. Lopez, and Manuel Marquez were injured seriously but not fatally.

(282.) — A slight rupture occurred, August 16, in a boiler at the works of the Lebanon Bottling, Water & Ice Co., Lebanon, Tenn.

(283.) — A tube ruptured, August 16, in a water-tube boiler at the No. 2 mill of the Bryant Paper Co., Kalamazoo, Mich. Daniel Pikkaart was injured.

(284.) — Two boilers exploded, August 16, in the plant of the Autauga Lumber Co., at Spur, on the Mobile & Ohio railway, fifteen miles from Prattville, Ala. Engineer Thomas Cherry was instantly killed, and three other men were fatally injured. Seven men also received lesser injuries, and the plant was wrecked.

(285.) — A boiler ruptured, August 19, in Bossmeyer Brothers' grain elevator, Abdal, Neb.

(286.) — On August 21 a cast-iron header fractured in a water-tube boiler in the Germania Bank, New York city.

(287.) — Six cast-iron headers ruptured, August 21, in a water-tube boiler at the power house of the Valley Electric Co., New Brighton, Pa.

(288.) — On August 22 twelve cast-iron headers ruptured, in three water-tube boilers, at the "Listers Plant" of the American Agricultural Chemical Co., Newark, N. J. The accident was due to low water.

(289.) — The boiler of a hoisting engine exploded, August 23, on the barge *Paterson*, at the foot of Seventeenth St., Hoboken, N. J. John Dyer, Lawrence Fitzsimmons, Charles A. Gibbons, Edward Harche, Maurice N. Hopkins, and Claude Neiff were killed, and Oliver Brightman received injuries which were thought to be fatal. Three other men, named Fitzsimmons, Diager, and Meis, also received minor injuries.

(290.) — The boiler of a threshing outfit exploded, August 24, near Bowling Green, Ohio. Herbert Parkason, owner of the outfit, was injured so badly that he died a few hours later, and the outfit itself was destroyed.

(291.) — On August 25 a flue failed in the boiler of a steam launch on Lake Hamilton, near Ludington, Mich.

(292.) — The boiler of locomotive No. 1014, of the Central of Georgia railway, exploded, August 25, at Raccoon Mills, near Summerville, Ga. Engineer Hutchins and brakeman Welches were instantly killed, and fireman John Borders was fatally injured. The locomotive was wrecked.

(293.) — A tube ruptured, August 26, in a water-tube boiler at the Philadelphia Rapid Transit Co.'s power house, Beach and Laurel Sts., Philadelphia, Pa.

(294.) — A slight rupture occurred, August 26, in a boiler at the plant of the American Insulating Material Mfg. Co., Alexandria, Ind.

(295.) — A boiler exploded, August 26, in Robbins & Spencer's flouring and feed mill, Scranton, Pa. Charles W. Robbins and Hilda Ziegler received injuries which were said to be fatal, and Frederick Stevens and Samuel Seimalla were injured seriously but not fatally. Fire followed the explosion, and the total property loss was estimated at $125,000.

(296.) — A boiler exploded, August 26, in Dr. A. M. Kalback's sawmill, near Pondsville, some eight miles north of Hagerstown, Md. George W. Beard was killed instantly, Samuel Shirley and Elmer Stevens were injured so badly that they died within a few hours, and Edward Ridenour was injured seriously but probably not fatally.

(297.) — On August 27 a tube ruptured in a water-tube boiler in the Des Moines Edison Light Co.'s power station, Des Moines, Iowa. Chief engineer E. E. Blackmar was injured so badly that he died a few days later.

(298.) — A tube ruptured, August 28, in a water-tube boiler at the Savery hotel, Des Moines, Iowa. Frederick G. Kelley and John M. Price were severely injured, the former dying a few days later. Chief engineer Ernest Bailey and fireman C. Friday were also slightly injured.

(299.) — The boiler of a dinkey engine exploded, August 28, on the tram road of the Jackson Coal & Coke Co., at Emmart station, near Elkins, W. Va. Theodore Miller was killed, and J. P. Hardrix, Clarence Lowther, Melvin Allen, Okey C. Carder, and Michael Yandi were injured, some of them fatally. The explosion appears to have been due to the locomotive plunging to the ground from a trestle.

(300.) — A number of tubes failed, August 30, in a water-tube boiler at the Municipal Electric Light plant, Richmond, Ind.

(301.) — Nine cast-iron headers fractured, August 31, in a water-tube boiler at the lighting and ice plant of the Muskogee Gas & Electric Co., Muskogee, Ind. T. Fireman M. Dumas was slightly injured.

(302.) — On August 31 a tube ruptured in a water-tube boiler at the department store of J. E. Baum, Omaha, Neb.

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(303.) — A boiler exploded, September 3, in John Pickett's sawmill, near New Marion, Ind. John Pickett, Jesse Pribble, and Paul Snipe were badly injured, and the engine house and adjoining buildings were wrecked.

(304.) — The boiler of a threshing outfit exploded, September 3, on Henry Russell's farm, three miles east of Flandreau, S. D. William Weigle and Walter Weigle were injured.

(305.) — On September 4, a boiler exploded in Vrasel's cotton gin, Gonzales, Tex.

(306.) — A boiler used in drilling for oil exploded, September 5, at Quinton, I. T. William Perry and his son, and Frank Glenn, were injured seriously and perhaps fatally.

(307.) — A tube ruptured, September 5, in a water-tube boiler on the ore steamer *Davidson*, near South Chicago, Ill. John Olson and William Ford were seriously injured.

(308.) — A boiler exploded, September 6, in S. H. Barton's cotton gin, Holland, Tex. S. H. Barton, William Barton, Blake Barton, Edward Latham, Frank Griffin, William Latham, Duke Harmon, Samuel Barton, and a man named Mosely were injured more or less seriously, and the plant was completely wrecked.

(309.) — On September 7, a tube ruptured in a water-tube boiler at the North Delaware Ave. plant of the Philadelphia Rapid Transit Co., Philadelphia, Pa.

(310.) — A boiler ruptured, September 8, in the J. B. Worth Co.'s ice manufacturing plant, Petersburg, Va.

(311.) — A slight boiler explosion occurred, September 9, at the mine of the Cahaha Southern Coal Mining Co., Hargrove, Ala. Dudley Lewis was injured.

(312.) — On September 9, a boiler exploded in the Wilbur & Haskin sawmill, near Marcus, Wash. The mill was considerably damaged.

(313.) — The boiler of a Southern railway locomotive exploded, September 12, at Birmingham, Ala. Engineer Richard Johnson and fireman Joseph Hogan were badly scalded. The boiler itself was wrecked, but the running gear of the locomotive was not seriously damaged.

(314.) — A tube failed, September 13, in a water-tube boiler at the Edison Electric Co.'s plant, Santa Barbara, Cal.

(315.) — The boiler of a Pennsylvania railroad switching locomotive exploded, September 15, at Kinzie and Wood streets, Chicago, Ill. William J. O'Brien was killed, and James Downs, Barrett Perry, and G. W. Pitt were injured.

(316.) — The boiler of a Baltimore & Ohio locomotive exploded, September 15, at Sheffield Crossing, near Elyria, Ohio. Fireman Frank E. Murphy was killed, and engineer Michael Barney and another man named Runge were injured.

(317.) — A boiler exploded, September 16, in the plant of the Higgins Spring & Axle Co., Racine, Wis.

(318.) — A tube ruptured, September 17, in a water-tube boiler at the plant of the Des Moines Edison Light Co., Des Moines, Iowa.

(319.) — On September 17 a boiler exploded in the Ferrer factory, at Asorradero, in the Anguangueo district of the state of Michoacan, Mexico. Eleven persons were killed outright, three others were fatally injured, and nine more were injured more or less seriously, but not fatally. The property loss was large.

(320.) — A slight rupture occurred, September 17, in a boiler at the plant of the Jesse Jones Paper Box Co., Philadelphia, Pa.

(321.) — On September 18 the crown-sheet of a locomotive boiler collapsed in the plant of E. W. Hopkins, Stambaugh, Mich.

(322.) — A boiler ruptured, September 20, in the Southern Cotton Oil Co.'s plant at Linden, Ala.

(323.) — On September 20 a boiler ruptured in the King-Ryder Lumber Co.'s plant, Bonami, La.

(324.) — The cast-iron mud drum of a water-tube boiler exploded, September 20, at the plant of the North American Cold Storage Co., Chicago, Ill. William Wyborg, fireman, and Chester Wells, oiler, were injured. The property loss was large.

(325.) — The boiler of a threshing outfit exploded, September 21, on J. Sawyer's farm, near Roland, Man. J. Sawyer, Thomas Phillips, and Archibald

Hodgson were seriously injured, and the engineer and fireman also received lesser injuries.

(326.) — A tube ruptured, September 21, in a water-tube boiler at the Plankington plant of the National Packing Co., Milwaukee, Wis.

(327.) — The boiler of a Pennsylvania railroad locomotive exploded, on or about September 22, at Burton City, Ohio. Conductor George E. Rockhill was instantly killed, engineer William Bray and brakeman H. Crum were injured so badly that they died within a few hours, and fireman Norman Riffle was injured seriously and perhaps fatally.

(328.) — A boiler explosion occurred, September 23, in the basement of a saloon at 800 Ninth Avenue, New York city. Antonio Massillo, the janitor, was severely injured.

(329.) — The crown sheet of a locomotive boiler collapsed, September 23, at the Louisiana Logging Co.'s plant, Coldwater, La.

(330.) — A tube ruptured, September 23, in a water-tube boiler at the Potomac Electric Power Co.'s plant, Washington, D. C.

(331.) — On September 24 a cast-iron sectional boiler ruptured at the Phosphor Bronze Smelting Co.'s plant, Philadelphia, Pa.

(332.) — A boiler used for operating an ensilage-cutting machine exploded, September 25, on H. E. Hoover's farm, near Broad Ripple, Ind. Fire followed the explosion, causing a property loss of about $10,000.

(333.) — A boiler used in drilling for oil exploded, September 26, on the Jacob C. Goble farm, near Westfield, Ill. One man, named Kale, was slightly burned.

(334.) — On September 26 a boiler exploded in J. M. Kent's cotton gin, Madisonville, Tex. Merritt Kent, a son of the owner of the mill, was instantly killed, and Joseph Holliday was fatally injured. Thomas Dean was also injured seriously, but not fatally. The property loss was about $3,500.

(335.) — A boiler exploded, September 26, in the conservatories of George M. Kellogg, florist, three miles from Pleasant Hill, Mo., partially destroying the plant. The property loss was estimated at $75,000.

(336.) — A large number of cast-iron headers fractured, September 27, in a water-tube boiler at the New Haven Iron & Steel Co.'s plant, New Haven, Conn.

(337.) — A blowoff pipe exploded, September 27, at the planing mill of Kelsey, Smith & Co., White Plains, N. Y. Engineer Robert Sipp was injured.

(338.) — A boiler used for operating a blowing engine exploded, September 27, in the plant of the St. Louis Blasting & Furnace Co., Soper St., St. Louis, Mo. The property loss was estimated at from $10,000 to $12,000.

(339.) — A boiler exploded, September 27, in a machine shop at Providence, R. I. A young man named Hawkins was instantly killed.

(340.) — On September 28 a boiler exploded in the power house of the Railway & Light Co., Seventeenth and Mound Sts., Columbus, Ohio.

(341.) — A boiler ruptured, September 29, in M. Delohery's hat factory, Danbury, Conn.

(342.) — A stop-valve ruptured, September 30, on a main steam pipe in the department store of the John Shillito Co., Cincinnati, Ohio. Joseph Swope, fireman, was injured so badly that he died a short time afterward.

(343.) — A vertical boiler ruptured, September 30, at the Acushnet Mill Corporation's plant, New Bedford, Mass.

October, 1907.

(344.) — On October 1 an accident occurred to the boiler at the McClenahan Granite Co.'s stone quarry, Port Deposit, Md.

(345.) — A boiler ruptured, October 2, in the Middle River Manufacturing Co.'s woolen mill, Stafford Springs, Conn.

(346.) — A boiler belonging to J. Holbrook & Sons ruptured, October 2, at South Sherborn, Mass.

(347.) — The crown sheet of a locomotive collapsed, October 4, at the Cherokee mines of the Virginia-Carolina Chemical Co., Charleston, S. C.

(348.) — Two boilers exploded, October 7, in the Munroe flat building, Joliet, Ill.

(349.) — A tube ruptured, October 8, in a water-tube boiler at the Thomas Furnace Co.'s plant, Milwaukee, Wis.

(350.) — The boiler of a donkey engine exploded, October 8, at the lower lumber camp of the A. F. Coats Logging Co., on the Wishkah River, near Aberdeen, Wash. The engineer, whose name is variously given as Carl Peterson or Christopher Johnson, was instantly killed.

(351.) — A tube ruptured, October 9, in a water-tube boiler at the plant of the Portland Milling Co., Portland, Mich. Engineer Thomas Turner was injured.

(352.) — On October 9 a boiler exploded at the White Oak mine, near Marissa, and some thirty miles from Belleville, Ill. Edward Evans was killed, and Roy Evans and James Rourke were scalded, the former perhaps fatally so.

(353.) — On October 9 a tube ruptured in a water-tube boiler at the Ashland mine of the Cleveland Cliffs Iron Co., Ironwood, Mich.

(354.) — The boiler of a traction engine exploded, October 10, near Carroll, Iowa. Anton Thieleke and two other men were injured.

(355.) — A tube failed, October 10, in a boiler at the plant of the Nelson Baker Co., Detroit, Mich.

(356.) — A slight boiler accident occurred, October 10, at the Free Public Library, Worcester, Mass.

(357.) — The boiler of Jacob Markle's sawmill exploded, October 12, on the Walker Smith farm, at Patton station, near Punxsutawney, Pa. John Thomas was killed, and George Thomas, John Crow, and Anderson Smith were seriously injured. The mill was partially wrecked.

(358.) — The boiler of freight locomotive No. 1065, of the Central of Georgia railway, exploded, October 12, at Reynolds, a station on the Columbus division, forty-two miles from Macon, Ga. Conductor William L. Allen and engineer B. L. Avera were instantly killed, and fireman George Howard was fatally injured. Brakeman Alexander Perry was also injured slightly.

(359.) — A boiler exploded, October 12, in O. L. Davis' sawmill, near Warren, Tex., instantly killing the owner's son and George Moye. Three other persons were also injured.

(360.) — A heating boiler exploded, October 13, in John J. Howley's residence, Scranton, Pa., instantly killing its owner.

(361.) — The boiler of a New York, New Haven & Hartford railroad locomotive exploded, October 14, at Belle Dock, New Haven, Conn. The locomotive was completely wrecked.

(362.) — On October 16 a boiler exploded at the Belton Oil Co.'s plant, Belton, Tex. Robert Owens and Ramie Dye were killed. The property loss was estimated at $3,000.

(363.) — The boiler of a rice threshing outfit exploded, October 16, on Charles Martin's farm, three miles east of Iota, La. Demas Romaine, George Dumond, John Martin, and two other men whose names we have not learned, were injured. One of the injured died shortly afterward, and another was not expected to recover.

(364.) — A tube ruptured, October 16, in a water-tube boiler at the plant of the American Gas & Electric Co., Altoona, Pa.

(365.) — A boiler exploded, October 17, in W. W. Mick's sawmill, Spottsylvania, Pa.

(366.) — On October 18 a boiler exploded at the J. M. Guffy Petroleum Co.'s plant, Jennings, La. The boiler house was destroyed.

(367.) —A boiler exploded, October 18, in the Quaker Oats plant, Battle Creek, Mich. Charles King was fatally scalded.

(368.) — A boiler ruptured, October 19, in the office building of the Hartford Deposit Co., Chicago, Ill.

(369.) — On October 19 a boiler exploded at Golden's cotton gin, Arkadelphia, Ark.

(370.) — A boiler exploded, October 19, at the Colloma oil lease, on the Kern river field, near Bakersfield, Cal. Frank Thurston and George Johnson were slightly injured. The property loss was estimated at $3,000.

(371.) — A boiler exploded, October 19, in William Johnson's sawmill, on Henry Ferguson's farm, three miles west of Brooks, Ky. Edward Johnson (son of the owner of the mill) was killed, and Richard Ferguson, William Ferguson, and Albert Johnson were seriously injured. It was said that two of the injured would probably die.

(372.) — On or about October 20 a boiler exploded at Louisville, Ill., badly scalding Arthur Hendy.

(373.) — A tube ruptured, October 20, in a water-tube boiler at the power house of the South Side Elevated Railroad Co., Fortieth and State Sts., Chicago, Ill.

(374.) — A cast-iron header ruptured, October 21, in a water-tube boiler at the Edison Electric Co.'s plant, Santa Barbara, Cal.

(375.) — A boiler exploded, October 22, during the course of a big fire which destroyed an entire block in Brooklyn, N. Y. The boiler, we understand, was in the plant of Schwab Bros. & Co., at Park and Washington avenues.

(376.) — On October 22 a blowoff pipe burst at the Red Oak Electric Co.'s plant, Red Oak, Iowa.

(377.) — A tube ruptured, October 22, at the plant of the National Rolling Mill Co., Vincennes, Ind.

(378.)— A boiler exploded, October 23, at mine No. 204 of the Sunday Creek Coal Co., two miles east of Nelsonville, Ohio. Clifford Wolfe, Elmer Boggs, and Charles Kettle were killed, and David Peters and Ora West were seriously injured. The power house and tipple were wrecked.

(379.) — On October 23 a cast-iron manhole mouthpiece ruptured on a boiler at the plant of the National Biscuit Co., Kansas City, Mo.

(380.) — The boiler of J. Carroll's sawmill exploded, October 24, at Fancy

Farm, Graves county, Ky., and Mr. Carroll was thrown fifty feet and badly injured.

(381.) — On October 24 an accident occurred to the main steam connection of a boiler at the plant of the William Farrell Lumber Co., Farrell, Ark.

(382.) — A boiler exploded, October 24, in the basement of the Permanent building, Euclid Avenue, Cleveland, Ohio. The fireman was slightly injured.

(383.) — A cast-iron heating boiler fractured, October 27, in V. M. Vickery's apartment block, Worcester, Mass.

(384.) — A boiler ruptured, October 28, at the Western Motor Works, Logansport, Ind.

(385.) — A tube ruptured, October 30, in a water-tube boiler at the Philadelphia Rapid Transit Co.'s power plant, Second St. and Wyoming Ave., Philadelphia, Pa.

(386.) — The boiler of locomotive No. 823, of the Lehigh Valley railroad, exploded, October 30, at Hinman, near Sayre, Pa. Three men were slightly cut and bruised. The explosion consisted in the failure of the crown-sheet.

(387.) — The boiler of a passenger locomotive exploded, October 30, on the Grand Trunk railway, at Newberry, forty miles west of London, Ont. Engineer S. Rutherford was killed, and the fireman (whose name we do not know) was fatally injured.

(388.) — On October 30 a boiler exploded in the trolley power house at Frederick, Md. Engineer Luther Ahalt was scalded to death.

November, 1907.

(389.) — A boiler exploded, November 1, in Klingensmith's sawmill, at Vandergrift, Pa. Engineer H. O. Blose was injured so badly that he died within an hour. Philip Klingensmith and Henry Welsh also received lesser injuries.

(390.) — A boiler exploded, November 1, on the dredge boat *Lewis*, on the Elk river, at Elkton, Md. The boat was partially wrecked.

(391.) — On November 3 a boiler ruptured in the Clearfield Lumber Co.'s sawmill, Morehead, Ky.

(392.) — A tube ruptured, November 3, in a water-tube boiler at the plant of the Munising Paper Co., Munising, Mich.

(393.) — A slight rupture occurred, November 4, in a boiler at G. G. Rockwell's flouring mill, North Baltimore, Ohio.

(394.) — A tube collapsed, November 6, in a boiler at the Aurora plantation of Mrs. C. H. Norman, New Orleans, La.

(395.) — The boiler of a narrow gage locomotive exploded, November 6, at the La Belle Iron Works, Steubenville, Ohio. Charles Reed, William Smith, Henry Andrews, William Scott, and Daniel O'Brien were killed, and William Carnahan, James Edwards, and J. A. Sanders were fatally injured. Part of the open hearth plant was also wrecked.

(396.) — On November 6 a blowoff pipe burst at the church of the Metropolitan Church Association, Waukesha, Wis. Engineer Charles Hunt was injured so badly that he died two days later.

(397.) — A blowoff pipe ruptured, November 11, at the Domestic Palace Laundry, Kankakee, Ill. Superintendent A. E. Anderson and engineer D. Scatterday were slightly scalded.

(398.) — A heating boiler exploded, November 12, in the new Eastman dormitory, at East Greenwich Academy, East Greenwich, R. I. Miss Hester Gould, Miss Florence Bissell, and Miss Edith Kellogg were seriously injured, and the building was partially wrecked. The property loss was estimated at $10,000.

(399.) — A boiler exploded, November 12, in Harvey & Shannon's roller mills, Marrowbone, Ky. The engineer and his assistant received injuries which it was thought would prove fatal, and Gray Y. Turner, the manager of the mill, was also injured to a lesser degree.

(400.) — On November 12 a boiler exploded in James H. Trulock's cotton gin, seven miles south of Pine Bluff, Ark. Mr. Trulock and Oscar Robinson were killed. Alexander Young, William Robinson, and Jesse Byers were also injured, and it was said that the two last mentioned could not live. The gin was demolished.

(401.) — On November 14 a tube burst in a boiler at the Chittenden hotel, owned by the Iroquois Company, at Columbus, Ohio. Engineer Charles Patton was injured.

(402.) — A tube burst, November 14, in a water-tube boiler at the Fremont St. station of the Worcester Consolidated Street Railway Co., Worcester, Mass. Dommick Germdu, William Bostock, and John Squct were slightly injured.

(403.) — On November 15 a boiler ruptured in the City Water Works & Electric Light plant, Williamsport, Ind. Fireman Con. Long was injured.

(404.) — A tube ruptured, November 15, in a water-tube boiler at the plant of the West Jersey & Sea Shore R. R. Co., Westville, N. J. Charles Kindrick, Robert Snuffin, Steven Carr, James Hagen, Patrick Gilmartin, and William White were injured.

(405.) — A boiler exploded, November 16, in Patrick White's cotton gin, between Rogersville and Whitehead, Lauderdale county, Ala. Engineer Archibald Snoddy and fireman Edward Weathers were instantly killed, and another man was fatally injured. The gin was badly wrecked.

(406.) — On November 17 a boiler exploded at G. B. Markle & Co.'s Highland No. 2 colliery, Jeddo, Pa. Property loss about $3,000.

(407.) — A slight boiler explosion occurred, November 18, at the house of fire engine company No. 6, located at Ninth and Market Sts., St. Louis, Mo. The property loss was estimated at approximately $1,000.

(408.) — A tube ruptured, November 19, in a water-tube boiler at the plant of the Bristol Gas & Electric Co., Bristol, Tenn.

(409.) — A boiler exploded, November 20, at the rolling mills, Sheffield, Ala.

(410.) — On November 20 a boiler exploded at the plant of the John L. Roper Lumber Co., Gilmerton, Va. F. E. Ferrell, Ambrose Dozier, Rufus R. Sorey, W. F. Garnes, Scott Wilson, and R. E. Frank were killed, and Henry Gatling and James Murphy were injured. The property loss was heavy.

(411.) — A cast-iron heating boiler fractured, November 21, at the Holy Name Church, Chicopee, Mass. Every section in the heater was cracked.

(412.) — A tube ruptured, November 21, in a water-tube boiler at the Kokomo Steel & Wire Co.'s plant, Kokomo, Ind. Burt Silvey was fatally injured.

(413.) — A boiler exploded, November 22, in the sawmill of Killinger

Bros. & Co., at Carpenter, on the Kanawha & West Virginia railroad, twenty miles from Charleston, W. Va. W. M. Killinger (one of the owners) was killed. D. C. Williams, James Odel, and another man named Samples were also injured.

(414.) — A cast-iron header fractured, November 22, in a water-tube boiler at the Philadelphia Rapid Transit Co.'s power station, Thirteenth and Mt. Vernon Sts., Philadelphia, Pa.

(415.) — A tube burst, November 22, in a water-tube boiler in a cotton mill at Kingston, Ont. Wade Smith was terribly and perhaps fatally scalded.

(416.) — On November 24 a boiler exploded in the basement of John Ashworth's hotel, Bloomfield, N. J. The property loss amounted to several thousand dollars. One estimate gives it as $15,000.

(417.) — A boiler exploded, November 25, in Frank Lamberton's sawmill, Paonia, Colo. The mill was destroyed.

(418.) — A boiler exploded, November 27, at the Emma mine sawmill, Dunton, Colo.

(419.) — A blowoff pipe ruptured, November 28, in A. Booth & Co.'s cold storage plant, Omaha, Neb.

(420.) — A tube ruptured, November 29, in a water-tube boiler at the plant of the Barker Cotton Mills Co., Mobile, Ala.

(421.) — On November 29 a tube ruptured in a water-tube boiler at H. A. Parker & Co.'s paper mill, Pepperell, Mass. Roy Palmer was killed, and James O'Neil was injured.

(422.) — A boiler used for operating a corn shredder exploded, November 29, on John Parks' farm, near Roachdale, Ind. Henry Fall (owner of the boiler) and Harvey Broom were seriously injured.

(423.) — A tube ruptured, November 29, in a water-tube boiler belonging to the Havlin Hotel Co., Cincinnati, Ohio.

(424.) — A boiler used for drilling a well exploded, November 29, on John Stough's farm, some two miles southwest of Evansport, Ohio. A young man named Wagner was seriously injured.

(425.) — A slight boiler accident occurred, November 30, at the sawmill and planing mill of the Langstaff-Orm Manufacturing Co., Paducah, Ky.

(426.) — On November 30 a tube ruptured in a water-tube boiler at the plant of the R. Herschel Manufacturing Co., East Peoria, Ill. John Schaab was killed.

(427.) — A heating boiler exploded, November 30, in the Home for Aged Women, Portsmouth, N. H. The building and the heating apparatus were considerably damaged.

(428.) — A heating boiler exploded, November 30, in the basement of the Maine Central railway station, Brunswick, Me. Night baggage master William B. Woodward and car inspector Walter W. Harris were killed, and Edmund Tarrier, Frederick Sylvester, and Mrs. C. J. Bailey were injured. The building was also badly damaged.

December, 1907.

(429.) — A header fractured, December 2, in a water-tube boiler at the flouring mill and elevator of the Blair Milling Co., Atchison, Kans.

(430.) — The boiler of a threshing outfit exploded, December 2, at Kenton, Ohio, while being fired up for use in running a corn shredder. William Burdett was fatally injured.

(431.) — A boiler exploded, December 4, in the boiler room of Greenwood colliery No. 2, of the Delaware & Hudson Company, Scranton, Pa. Fireman John Cawley was instantly killed, and John Hughes received serious and perhaps fatal injuries.

(432.) — On December 4 a boiler exploded in the basement of the German Home for the Aged, Rochester, N. Y. Engineer John Schumacher was instantly killed. The property loss was estimated at from $1,500 to $2,000.

(433.) — A tube burst, December 5, in a water-tube boiler in P. H. Glatfelter's paper mill, Spring Grove, Pa.

(434.) — A boiler exploded, December 5, in the West Side Fire House, Atlantic City, N. J. Firemen Philip Somers, Philip Miller, Daniel Connolly, and David Dare were injured, and the building was considerably damaged. (At the time of the explosion a belief was prevalent in the neighborhood that the explosion was caused by dynamite in the coal. In the apparent absence of any evidence of this, we have no hesitation about including the accident among the boiler explosions of the month, because such explosions are often erroneously attributed to dynamite, by those who have had no experience of the tremendous amount of energy that may be liberated by a boiler explosion, pure and simple.)

(435.) — A heating boiler exploded, December 5, in W. H. Wynne's residence, Atlanta, Ga. The owner's little son was painfully burned.

(436.) — A boiler exploded, December 5, in George H. Winters' cider mill at Preakness, near Paterson, N. J. Moses Winters (a son of the owner) was instantly killed, and Philip Beck was seriously injured. Fire followed the explosion, and the mill was destroyed.

(437.) — On December 5 a boiler exploded in the Endicott-Johnson Co.'s sole leather tannery, at Endicott, N. Y. Two boys, Edgar Wells and Walter Wells, were badly injured, the former dying a short time after the explosion.

(438.) — A boiler exploded, December 6, in J. B. Washington's cotton gin, two miles from Earle, Ark. John Donaldson was killed, and J. B. Washington, George Cullwell, and a boy whose name we do not know were injured. The property loss was estimated at about $2,500.

(439.) — The boiler of a locomotive exploded, December 6, on the Burke and Wallace branch of the Northern Pacific railway, near Missoula, Mont. Fireman Buls, brakeman Hodges, and another man whose name we do not know were killed, and engineer Copenhaven was fatally injured.

(440.) — A boiler exploded, December 6, on the stern-wheeled tugboat *Archon*, in Company's Canal, about five miles from its junction with the Mississippi River, near New Orleans, La. Capt. Tadon J. LeBlanc, pilot Zachariah Fontenette, and deck hand Eric Plaisant were seriously injured, and the boat was almost totally wrecked.

(441.) — On December 6 a boiler exploded in the Roberts-Brown lumber mill, near Mansfield, La. The fireman, whose name we have not learned, was killed instantly.

(442.) — On December 6 a boiler exploded in Hartman's sawmill, Woodville, Ala. Engineer William Thompson was seriously injured, and Mr. Hartman (the owner) and G. J. Hodges were injured less severely.

(443.) — On December 7 a slight rupture occurred in a boiler in the dry goods store of H. L. Morrison's Sons, Ashtabula, Ohio. W. H. Morrison was slightly scalded.

(444.) — The elbow of a blowoff pipe ruptured, December 7, at the plant of the Delaware Water Co., Delaware, Ohio. W. T. Davison, the engineer, was slightly scalded.

(445.) — On December 8 a boiler exploded in a sugar mill on Rafael Peon's Chunchumil Hacienda, near Merida, Mex. Five persons were killed and ten others were seriously injured.

(446.) — On December 9 a large number of tubes pulled out of a water-tube boiler at the plant of the Northern Iron Co., Standish, N. Y.

(447.) — A boiler exploded, December 9, at the plant of the Hygienic Blanket Co., Hubbardston, Mass. Night watchman Alexander Greco was killed. Fire followed the explosion, and the total property loss was about $17,000.

(448.) — A boiler exploded, December 9, in the plant of the American Steel & Wire Co., at Allentown, Pa. John Gyrus and Simon Ralmomansky were killed instantly, and Francis Matula was injured so badly that he died within a few hours. George Kreichler was also injured severely, but not fatally. The New York *Sun* estimates the monetary loss, including that due to the stoppage of the plant, at $100,000.

(449.) — A tube ruptured, December 9, in a water-tube boiler at the Loray Mills, Gastonia, N. C.

(450.) — The boiler of locomotive No. 1149, of the Grank Trunk railway, exploded, December 10, three miles south of Pontiac, Mich. Fireman E. T. Montgomery was killed, and engineer William Brown was seriously injured. The locomotive was completely wrecked.

(451.) — The boiler of a freight locomotive exploded, December 11, on the Northern Pacific railway, near Bozeman, Mont. Fireman John Welch was instantly killed, and head brakeman Veyno was injured seriously and probably fatally.

(452.) — A boiler exploded, December 12, on the Detroit river, scalding William Lara.

(453.) — A boiler exploded, December 13, in the basement of the Edgewater Bank, Evanston Ave., Chicago, Ill. The building was damaged to the extent of about $200.

(454.) — A blowoff pipe ruptured, December 13, in the Salt Lick Lumber Co.'s plant, Salt Lick, Ky. Fireman George Hayes was injured.

(455.) — A boiler exploded, December 15, on a dredge boat belonging to the Woolman Construction Co., on the Cass river, near Shabbona, Mich. Three men were slightly injured.

(456.) — On December 17 a boiler exploded in Harris & Craven's sawmill, near Merrimac, Wood county, Tex. Peter Sellars was instantly killed, and Jasper Jarred was injured seriously and perhaps fatally. Two boys named Davis also received minor injuries.

(457.) — A heating boiler exploded, December 17, in the Omohundro Ave. public school building, Norfolk, Va. A panic among the pupils was averted by the coolness of the teachers.

(458.) — A boiler exploded, December 19, in the Ludlow shops, Cincinnati, Ohio. Armin Williams was scalded.

(459.) — A tube ruptured, December 19, in a water-tube boiler at the B. F. Goodrich Co.'s plant, Akron, Ohio.

(460.) — On or about December 19 a boiler exploded in O. I. M. Houck's bakery, York City, Pa. George Gates was slightly injured, and the entire interior of the bakery was demolished.

(461.) — On December 21 a water-tube boiler was destroyed by an explosion in the Dominion Coal Co.'s No. 2 colliery, at New Aberdeen, N. S. Five men were injured, and two of these have since died. The total monetary loss was estimated at over $7,000. It has not yet been definitely determined whether this explosion was due primarily to the steam pressure, or whether it followed as a consequence of an explosion of gas in the furnace, or from some other external cause. It is included here, however, for the sake of completeness.

(462.) — A portable boiler belonging to William Nixon exploded, December 24, at Lambeth, four miles from London, Ont. William Nixon, William Schram, Arthur Porte, Joseph Poole, and Henry Woods were injured.

(463.) — On December 24 a boiler exploded in the Greeley sugar factory, Greeley, Colo. J. Burkhardt, O. Ellison, and George Hancock were injured.

(464.) — The boiler of a dredging boat belonging to the Hoosier Sand & Gravel Co. exploded, December 24, on White river, Indianapolis, Ind.

(465.) — On December 25 a boiler exploded at Hinckley, Ill., in the basement of a building owned by the Aurora Brewing Co. A saloon and billiard hall on the premises were partially wrecked.

(466.) — A tube ruptured, December 27, in a water-tube boiler at the Edison Electric Illuminating Co.'s plant, at the foot of Sixty-sixth St., Brooklyn, N. Y. Fireman V. Cimato was scalded.

(467.) — A boiler exploded, December 30, in R. E. Warren's sawmill, ten miles from Hawkinsville, Ga., killing two women and demolishing the mill.

(468.) — On December 31 a boiler exploded in the basement of the building occupied by Washington Fire Engine Co. No. 1, New Brunswick, N. J. The building was damaged to the extent of about $1,200.

(469.) — On December 31 a boiler exploded at the plant of the Minnequa Cooperage Co., at the foot of East Fourth St., Little Rock, Ark. The building was considerably damaged.

WE can still supply copies of our little book entitled *The Metric System*, at $1.25 per copy when bound in sheep, or at $1.50 when printed on bond paper and bound in a stouter leather. It gives a short history of the metric system, followed by extensive tables for the convenient comparison of metric measures with the equivalent English ones. Here are a few expressions of opinion concerning it:

"It will prove invaluable." — *Commercial Bulletin.*

"The best history of the system that we have seen." — *Scientific American.*

"It should serve a very useful purpose." — *American Machinist.*

"One of the most valuable publications of the kind yet given to the public." — *American Wool and Cotton Reporter.*

"The most striking features of the tables are simplicity of arrangement and clearness of type." — *Electrical World.*

"Of the many metric conversion tables issued, this is by far the best and most convenient." — *Engineering News.*

"It is an excellent thing, in admirable form." — *Prof. R. H. Thurston.*

"It is a little jewel." — *Judge Thomas Updegraff.*

The Locomotive.

A. D. Risteen, Ph.D., Editor.

HARTFORD, JANUARY 25, 1908.

The Locomotive *can be obtained free by calling at any of the company's agencies. Subscription price 50 cents per year when mailed from this office. Bound volumes one dollar each. (Any volume can be supplied.)*

Mr. Charles S. Blake.

Mr. Charles S. Blake.

On November 18, 1907, Mr. Charles Spafford Blake, whose portrait we present in this issue, was elected Secretary of the Hartford Steam Boiler Inspection and Insurance Company. In deference to the new incumbent's sense of modesty and propriety, we are merely recording the fact of the appointment, together with some few biographical details which may serve to introduce Mr. Blake to our patrons, and to such of our employes as have not had an opportunity of meeting with him in person.

Mr. Blake has had a wide range of experience in the practical engineering field, as well as in the different branches of boiler insurance. Born at Windsor Locks, Connecticut, on October 25, 1860, he inherited a tendency towards mechanics from his father, the late Captain John W. Blake, who had served as mechanical expert for the United States Government at the Springfield Armory, and who was also in the South Atlantic Squadron during the Civil War, and afterwards in the United States Marine Inspection Service. (We may add, in passing, that Captain John W. Blake traveled extensively in Africa in his early life, traversing some two thousand miles in the interior of the Dark Continent, mainly without any white companion. He never visited the great lakes at the sources of the Nile and the Congo, but knew of their existence, from the natives, before they were discovered by Livingstone.)

After leaving school, Mr. Blake's first business experience was with the original United Press Association, whom he served for a time in the capacity of reporter for the New York papers, his territory covering Jersey City and the adjoining cities and towns. Then, desiring a practical training in mechanics, he served an apprenticeship with the Central Iron Works of Jersey City, whereby he became familiar with boiler and engine construction, both marine and stationary, together with other branches of marine mechanics. Before his twenty-first birthday he was granted a license as marine engineer, to operate vessels of 100 tons and under, and shortly afterward he was licensed as a chief engineer of ocean vessels. A few months before the close of the war between Chile and Peru, he received a commission as engineer in the Peruvian navy, and was upon waiting orders when the war ceased.

After an experience alternating between marine and stationary service, he entered the steam boiler insurance field, in 1884, as an inspector of boilers; and in three years he became chief inspector and adjuster, at the Philadelphia and Chicago agencies, respectively, of the company with which he was then connected. On June 1, 1898, he entered the employ of the Hartford Steam Boiler Inspection and Insurance Company, at Hartford, as general agent. On July 12, 1904, he was elected to the position of supervising general agent, and on February 12, 1907, was advanced to second vice-president, which position he relinquished to accept the secretaryship.

A. D. RISTEEN.

AT the quarterly meeting of the board of directors of the Hartford Steam Boiler Inspection and Insurance Company, held January 1, Mr. Charles M. Jarvis was elected a director, to fill the vacancy in the board caused by the death of Mr. Joseph B. Pierce. Mr. Jarvis is a resident of Berlin, Connecticut, and First Vice-President of the American Hardware Corporation, of New Britain.

Obituary.

Aid Collins.

Aid Collins, for many years an inspector and special agent for the Hartford Steam Boiler Inspection and Insurance Company in its Northwestern department, died, November 7, 1907, at Minneapolis, Minnesota.

Mr. Collins was born November 29, 1842, at Russellville, Ohio, and in his early years worked as a millwright, being skilled in all the branches of the art, including woodworking, machine shop practice, and blacksmithing. He entered the employ of the Hartford Steam Boiler Inspection and Insurance Company on September 23, 1873, and served it continuously and faithfully from that date up to the very day of his death. He was a veteran of the Civil War, serving in the Fifth Virginia infantry and the One Hundred and Sixty-second Ohio infantry, in the Virginia and Shenandoah campaigns. He was a mason, and was deeply interested in masonic work. He was also a member of the John A. Rawlins post of the Grand Army of the Republic, of Minneapolis, and his funeral services were conducted under the auspices of that organization.

Mr. Collins was highly esteemed by all who knew him. His health had been failing for some two years, but he was still able to attend to his usual duties as special agent, and the end came very unexpectedly. He was seized with heart-failure at his office in the Globe building, and while medical attention was promptly given by a physician who was close at hand, it was unavailing, and Mr. Collins passed away, painlessly and peacefully, three hours later.

James Madison Moore.

James Madison Moore, an inspector in the home department of the Hartford Steam Boiler Inspection and Insurance Company, died January 8, 1908, at his home on Vernon street, Hartford, Connecticut, of cardiac trouble, following arterio-sclerosis. Mr. Moore was born May 3, 1844, at Brooklyn, New York, and served his time at the machinist's trade with Bement & Dougherty, of Philadelphia, after which he worked for William Sellers, of the same city. From Philadelphia he went to Nashville, Tennessee, where he held a position of responsibility with a railroad company for some two years. Returning east, he next entered the employ of the Woodruff & Beach Iron Works, of Hartford, as general machinist, remaining here some four or five years. He then went to New Haven, in the employ of the New York, New Haven and Hartford Railroad Company, taking charge of Belle Dock, and serving in the dual capacity of head engineer and dock master. Upon resigning this position he became associated with L. Candee & Company, rubber manufacturers, of New Haven, as chief engineer; and on June 22, 1885, he entered the employ of the Hartford Steam Boiler Inspection and Insurance Company, as an inspector in its home department.

Mr. Moore was a highly competent inspector, combining a thorough knowledge of boilers and their accessories with a sound and well trained judgment. He had a keen understanding of human nature also, and loved a genuine character in whatever station it was found; but he was unalterably opposed to hypocrisy and dissimulation, or to unjustifiable pretensions of any kind, and could detect these instantly. He possessed a ready wit, and in his conversation he drew freely upon a seemingly inexhaustible store of illustrative anecdotes. He had a strong love for good poetry, and notably for that of Scott and Goldsmith, long passages of which he could repeat from memory. He was loved by all, but most by those who were brought into intimate association with him, and who had learned to know him as he could be known only by such close association.

Mr. Moore was a mason, and a member of Hartford Lodge No. 88, for many years. He leaves three living children: Alice L., wife of Reverend Robert B. Gooden, of Long Beach, California; Ella M., wife of Wilbur N. Larkum, of Hartford; and J. Leonard Moore, of Hartford. His eldest daughter, Carolyn S., wife of Dr. Edward Eberle of Hartford, died in April, 1902.

The circumstances attending Mr. Moore's death were peculiarly sad. His wife died on January 6, and Mr. Moore himself passed away just before the hour set for her funeral.

Human Fallibility.*

In our issue for October, 1904, we published an analysis of the railroad accidents that had occurred in the United States during the first six months of 1904, our object being to show the importance of the element of human fallibility in railroad engineering. The results showed that 68 per cent. of the accidents were due entirely to the mental or physical state of the human agent, and we summed up the article by showing that whenever an accident occurred, the odds were two to one that the man was at the bottom of it, and not the machine. After an interval of over three years, we have made another analysis, this time of the railroad accidents that have occurred in the United States during the twelve months ending March 31, 1907. It is interesting to note the similarity between the results shown in the two tables. The 74 per cent. in the present table, representing the human agent, is within 6 per cent. of the corresponding figure as given in the former table; while the percentages of accidents due to "mistake" and "forgot" are within 3 per cent. of each other.

The figures given are compiled from the reports of the Interstate Commerce Commission, covering a total of 166 prominent train accidents. In these accidents 476 persons were killed, and 2,469 were injured; and the damage to property is estimated to be $2,061,297. The reports of the Commission are, as a whole, very clear and complete; but it is impossible for anyone to get all the data of every accident, and we have rejected 15 per cent. of the accounts as not being as complete as we should wish them to be, for our purpose. Our table, as given below, is therefore based upon a total of 141 accidents.

Sometimes, unfortunately, the Commission is compelled to give the reason of the accident as "false clear block signal," or "misplaced switch," leaving us in doubt whether the false signal was given because the apparatus

*By V. Hugo, Manager, St. Louis, Mo.

itself was out of order, or because the man made a mistake in setting it, or forgot to set it; or whether the signal was falsely given, through the malice of some person not employed by the road.

In preparing a table of this kind, a great deal depends upon the personal equation of the compiler, for in some cases an accident may be classed, with equal propriety, under either one of two or more headings. For example, one accident was due to the fact that when an engineman received a meeting order, he put it in his pocket without reading it. This might fairly be classified as "forgot"; but that man had been on duty for 40 hours, and so, under the circumstances, we have classed this under the heading "physically incapacitated," believing that a man who has been on duty 40 hours should not be held responsible for his acts. One accident was due to a runaway on a steep grade,— the engineman continuing to use steam too long after passing the summit. We take this case to be a mistake in judgment and a disregard of common sense, so that it might have been placed under the head of "mistake." We have classed it, however, under "reckless." All the accidents due to the operator intentionally disregarding an order are classed under "reckless."

Where the air brakes failed to work, and it was determined, later, that they had not been tested, we have classed the accidents under the

Causes of Railroad Accidents.

	Nature of Cause	Percentage of accidents due to the cause assigned	Remarks and Explanations
The man	Mistake, . .	28	Nearly all due to mistakes in giving or receiving signals, or in writing or reading orders. Two per cent. due to confusion in throwing switches.
The man	Forgot, . . .	27	Just plain forgot to do what he was told to do.
The man	Reckless, . .	16	Exceeded yard speed limit; failed to observe five-minute interval between trains; did not test air brakes, etc. Might be called intentional mistakes, and would not be called mistakes at all, if he had not been caught.
The man	Physically incapacitated,	3.5	Men fell asleep, presumably on account of previous exposure or exhaustion.
The machine	Defective equipment, .	12	Broken rail; broken wheel; failure of air brake; broken switch.
The machine	Defective roadbed.	6.3	Mostly washouts; track out of gage.
The weather	Elements, . .	3.5	Fog or snow interfering with the reading of signals; wind blowing out signal lamps.
	Malice,	2.8	Malicious interference from persons not employed by the railroad.

head of disregarding orders. Where it is shown that the air brakes had been tested, and yet failed, we have classed the accidents under "defective equipment." It might be said that all the accidents that occur as a result of the fallibility of the human agent are due to disregard of orders; for if the human agent forgot to do a thing, it was because he disregarded the implied order not to forget it. Several accidents under the head of "reckless" were due to the engineer exceeding the yard speed rules. We have taken it for granted that he knew those rules, and that he disregarded them willfully; and we have taken a similar position with respect to the several accidents that were due to the engineman disregarding the five minute interval between trains. One might say that he forgot to maintain this interval, and that the accident should be classed under "forgot"; but we take this order to be of such a nature that when the man disregarded it, we may assume that he did so intentionally.

In a few cases, where accidents were due to failure of the air brakes, and this, in turn, was found to have been caused by an air cock in the line being closed, the opinion has been given that the air cock was maliciously closed by tramps riding on the train. This, of course, may be so; but in view of the difficulty of getting a man, who is in a measure responsible for an accident, to tell the whole truth, and not try to lay the blame upon some irresponsible agent, we are inclined to think that the cocks in question were not closed by tramps, but that their being closed when they should not be, was due to the fault of the trainmen in not properly testing the brakes.

The vagaries of the human mind are shown very plainly in many instances. Thus in one case an experienced operator, in writing down an order, substituted, for the name of the station, a name that he did not intend to write, and afterwards could not explain his action. In another, an operator omitted a word from the order, although he repeated it correctly to the dispatcher. In other words, his voice registered the message that was received by his brain, but his fingers did not. One accident was due to the fact that the conductor, the engineman, and the whole crew, overlooked a meeting order, although that order had been delivered to them only thirty minutes before. In this case, however, all the men had been on duty sixteen hours.

On the whole, it is shown that the equipment and road-bed are satisfactory; that the elements interfere very little with the operation of the train; that the maliciousness of persons not employed by the railroad is a decidedly minor factor; and, finally, that the *man* is the cause of three out of every four accidents. The trouble with the man is, that his wits go wool-gathering. This word may not be replete with dignity, but neither are the actions of a man who has lost his head; and so we consider the word well chosen, and make no apologies for it. If we could stop this wool-gathering, we should thereby reduce our railroad accidents by 74 per cent.

It appears clearly from the foregoing, that what the railroad man needs is mental training; and this, backed up by shorter hours of work and longer hours of sleep, should make him more dependable.

Inspectors' Reports for May, June, July, and August, 1907.

Nature of Defects.	May.		June.		July.		August.	
	Total defects.	Dangerous.	Total defects.	Dangerous.	Total defects.	Dangerous.	Total defects.	Dangerous.
Cases of deposit of sediment, .	1,682	144	1,800	114	1,867	109	1,511	100
Cases of incrustation and scale,	3,439	131	3,482	96	3,686	147	3,240	112
Cases of internal grooving, .	288	23	267	15	276	15	329	9
Cases of internal corrosion, .	1,118	47	1,356	51	1,660	73	1,263	33
Cases of external corrosion, .	926	44	991	105	1,152	66	949	77
Defective braces and stays, .	227	56	208	60	280	47	146	31
Settings defective, . . .	554	55	644	66	736	64	524	54
Furnaces out of shape, . .	730	39	815	33	750	41	680	29
Fractured plates, . . .	368	47	303	44	274	34	258	51
Burned plates, ...	430	46	395	38	420	29	376	42
Laminated plates, . . .	92	12	96	8	116	4	64	6
Cases of defective riveting, .	314	39	361	81	269	53	260	54
Defective heads, . . .	141	16	194	19	205	18	130	10
Leakage around tubes, . .	926	97	968	184	823	115	869	131
Cases of defective tubes, . .	913	359	653	126	756	187	687	234
Tubes too light, . . .	140	37	149	40	168	56	141	46
Leakage at joints, . . .	505	36	485	35	392	51	433	40
Water-gages defective, . .	238	47	253	75	233	57	198	48
Blow-offs defective, . . .	368	81	407	116	459	143	332	102
Cases of deficiency of water, .	29	12	38	17	36	12	38	10
Safety-valves overloaded, .	146	39	91	30	111	31	103	40
Safety-valves defective, . .	97	21	106	37	148	45	109	36
Pressure gages defective, .	694	37	692	47	568	41	579	39
Without pressure gages, .	15	15	20	20	37	37	10	10
Unclassified defects, . .	3	3	0	0	4	4	0	0
Totals, ...	14,383	1,483	14,774	1,457	15,426	1,479	13,229	1,344

Inspectors' Reports for September, October, November, and December, 1907.

Nature of Defects.	September.		October.		November.		December.	
	Total defects.	Dangerous.	Total defects.	Dangerous.	Total defects.	Dangerous.	Total defects.	Dangerous.
Cases of deposit of sediment,	1,657	102	1,658	98	1,512	123	1,509	112
Cases of incrustation and scale,	3,241	119	3,136	82	3,015	121	2,919	98
Cases of internal grooving,	208	16	167	14	249	36	255	26
Cases of internal corrosion,	947	31	892	29	876	40	903	57
Cases of external corrosion,	966	91	812	74	748	58	670	53
Defective braces and stays,	169	33	177	34	175	42	141	41
Settings defective,	504	66	509	43	478	56	441	53
Furnaces out of shape,	593	30	551	25	571	36	555	36
Fractured plates,	246	46	300	44	285	47	269	39
Burned plates,	361	47	347	31	411	64	410	30
Laminated plates,	78	8	68	9	68	6	58	5
Cases of defective riveting,	290	68	403	44	261	57	235	51
Defective heads,	159	15	182	18	133	29	125	20
Leakage around tubes,	1,061	193	1,093	184	907	165	972	114
Cases of defective tubes,	764	268	644	230	466	116	525	124
Tubes too light,	146	56	115	37	102	31	155	34
Leakage at joints,	436	26	471	24	455	41	430	41
Water-gages defective,	271	58	271	65	244	51	257	62
Blow-offs defective,	361	118	382	110	314	97	290	88
Cases of deficiency of water,	35	13	32	9	33	13	26	8
Safety-valves overloaded,	109	43	99	35	97	31	81	42
Safety-valves defective,	91	37	87	18	103	41	106	40
Pressure-gages defective,	751	35	682	36	633	42	558	37
Without pressure-gages,	22	22	12	12	9	9	30	30
Unclassified defects,	0	0	0	0	1	0	1	1
Totals,	13,466	1,541	13,090	1,305	12,146	1,352	11,921	1,242

Inspectors' Reports.

On pages 25 and 26 we present a general summary of the work done by the inspectors of the Hartford Steam Boiler Inspection and Insurance Company, showing the number of defects of various kinds that were discovered each month, from May, 1907, to December, 1907, inclusive. The number of visits of inspection made, the total number of inspections, the number of complete internal inspections, the number of hydrostatic tests performed, and the number of boilers condemned, during the various months of this period, are given in the "Summary by Months," which will be found on page 28.

Summary of Inspectors' Reports for the Year 1907.

During the year 1907 the inspectors of the Hartford Steam Boiler Inspection and Insurance Company made 163,648 visits of inspection, examined 308,571 boilers, inspected 124,610 boilers both internally and externally, subjected 13,799 to hydrostatic pressure, and found 700 unsafe for further use. The whole number of defects reported was 159,283, of which 17,345 were considered dangerous. The usual classification by defects is given below, and a summary by months is given on page 28.

Summary, by Defects, for the Year 1907.

Nature of Defects.	Whole Number.	Dangerous.
Cases of deposit of sediment,	18,917	1,315
Cases of incrustation and scale,	38,427	1,333
Cases of internal grooving,	3,010	258
Cases of internal corrosion,	12,802	528
Cases of external corrosion,	10,230	768
Defective braces and stays,	2,219	578
Settings defective,	6,363	699
Furnaces out of shape,	7,564	396
Fractured plates,	3,551	568
Burned plates,	4,878	499
Laminated plates,	898	92
Cases of defective riveting,	3,582	823
Defective heads,	1,764	238
Leakage around tubes,	11,357	1,599
Cases of defective tubes,	8,266	3,054
Tubes too light,	1,947	563
Leakage at joints,	5,557	430
Water-gages defective,	3,008	707
Blow-offs defective,	4,216	1,250
Cases of deficiency of water,	413	156
Safety-valves overloaded,	1,231	415
Safety-valves defective,	1,211	407
Pressure gages defective,	7,651	465
Without pressure gages,	194	194
Unclassified defects,	27	10
Totals,	159,283	17,345

COMPARISON OF INSPECTORS' WORK DURING THE YEARS 1906 AND 1907.

	1906.	1907.
Visits of inspection made,	159,133	163,648
Whole number of inspections made,	292,977	308,571
Complete internal inspections,	120,416	124,610
Boilers tested by hydrostatic pressure,	13,250	13,799
Total number of defects discovered,	157,462	159,283
" " of dangerous defects,	15,116	17,345
" " of boilers condemned,	690	700

SUMMARY BY MONTHS FOR 1907

MONTH.	Visits of inspection.	Number of boilers examined.	No. inspected internally and externally.	No. tested hydro-statically.	No. con-demned.	No. of defects found.	No. of dangerous defects found.
January,	13,577	27,824	8,928	863	36	12,707	1,486
February,	13,354	26,006	7,703	881	51	11,166	1,429
March,	14,887	27,408	9,284	1,218	67	12,271	1,475
April,	14,743	27,200	11,404	1,241	55	14,704	1,752
May,	13,458	26,173	11,292	1,224	88	14,383	1,483
June,	13,221	23,754	11,591	1,129	51	14,774	1,457
July,	12,742	22,619	13,266	1,466	73	15,426	1,479
August,	12,442	23,072	11,137	1,505	50	13,229	1,344
September,	12,654	23,245	10,823	1,252	46	13,466	1,541
October,	14,493	27,213	10,516	1,285	37	13,090	1,305
November,	14,197	26,917	9,463	963	84	12,146	1,352
December,	13,880	27,140	9,203	772	62	11,921	1,242
Totals,	163,648	308,571	124,610	13,799	700	159,283	17,345

The following table is also of interest. It shows that our inspectors have made over two and a half million visits of inspection, and that they have made more than five million inspections, of which nearly two million were complete internal inspections. The hydrostatic test has been applied in over a quarter of a million cases. Of defects, more than three million have been discovered and pointed out to the owners of the boilers; and more than a third of a million of these defects were, in our opinion, dangerous. Upwards of nineteen thousand boilers have been condemned by us as unfit for further service, good and sufficient reasons for the condemnation being given to the assured in every instance.

GRAND TOTAL OF THE INSPECTORS' WORK SINCE THE COMPANY BEGAN BUSINESS, TO JANUARY 1, 1908.

Visits of inspection made,	2,611,311
Whole number of inspections made,	5,053,985
Complete internal inspections,	1,977,454
Boilers tested by hydrostatic pressure,	251,337
Total number of defects discovered,	3,333,350
Number of dangerous defects discovered,	343,220
Total number of boilers condemned,	19,128

Boiler Explosions During 1907.

We present, herewith, our usual annual summary of boiler explosions, giving a tabulated statement of the number of explosions that have occurred in the United States (and adjacent parts of Canada and Mexico) during the year 1907, together with the number of persons killed and injured by them. As we have repeatedly explained, it is difficult to make out accurate lists of boiler explosions, because the accounts that we receive are not always satisfactory; but, as usual, we have taken great pains to make the present summary as nearly correct as possible. It is based upon the monthly lists of explosions that are published in The Locomotive; and in making out these lists it is our custom to obtain several different accounts of each explosion, whenever this is practicable, and then to compare these accounts diligently, in order that the general facts may be stated with a considerable degree of accuracy. We have striven to include all the explosions that have occurred during 1907, but it is quite unlikely that we have been entirely successful in this respect, for many accidents have doubtless occurred that have not been noticed in the public press, and many have doubtless escaped the attention of our numerous representatives who furnish the accounts. We are confident, however, that most of the boiler explosions that have attracted any considerable amount of attention are here represented.

The total number of boiler explosions in 1907, according to the best information we have been able to obtain, was 471, which is 40 more than were recorded for 1906. There were 431 in 1906, 450 in 1905, 391 in 1904, and 383 in 1903. In two cases, during the year 1907, two boilers exploded simultaneously. (See Nos. 284 and 348 in our regular lists.) In each of these instances we have followed our usual practice and counted each boiler separately in making out the summary, believing that by so doing we should represent the actual damage more accurately than we should if we simply recorded the number of separate occasions on which boilers have exploded.

Summary of Boiler Explosions for 1907.

Month.	Number of Explosions.	Persons Killed.	Persons Injured.	Persons Killed and Injured.
January,	42	30	9	39
February,	50	33	60	93
March,	35	30	32	62
April,	44	25	31	56
May,	25	8	23	31
June,	37	19	34	53
July,	32	20	33	53
August,	38	33	35	68
September,	41	23	48	71
October,	46	22	28	50
November,	40	30	34	64
December,	41	27	53	80
Totals,	471	300	420	720

The number of persons killed in 1907 was 300, against 235 in 1906, 383 in 1905, 220 in 1904, and 293 in 1903; and the number of persons injured (but not killed) in 1907 was 420, against 467 in 1906, 585 in 1905, 394 in 1904, and 522 in 1903.

The average number of persons killed, per explosion, during 1907, was 0.637, and the average number of persons injured but not killed, per explosion, was 0.892.

During the year 1907 there were many very serious explosions, but we are glad to be able to record the absence of any that would compare, in regard to the number of persons killed, with the fearful explosion at Brockton, Mass., in 1905, or with that on the U. S. gunboat *Bennington*, in the same year.

Summary of Boiler Explosions, from 1879 to 1907 Inclusive.

YEAR.	Number of Explosions.	Persons Killed.	Persons Injured.	Persons Killed and Injured.
1879	132	208	213	421
1880	170	259	555	814
1881	159	251	313	564
1882	172	271	359	630
1883	184	263	412	675
1884	152	254	251	505
1885	155	220	278	498
1886	185	254	314	568
1887	198	264	388	652
1888	246	331	505	836
1889	180	304	433	737
1890	226	244	351	595
1891	257	263	371	634
1892	269	298	442	740
1893	316	327	385	712
1894	362	331	472	803
1895	355	374	519	893
1896	346	382	529	911
1897	369	398	528	926
1898	383	324	577	901
1899	383	298	456	754
1900	373	268	520	788
1901	423	312	646	958
1902	391	304	529	833
1903	383	293	522	815
1904	391	220	394	614
1905	450	383	585	968
1906	431	235	467	702
1907	471	300	420	720
Totals.	8,512	8,433	12,734	21,167

Hartford Steam Boiler Inspection and Insurance Company.

ABSTRACT OF STATEMENT, JANUARY 1, 1907.

Capital Stock, . . . $500,000.00.

ASSETS.

	Par Value.	Market Value.
Cash in office and in Bank, ...		$143,952.21
Premiums in course of collection (since Oct. 1, 1906),		173,449.47
Interest accrued on Mortgage Loans, ...		26,448.03
Loaned on Bond and Mortgage, ...		1,047,720.00
Real Estate, ...		9,450.00
State of Massachusetts Bonds, ...	$100,000.00	92,000.00
County, City, and Town Bonds, ...	326,000.00	340,330.00
Board of Education and School District Bonds, .	34,000.00	35,800.00
Drainage and Irrigation Bonds, ...	3,000.00	3,000.00
Railroad Bonds, ...	1,439,000.00	1,582,090.00
Street Railway Bonds, ...	62,000.00	62,250.00
Miscellaneous Bonds, ...	87,500.00	87,665.00
National Bank Stocks, ...	41,800.00	60,970.00
Railroad Stocks, ...	194,200.00	259,201.00
Miscellaneous Stocks, ...	65,500.00	53,920.00
	$2,353,000.00	
Total Assets, ...		$3,978,245.71

LIABILITIES.

Re-insurance Reserve, ...		$1,931,847.29
Commissions and brokerage, , ...		34,689.89
Losses unadjusted, ...		26,250.80
Surplus, ...	$1,485,457.73	
Capital Stock, ...	500,000.00	
Surplus as regards Policy-holders, .	**$1,985,457.73**	1,985,457.73
Total Liabilities, ...		$3,978,245.71

On December 31, 1906, the Hartford Steam Boiler Inspection and Insurance Company had 95,310 steam boilers under insurance.

L. B. BRAINERD, Pres. and Treas. FRANCIS B. ALLEN, Vice-President.
C. S. BLAKE, Secretary. L. F. MIDDLEBROOK, Asst. Sec.
E. J. Murphy, M. E., Consulting Engineer.
F. M. Fitch, Auditor.

BOARD OF DIRECTORS.

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Incorporated 1866.

Charter Perpetual.

The Hartford Steam Boiler Inspection and Insurance Company

ISSUES POLICIES OF INSURANCE COVERING

ALL LOSS OF PROPERTY

AS WELL AS DAMAGE RESULTING FROM

LOSS OF LIFE AND PERSONAL INJURIES DUE TO STEAM BOILER EXPLOSIONS.

Full information concerning the Company's Operations can be obtained at any of its Agencies.

Department.	Representatives.	Offices.
NEW YORK, . .	C. C. GARDINER, JR., Manager, R. K. McMURRAY, Chief Inspector,	New York City, N. Y., 100 William St.
NORTHEASTERN, .	C. E. ROBERTS, Manager, F. S. ALLEN, Chief Inspector,	Boston, Mass., 101 Milk St. Providence, R. I., 29 Weybosset St.
PENNSYLVANIA, .	CORBIN & GOODRICH, Gen. Agents, WM. J. FARRAN, Chief Inspector,	Philadelphia, Pa., 432 Walnut St.
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GULF, . . .	PETER F. PESCUD, General Agent, R. T. BURWELL, Chief Inspector,	New Orleans, La., 818 Gravier St.
HOME, . . .	E. H. WARNER, General Agent, H. C. LONG, Special Agent, F. H. WILLIAMS, JR., Special Agent, F. S. ALLEN, Chief Inspector,	Hartford, Conn., 56 Prospect St.
SOUTHERN CONN.,	W. G. LINEBURGH & SON, Gen. Agts.,	Bridgeport, Conn., 1 Sanford Building.
PITTSBURG, . .	JAMES W. ARROTT, LTD., Gen. Agt., BENJAMIN FORD, Chief Inspector,	Pittsburg, Pa., 401 Wood Street.
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WESTERN, . .	THOS. E. SHEARS, General Agent, THOS. E. SHEARS, Chief Inspector,	Denver, Col., Room 2, Jacobson Bldg.
PACIFIC COAST, .	H. R. MANN & CO., General Agents, J. B. WARNER, Chief Inspector,	San Francisco, Cal., Merchants' Ex. Bldg

The Locomotive

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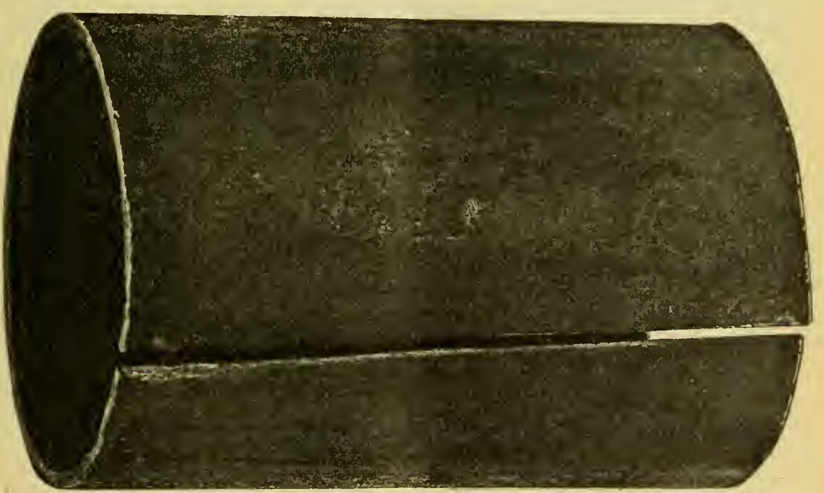
Concerning Boiler Tubes.

In the issue of The Locomotive for July, 1907, we published a short article in which we strongly recommended that boiler tubes be indelibly stamped at the mills where they are made, so that an inspection of such tubes, even after they had been in service for a long time, would reveal their origin, and the degree of excellence assigned to them by their makers. It has always appeared to us that the advantages of marking tubes in this way are so great, and so manifest, that there is hardly any room for argument in the matter. Stamping would certainly be advantageous to the purchaser of such tubes, and we should suppose that it would also be of advantage to a conscientious manufacturer,



A Boiler Tube That Split While Being Cut Off.

who is striving to turn out the best quality of material that he can; for his stamp would constitute a guarantee (actual or implied) of the grade of the tube, and hence it would presumably tend to increase his sales.

We present, herewith, a photo-engraving which will show the gravity of the present state of affairs. A four-inch tube ruptured, recently, in a water-tube boiler insured by this company, and a new tube, represented to be of the first quality, was purchased from a local and presumably reputable dealer, to take its place. The new tube was somewhat too long, so that it was necessary to cut about six inches off from one end of it, before it was set in the boiler. While the cut was being made, the tube split apart at the weld for some distance, and it was of course rejected at once. Examination of the end of the tube, which is shown in the engraving, disclosed the fact that the weld had been made by merely butting the edges of the tube together, without the slightest attempt at scarfing.

This tube was bought for a first-class one, and was to be set in a boiler carrying a working pressure of 150 pounds to the square inch; and under these circumstances, it would be some comfort to be able to trace it with certainty to its maker, and see what he had to say about its being made with a butt weld, and about its splitting apart when under no stress except that due to the action of the cutting-off tool.

According to representations that have been made to us, this tube came from a certain well-known and highly reputable tube-manufacturing concern. We are strongly inclined to the belief that this report is somehow in error; but we cannot prove it to be so, because the concern in question does not stamp its tubes so that they can be positively identified.

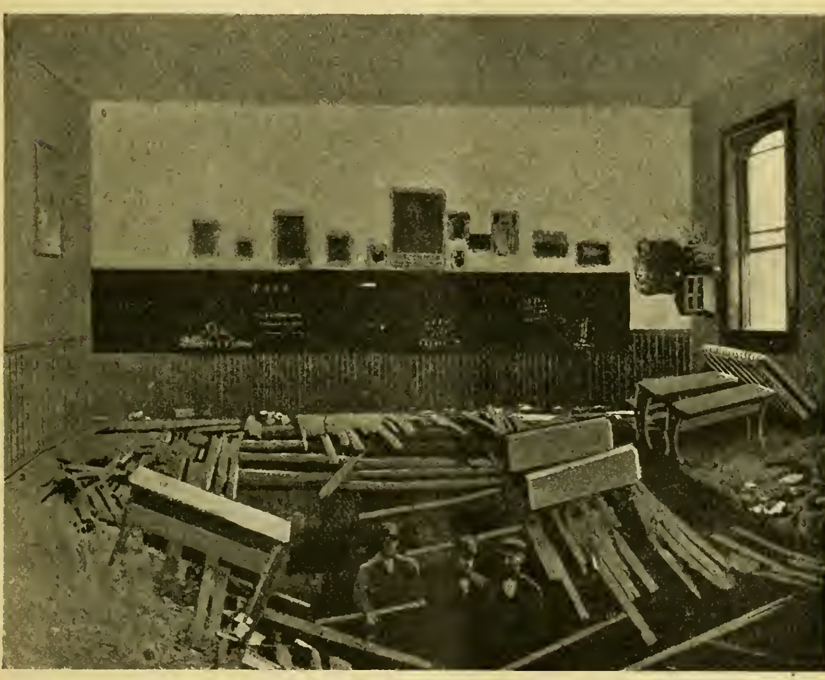
An incident of the cruise of the United States naval fleet to the Pacific ocean was the circulation of a baseless report of the explosion of a boiler on the battleship *Louisiana*. The Panama liner *Advance*, shortly before she reached New York, on January 18, received a mysterious wireless message announcing that the *Louisiana* was blown up at Rio de Janeiro, and that all on board were lost. The first message stated that the explosion occurred in a magazine; but a later one corrected this, and said that the accident consisted in the explosion of a boiler. It was impossible to trace the message to its source, but it was believed to come from some point on the Jersey coast. As there was no word of truth in the report, we are forced to conclude that the message represents somebody's idea of humor. Probably the humorous element was hard to see to the many who had relatives and friends among the officers and crew of the ship. If the person who sent this message was the same one who filled the air wirelessly with unprintable language at the time Sir Thomas Lipton last competed for the American cup, it would be a good plan to search him out, and give him a liberal application of tar and feathers.

Explosion of a Heating Boiler in a Public School.

A cast-iron sectional heating boiler exploded, on February 14, in a public school building at Adrian, Mo., as the pupils were engaged in the opening exercises of the morning. The building is of brick, two stories in height, and contains ten rooms, the boiler being located in the basement, under the primary department, in the southeast corner of the building.

The flooring of the primary department was torn up, as will be seen from the accompanying photo-engraving, and the inmates of the room, together with most of the furniture and flooring, were precipitated into the basement. There were fifty-six pupils enrolled as attendants in this room, and at the time of the explosion there were fifty-one present, in addition to the teacher, Miss Maude Morgan. All of the inmates were more or less severely burned by the steam, which filled the basement completely, and made the work of rescue very difficult.

Mr. Hoover, principal of the building, assisted by a dozen or so of the young men from the high school department, rushed into the basement without thought of their own danger, and were soon passing the little ones out to safety. Miss Morgan was pinioned by a fragment of the boiler and was severely burned; but we take pleasure in recording that she insisted upon the rescuers attending to the pupils first, before attempting to release her. All of the inmates of the primary room were more or less injured, and many of the children were taken out in an unconscious condition. Some of the larger boys who were engaged in the work of rescue were also overcome by the heat and steam. Seven of the children were very badly hurt indeed, and we are informed that one of the boys died on February 28, and that at that date it was believed that another would also



School-Room Wrecked by a Heating Boiler.

die, as the physicians had pronounced his case hopeless. Miss Morgan and eighteen of the pupils were also injured severely, and twenty-six were injured less seriously.

Room No. 2, adjoining the primary room, in charge of Miss Lucy Dowell, was likewise badly wrecked, several boards being blown from the floor and some of the joists loosened; but the floor did not fall.

Room No. 3 was not so badly shaken up, and Miss Leah Hudelson, the teacher, got her pupils out of the building in good order.

The exploded boiler was about six years old. It was fitted with the usual attachments, and it is said that the safety-valve was set to blow off at a pressure of thirty pounds per square inch. This appears to us to be unnecessarily high, although we cannot say that there was any reason to doubt the safety of the boiler at that pressure, as we have no data for deciding this point. The janitor who cared for the heating apparatus was not present at the time of the explosion.

The boiler was inspected last summer, it is said, though apparently not by a regular boiler inspector, trained to work of this character. No boiler insurance was carried.

Boiler Explosions.

January, 1908.

(1.) — A heating boiler exploded, January 1, during the course of a fire in the residence of Charles H. Tidy, at Greenville, Mich. J. W. Belknap and E. A. Kemp were injured by the explosion.

(2.) — On January 1 a tube ruptured in a water-tube boiler at the plant of the Alpha Portland Cement Co., Martin's Creek, Pa.

(3.) — A boiler exploded, January 3, in J. C. Gilham's saw-mill, at Elsy, six miles from Galena, Mo. J. C. Gilham, Charles McGoldrich, and George Howerton were injured seriously, and Sherman Wildman, Oscar Jones, Charles Kimerson, and Jacob Warr were slightly injured. The mill was wrecked.

(4.) — On January 3 a slight accident occurred to a boiler at the Harrington Milling Co.'s flouring mills, Harrington, Wash.

(5.) — A tube ruptured, January 3, in a water-tube boiler at the power house of the Parkersburg, Marietta & Inter-Urban Electric Co., Marietta, Ohio. Hugo Uhlman was scalded and burned so badly that he afterwards died, and Charles Conrath was injured badly but not fatally.

(6.) — A tube ruptured, January 4, in a water-tube boiler at the Savery Hotel, Des Moines, Iowa. William Jarvis and Arthur Jarvis were severely injured.

(7.) — On January 5 a boiler used for pumping purposes exploded near Hamilton, Ohio. George Morningstar was slightly injured. The boiler was operated by Contractor John P. Meehan who was putting in concrete walls for the new Two Mile bridge.

(8.) — A boiler accident occurred, January 5, in A. V. Morris & Son's knitting mill, Amsterdam, N. Y.

(9.) — The crown-sheet of a boiler used for operating a corn shredder blew out, January 6, on the Imhoof farm, seven miles west of McComb, Ohio. Frank Courtwright was injured so badly that he died two days later. John Miller, Thomas Renshaw, and William Teewalt were also injured seriously, but not fatally.

(10.) — On January 6 a boiler used for operating a corn shredder exploded on D. C. Hahn's farm, at Freesburg, seven miles south of Alliance, Ohio. Clarence Shidler was injured seriously and perhaps fatally.

(11.) — The boiler of "turtle-back" locomotive No. 1772, of the Baltimore & Ohio railroad, exploded, January 6, at Altamont, Md. Engineer Frank Smith was thrown 450 feet and seriously injured. The locomotive was badly wrecked, and so also was a signal tower near the scene of the explosion.

(12.) — On January 6 a boiler exploded in Riley Waters' saw-mill, near Bath, Menifee County, Ky. Engineer Joseph Justice was killed, and Mr. Waters was badly injured. (On September 13, 1906, a boiler exploded in this same mill, killing two men, and scalding two women and a child. See No. 293, in our regular list for 1906, in the issue of The Locomotive for January, 1907, page 148.)

(13.) — On January 6 a hot-water heating boiler exploded in the basement of Frederick Kimmel's residence, Seneca Park Circle, Rochester, N. Y. The building was badly damaged, and the property loss amounted to several thousand dollars.

(14.) — A boiler exploded, January 7, in William J. Thompson's saw-mill, at Sedan, twenty miles west of Portsmouth, Ohio. Jesse Thompson and John Thompson (sons of the owner) were killed, and several other persons were injured. The mill was demolished.

(15.) — A number of cast-iron headers fractured, January 8, in a water-tube boiler at the plant of the Semet Solvay Co., Ensley, Ala.

(16.) — A heating boiler exploded, January 8, in the high school building at Fort Worth, Tex. The heating plant was wrecked. (This is said to be the second boiler that has exploded in the same building since January 1, but we cannot give the date of the earlier explosion.)

(17.) — On January 9 a rendering tank exploded in the Western Meat Co.'s plant, South City, Cal. One man was killed, and the property loss was estimated at $4,000.

(18.) — A boiler exploded, January 9, in the meat-cutting department of F. G. Tigglebeck & Co.'s plant, Wheeling, W. Va. The boiler was thrown about 200 feet. Property loss about $800.

(19.) — On January 10 a boiler exploded on the Virginia Brown farm, East Liverpool, Ohio.

(20.) — A blow-off cock failed, January 11, at the A. Burdsall Co.'s plant, Indianapolis, Ind. William Drinkut was injured.

(21.) — A number of cast-iron headers fractured, January 11, in a water-tube boiler at the City Waterworks plant, South Bend, Ind.

(22.) — On January 11 a boiler exploded in William Halverson's Center Valley creamery and cheese factory, near Appleton, Wis.

(23.) — On January 13 a heating boiler exploded in a public school building at Ravenna, Neb.

(24.) — The boiler of freight locomotive No. 866, of the Erie railroad, exploded, January 13, near Rutherford, N. J. Fireman Otto Wagner was instantly killed, and engineer George Waidler was seriously injured. Charles Albers and Edward Asmenger, engineer and fireman, respectively, of locomotive No. 1080, which was coupled to the one that exploded, were also injured by flying débris. The track was badly torn up.

(25.) — A tube ruptured, January 15, in a boiler on the U. S. Hospital launch *Petrel*, at Portland, Me.

(26.) — A small boiler, used for heating water, exploded, January 15, in the basement of the Young Men's Christian Association building, Saratoga Springs, N. Y. Miss Rose Haas was slightly injured. The boiler was wrecked, and the property loss was estimated at $2,000.

(27.) — On January 16 a slight rupture occurred to a boiler at the Newell Water & Power Co.'s plant, Newell, W. Va.

(28.) — A boiler exploded, January 16, in J. W. Crofford's mill, at Ashland, Miss. Mr. Crofford was seriously injured, and Robert Walker received minor injuries. The mill was considerably damaged.

(29.) — A boiler belonging to the Colorado & Southern railroad exploded, January 17, at Trinidad, Colo. One man was seriously injured.

(30.) — A heating boiler ruptured, January 18, in the Wadsworth block, Waltham, Mass., causing considerable damage to stock in the Hub department store, situated in the block.

(31.) — On January 19 the steamer *F. A. Kilburn*, owned by the Independent Steamship Co., of Los Angeles, Cal., put in at Monterey Bay in distress, two of her boiler tubes having burst. John Lund and another man named Hanos were scalded, and it was thought that Hanos could not recover.

(32.) — On January 20 a pipe connection to a water-column failed at the Concord Light & Power Co. plant of the United Gas Improvement Co., Concord, N. H. Engineer A. W. Carpenter was scalded.

(33.) — A boiler exploded, January 20, in the cement works at Longue Pointe, near Montreal, P. Q. Thomas Lachy was injured so badly that he was not expected to recover. The building in which the boiler stood was badly wrecked.

(34.) — A heating boiler exploded, on or about January 21, in a public school building at Pennsgrove, near Philadelphia, Pa.

(35.) — A cast-iron heating boiler ruptured, January 22, in the store of Lamkin & Foster, Congress street, Boston, Mass.

(36.) — On January 23 a heating boiler exploded in the Young Men's Christian Association building, Lansing, Mich.

(37.) — A tube ruptured, January 23, in a water-tube boiler at the Massachusetts Mills, Lindale, Ga. Joshua Wanamaker was injured.

(38.) — On January 23 a boiler exploded at the plant of the International Cork Co., Williamsburg, New York City. Fire followed, and the plant was destroyed with a loss of about $60,000.

(39.) — On January 24, at the Seaview Ave. power station of the New York, New Haven & Hartford Railroad Company, Bridgeport, Conn., a pipe connection pulled out of a superheater attached to a boiler.

(40.) — A heating boiler ruptured, January 24, in the New Republic Hotel, Alpena, Mich. The accident is said to have been due to turning cold water into a hot and empty boiler.

(41.) — A boiler used for furnishing heat and power exploded, January 24, in the rear of the Tremont Hotel, Wabash, Ind. William Hudson was slightly injured, and the building in which the boiler stood was wrecked.

(42.) — A boiler exploded, January 25, in Dr. E. R. Waters' saw-mill, at Gilliam, near Shreveport, La. William McClellan, John Burnham, and George Jackson were killed, and Victor Thoman, William Jackson, Joseph White, and Thomas Collier were injured. The mill was considerably damaged, and the property loss was estimated at $2,000.

(43.) — Several cast-iron headers fractured, January 28, in a water-tube boiler at the New Haven Iron & Steel Co.'s plant, New Haven, Conn.

(44.) — On January 28 a tube failed in a water-tube boiler at the Blish Milling Co.'s flouring mill, Seymour, Ind.

(45.) — Several tubes ruptured, January 30, in a water-tube boiler at the Elyria Iron & Steel Co.'s plant, Elyria, Ohio.

(46.) — A tube ruptured, January 30, in a water-tube boiler at the Des Moines City Railway Co.'s electric power station, Des Moines, Iowa.

(47.) — On January 31 a boiler exploded in John Tucker's saw-mill, at Bowling Green, near Brazil, Ind. The mill was blown to atoms, but the men were all at dinner, and nobody was injured.

(48.) — A boiler exploded, January 31, in J. B. Lardinois' shop, at Brussels, near Sturgeon Bay, Wis. Ephraim Delfosse was injured so badly that he died a few hours later, and Mr. Lardinois, the owner of the shop, received slight injuries.

February, 1908.

(49.) — The boiler of an outfit owned by the Van Horn Company, and used in drilling for coal, exploded, February 1, on the Muddy river, near Riverton, Wyo. The machinery was entirely ruined.

(50.) — Two boilers exploded, February 2, at the Agua Blanca mine, Jalisco, Mex. Several persons were injured, and the property loss was about $10,000.

(51.) — A cast-iron sectional heating boiler ruptured, February 3, in the Hotel Woodcock, managed by W. P. Ruisseau & Son, Boston, Mass.

(52.) — A boiler exploded, February 3, in the puddling department of Van Alen & Co.'s nail mill, Northumberland, Pa. Willard Brouse, David Clark, Grant Reeder, Edward Kreps, Thomas Jones, Samuel Sarviss, and John F. Schovlin were killed, and eight other persons were injured, one of whom has since died. One end of the building in which the boiler stood was entirely wrecked. The property loss was probably about $10,000.

(53.) — On February 3 a slight rupture occurred in a boiler at the American Excelsior Laundry, Pine Bluffs, Ark.

(54.) — On February 3 a boiler exploded in the Welch-Bright Co.'s brick manufacturing plant, in Moon township, just across the borough line of Monaca, and the Pittsburg & Lake Erie's bridge from Beaver, Pa. George Fabish and John Fabinic were fatally injured, and four other men were injured less seriously. The building, a frame structure 300 feet long and 250 feet wide, was badly wrecked, and the property loss was estimated at $10,000 to $20,000.

(55.) — A boiler exploded, February 4, in the gas plant of the Public Service Corporation, Newark, N. J. One man was fatally scalded.

(56.) — On February 4 a number of sections fractured in a cast-iron heating boiler at the State street school, Menominee, Mich.

(57.) — The boiler of a Baltimore & Ohio freight locomotive exploded, February 4, in Linden township, near Elizabeth, N. J. Engineer John Arke, fireman Patrick Murphy, and brakeman James Callahan were slightly injured. Fragments of the boiler and machinery were thrown several hundred feet.

(58.) — A blowoff pipe ruptured, February 4, at the Duncannon Iron Co.'s plant, Duncannon, Pa. Three men were slightly injured.

(59.) — On February 5 a heating boiler exploded in the Herald & News Printing Office, Perry, N. Y.

(60.) — A blowoff connection failed, February 5, at Atkinson & Co.'s cocoa manufacturing plant, Brooklyn, N. Y.

(61.) — A slight boiler explosion occurred, February 6, in the plant of the Noblesville Heat, Light & Power Co., Noblesville, Ind.

(62.) — On February 7 a boiler ruptured at the greenhouses of Frank H. Traendly and Charles Schenck, Rowayton, Conn.

(63.) — The boiler of a freight locomotive exploded, February 7, at Echo, Ore. One man was seriously injured.

(64.) — Three heating boilers burst, February 9, in the U. S. Marine Hospital, Chicago, Ill.

(65.) — A boiler exploded, February 9, at the Macon Railway & Light Co.'s plant, Macon, Ga. Two men were injured.

(66.) — On February 10 a boiler accident occurred at the Burgess Sulphite Fiber Co.'s plant, Berlin, N. H. The damage was confined to the boiler.

(67.) — A tube failed, February 10, on a Big Four freight locomotive, at Shelbyville, Ind. Fireman John W. Dayhoff was injured so badly that he died a few hours later.

(68.) — On February 10 several tubes failed in a water-tube boiler at the Markham Manufacturing Co.'s plant, Plymouth, Mich.

(69.) — On February 10, while the cruiser *St. Louis* was lying off Sausalito, San Francisco Bay, the water-leg of one of her boilers blew out, or (according to an unofficial account) a tube failed in one of her boilers. E. Thompson, E. W. Baker, T. Lewis, and G. W. Smith were seriously scalded, and one other man received lesser injuries. The cruiser herself was not seriously damaged.

(70.) — On February 11 a slight boiler explosion occurred in the Sabina Flour Mill Co.'s plant, Sabina, Ohio.

(71.) — A tube ruptured, February 11, in a water-tube boiler at the F. B. Goodrich Co.'s plant, Akron, Ohio. (See also No. 79, below.)

(72.) — A heating boiler exploded, February 11, in George Semler's residence, Central Boulevard, Mt. Vernon, N. Y. A woman who was washing in the basement was seriously injured, and Michael Sullivan, a coachman, was bruised and shaken up. Fire followed the explosion, and the residence was practically destroyed, with a total property loss estimated at $25,000.

(73.) — On February 11 a boiler exploded at the Solomon Independent Ice Co.'s plant, at Brookside, near Troy, N. Y. Matthew Fitzgerald was instantly killed, and Archibald Chequin was injured so badly that he died a few hours later. The building in which the boiler stood was completely wrecked.

(74.) — A cast-iron heating boiler ruptured, February 12, in St. Joseph's Roman Catholic Church, Danbury, Conn.

(75.) — A boiler exploded, February 14, in the public school building at Adrian, near Butler, Mo. The floor of one of the rooms was torn up, and Miss Maude Morgan, teacher of the primary department, and fifty-one of her little pupils, were precipitated into the basement, together with the furniture of the room, and miscellaneous débris. The work of rescue began promptly, the boys from the high school department, situated in another part of the building, rendering manful and efficient service. The children were rapidly passed up out of the wreckage to safety. Miss Morgan and twenty-five of the children were severely injured, and twenty-six other pupils were injured less seriously. According to later advices, one of the boys that was hurt died on February 28, and it was believed that another would die also, as the physicians had pronounced his case hopeless. Estimates of the property loss vary from $2,000 to $4,000.

(76.) — On February 15 a boiler exploded at the American Fuel Co.'s coal mines, at Clarkville, near Gallup, McKinley County, N. Mex. Engineer Bell was killed instantly, and the fireman was scalded so badly that he died within a short time. The boiler house was wrecked, and estimates of the property loss run as high as $30,000.

(77.) — A boiler exploded, February 17, in the Young Men's Christian Association building, Holyoke, Mass. One man was severely injured.

(78.) — A boiler exploded, February 17, in the colliery of Coxe Bros. & Co., at Sheppton, near Wilkesbarre, Pa. John Hoffman and John Numirick were burned so badly that it was believed they could not recover, and the boiler room was demolished.

(79.) — On February 18 a tube ruptured in a water-tube boiler at the F. B. Goodrich's Co.'s plant, Akron, Ohio. (See also No. 71, above.)

(80.) — A boiler exploded, February 18, in a mill at Walden, N. Y., instantly killing Asa Sherwood.

(81.) — A tube burst, February 19, in a water-tube boiler at the University of Pennsylvania, Philadelphia, Pa.

(82.) — A blowoff pipe ruptured, February 19, at the Shelby plant of the Southern Cotton Oil Co., Shelby, N. C. Odus McDowell and Preston Taylor were injured.

(83.) — On February 19 an economizer exploded in the new power plant of the Hamilton Manufacturing Co., Lowell, Mass. Thomas Slattery, Jasper Lundberg, Oscar McFarland, Frank Gaynor, Michael Beecher, Henry Sullivan, John Murphy, Alfred Lindsay, Frank Riley, Axel Olson, Timothy H. Reardon, John J. Pindar and William L. Angell were injured by the explosion, most of them quite severely; and Thomas Kenneally was run down, in the street, by a hose carriage, and badly hurt. Two of the men hurt by the explosion were believed to be fatally injured; but we have not learned that any of them died. The plant was badly damaged, the property loss upon it being estimated at $20,000. Four stores and the Traders' National Bank, on Middlesex street, opposite the power house, were also damaged considerably, the loss on these buildings being about $2,500.

(84.) — A tube ruptured, February 20, in a water-tube boiler at the Fowler Packing Co.'s plant of the National Packing Co., Kansas City, Kan.

(85.) — A blowoff connection failed, February 20, on a boiler at the State Asylum for the Insane, Medical Lake, Wash.

(86.) — A boiler used for operating a feed cutter exploded, February 20, in J. T. Ryburn's barn, Chartiers township, near Washington, Pa., injuring Mr. Ryburn, his son William, Alexander Drake, and David Welch.

(87.) — The boiler of a portable saw-mill exploded, February 21, on George Stiving's farm, four miles south of Shelby, Ohio. Mr. Stiving was instantly killed, and another man named Whitney was slightly injured.

(88.) — On February 22 a boiler exploded in a saw-mill near Rock Creek, Jefferson County, Mo. John Reibold was injured so badly that he died three days later. James Reibold and Charles Schylt were also injured seriously but not fatally.

(89.) — A boiler belonging to the Sunset Road Oil Co. exploded, February 22, at Bakersfield, Cal. Charles D. House was instantly killed, his body being thrown to a distance of 1,000 feet.

(90.) — On February 25 a boiler exploded in H. D. McLeod's saw-mill, some two miles from Durant, Fla. Mr. McLeod was instantly killed, and Joseph Tucker, Jr., and several other employees (including a son of the owner) were painfully injured.

(91.) — On or about February 26 a boiler used for pumping petroleum exploded on the Davis farm, near North Baltimore, Ohio. The boiler house was demolished, and the boiler itself was projected to a distance of 500 feet.

(92.) — A tube pulled out of a water-tube boiler, February 26, at the "Station A" plant of the Detroit City Gas Co., Detroit, Mich. Fireman T. Betwee was injured.

(93.) — A boiler belonging to the Barstown Inter-Urban Line exploded, February 28, at Fern Creek, Ky. Two persons were seriously injured.

(94.) — A cast-iron header fractured, February 28, in a water-tube boiler at the Herman Zohrlaut Leather Co.'s plant, Milwaukee, Wis.

(95.) — A boiler exploded, February 29, in a mill at Coulterville, Ill. Leonard Wies was seriously injured.

(96.) — On February 29 a boiler exploded in Lewis' mill, two miles north of Sheridan, Ark.

March, 1908.

(97.) — A boiler exploded, March 2, in George English's sawmill, just east of Pompeii, Mich. Louis Mikesell was injured, and the mill was completely wrecked.

(98.) — A boiler exploded, March 2, at an oil well, near St. Marys, W. Va. Elgar G. Lantz was killed.

(99.) — On March 2 a boiler exploded in a sawmill about half a mile south of Colonia Garcia, Chihuahua, Mex. Engineer George Turley was instantly killed, and S. C. O'Donnal and Orin Farnsworth were severely injured. (We understand that Colonia Garcia is a Mormon colony.)

(100.) — A boiler exploded, March 3, in H. D. McLeod's sawmill, on the Alafia river, South Carolina. The owner of the mill was killed.

(101.) — The boiler of Southern freight locomotive No. 28 exploded, March 4, at Champion Spur, near Roberta, Ga. Engineer Charles O'Neill was fatally injured. Two other men were also scalded, one of them fatally so. The locomotive and four freight cars were completely wrecked, and the tracks were torn up for a hundred yards.

(102.) — On March 4 an upright boiler exploded in the Oregon R. R. & Navigation Co.'s scrap yard, Portland, Ore. L. C. Murray was slightly injured, and the boiler passed up through the roof of the building like a sky-rocket.

(103.) — A boiler exploded, March 5, in the Hall sawmill, at Stumptown, near Butler, Mo. Two men were seriously injured.

(104.) — On March 5 a stop-valve broke on a boiler in the Arnholt & Schaefer Brewing Co.'s plant, Philadelphia, Pa. Fireman Christopher Janoss, who was screwing up a nut on the valve at the time, was slightly injured.

(105.) — A boiler exploded, March 6, in Harper & Smith's sawmill, near Timmonsville, S. C. Mrs. Minnie Rose was killed.

(106.) — A tube cracked, March 6, in a water-tube boiler at the City Water Works, Bloomington, Ill.

(107.) — A blowoff pipe failed, March 7, on a boiler at the "Pennsylvania Dock" of the Pennsylvania Coal & Supply Co., Milwaukee, Wis. Ignatz Borkowsky was killed.

(108.) — A boiler exploded, March 8, at one of the Zeidley oil wells, near Jennings, La. A. Sounier, Nathan Connolly, and Joseph Langley were badly injured. The boiler, which was blown to fragments, belonged to the Crowley-Eunice Oil Co.

(109.) — A slight boiler explosion occurred, March 8, in St. Thomas' Church, Baltimore, Md.

(110.) — A tube ruptured, March 8, in a water-tube boiler in the New York Central & Hudson River R. R. Co.'s roundhouse, at West Albany, N. Y. Lewis Schultz, a fireman, was scalded.

(111.) — On March 9 the cast-iron mud-drum of a water-tube boiler exploded at the Arlington Mills, Lawrence, Mass. Joseph Greet was injured.

(112.) — On March 9 a furnace collapsed in a boiler located in the rear of 218 Dock St., Philadelphia, Pa., controlled by D. M. Ellis, and used for light manufacturing. Adolp Leiffer, Daniel Krewson, Henry Haase, and Irvin Hirst were injured. The two last-mentioned persons were strangers about the premises, and one of them died from his injuries a few days later.

(113.) — A boiler exploded, March 10, in John Amoral's barn, some two miles from Armington's Corners, in East Providence, R. I. Manuel Swarez and John A. Silva were seriously injured, and Swarez died from his injuries, ten days later.

(114.) — A boiler exploded, March 11, in the pump-house of the City Water Works, Gallipolis, Ohio. The fires had been banked for the night, and nobody was in the building at the time. Mrs. Anna Steed was struck by flying débris, however, and one of her arms was broken. The plant was wrecked.

(115.) — The boiler of a portable sawmill owned by William Johnson exploded, March 11, about three miles from Sarnia, Ont. James Harkins was instantly killed, and Joseph Kemsley and Charles Kemsley were injured. The boiler was hurled fifty rods.

(116.) — A boiler tube burst, March 12, at the Mt. Pleasant colliery, Scranton, Pa. Two persons were seriously injured.

(117.) — On March 14 a boiler belonging to Clarence Carrigan exploded at Davis Station, S. C. One person was killed.

(118.) — On March 15 a tube ruptured in a water-tube boiler in the J. L. Hudson Co.'s department store, Detroit, Mich. Engineer Adam Wright and fireman Charles Cook were injured so badly that both died shortly afterwards. The property loss was considerable.

(119.) — A steam digester exploded, March 16, in John Walter's phosphate mill, near Hanover, Pa. The property loss was about $500.

(120.) — Two tubes ruptured, March 16, in a water-tube boiler at the plant of the Independent Breweries Co., St. Louis, Mo.

(121.) — A tube ruptured, March 17, in a water-tube boiler at the Lawrence Cement Co.'s plant, Siegfried, Pa. Fireman Giaiani Cocalain was slightly injured.

(122.) — A boiler explosion occurred, March 17, in the plant of the Oakland Gas, Light & Heat Co., Oakland, Cal. Two persons were severely injured.

(123.) — A boiler expleded, March 17, in George Kempf's planing mill, Crandon, Wis. George Kempf (the owner) and William Hawkins were almost instantly killed, and George Minton received injuries from which he died within an hour or two. Henry Kempf was also injured seriously, but not fatally.

(124.) — On March 18 a boiler exploded in G. W. Moore's sawmill, at Homeland, near Folkston, Ga. Mr. Moore was killed, and three other persons were injured.

(125.) — On March 19 a slight rupture occurred in a boiler at the Priscilla Woolen Co.'s plant, Spencer, Mass.

(126.) — A tube ruptured, March 19, in a water-tube boiler at the Murphy Power Co.'s steam heating and cold storage plant, Detroit, Mich. John Kennedy and Frank Mapes were injured, and the boiler was badly damaged.

(127.) — The boiler of the Delaware & Hudson R. R. Co.'s freight locomotive No. 813 exploded, March 22, at Schenevus, N. Y. Engineer Louis Hendrickson and brakeman A. Kerfage were killed almost instantly, and fireman S. O. Smith was scalded so badly that he died shortly after being removed to the hospital. Coals from the firebox of the exploded locomotive set fire to the railroad station, the Commercial Hotel, and a large store-house near the hotel. The station and the hotel were saved, but the store-house and its contents were destroyed.

(128.) — A tube ruptured, March 23, in a water-tube boiler at the Ashaway Line & Twine Mfg. Co.'s plant, Ashaway, R. I.

(129.) — A heating boiler exploded, March 23, at the South Bend Floral Co.'s greenhouses, South Bend, Ind. O. A. Wood was injured, and the property loss was about $1,500.

(130.) — On March 26 a locomotive boiler, used for operating a hoisting engine, exploded at the Green Mountain stripping of the L. & W. B. Coal Co., near Hazelton, Pa.

(131.) — On March 28 a tube and a cast-iron header ruptured in a water-tube boiler at the Kehlor Flour Mills Co.'s plant, East St. Louis, Ill.

(132.) — On March 28 a slight accident occurred to a boiler in Charles Ziegenbalg's rendering plant, St. Louis, Mo.

(133.) — On March 31 a rendering tank failed in the plant of the Henry Muhs Co., Paterson, N. J. One man was slightly injured.

One or more boilers exploded, January 5, on the Argentine steamship *Imperatrice,* off the island of Ushant, near Brest, France. The ship foundered, but the crew were saved by a fishing smack.

Here is a little story that we certify to be true. The incident came to our knowledge many years ago, and we could give the names of the town and of the shop and of the boss, if we wanted to, which we don't. The story hasn't any particular moral, so far as we know, and it doesn't illustrate anything under the blue vault of heaven, except the readiness with which some men will tackle a job that they don't really understand. A hard-headed old mechanic one day hired a new man, who came into his shop and represented himself to be a first-class machinist. A couple of hours after he had gone to work, the aforesaid hard-headed boss came along and found the new man prying the tail end of his lathe along the floor with a crow-bar, while the head end remained fixed. Asking what was up, the boss received the reply that the work had got to be turned on a taper, and the tail end of the lathe had therefore got to be set over. The new man got rid of his job at once, and the boss simultaneously got rid of a lot of dark-brown language.

Inspectors' Reports.

On page 46 we present a general summary, by defects, of the work done by the inspectors of the Hartford Steam Boiler Inspection and Insurance Company, during the months of January, February, and March, 1908. We also give, below, a summary for these months, showing the number of visits of inspection made, the total number of boilers examined, the total number inspected internally, the number tested by hydrostatic pressure, and the number of boilers condemned.

	Month (1908).		
	January.	February.	March.
Visits of inspection,	15,169	14,003	15,004
Total number of boilers examined,	28,722	26,348	27,790
Number inspected internally,	9,388	8,623	9,309
Number of hydrostatic tests,	523	585	742
Number of boilers condemned,	39	40	35

Inspectors' Reports for January, February and March, 1908.

Nature of Defects.	January.		February.		March.	
	Total defects.	Dangerous.	Total defects.	Dangerous.	Total defects.	Dangerous.
Cases of deposit of sediment,	1,503	86	1,323	144	1,564	107
Cases of incrustation and scale,	2,954	94	2,903	113	3,169	101
Cases of internal grooving,	172	19	159	18	166	21
Cases of internal corrosion,	923	42	866	42	998	41
Cases of external corrosion,	726	56	621	42	702	36
Defective braces and stays,	169	30	161	27	184	41
Settings defective,	439	72	337	36	427	64
Furnaces out of shape,	522	33	473	28	574	30
Fractured plates,	240	41	212	35	269	53
Burned plates,	352	43	401	55	401	44
Laminated plates,	63	7	39	6	52	6
Cases of defective riveting,	177	14	309	91	425	77
Defective heads,	105	18	113	25	113	19
Leakage around tubes,	895	218	866	86	891	117
Cases of defective tubes,	516	174	690	250	649	212
Tubes too light,	108	33	176	67	115	28
Leakage at joints,	385	29	477	37	429	37
Water-gages defective,	187	47	202	50	212	54
Blow-offs defective,	294	86	329	85	359	114
Cases of deficiency of water,	37	6	48	13	38	19
Safety-valves overloaded,	113	27	99	26	120	35
Safety-valves defective,	63	19	91	33	93	26
Pressure gages defective,	547	37	550	46	651	39
Without pressure gages,	23	23	75	75	30	30
Unclassified defects,	2	1	2	1	0	0
Totals,	11,515	1,255	11,522	1,431	12,631	1,351

Burning Ashes.

Every once in a while we hear of compounds that are proposed apparently in all seriousness, for the purpose of greatly improving the efficiency of a coal fire, or even for enabling the fire to be run successfully with ashes alone, or with ashes in combination with a relatively small proportion of fresh coal. We have not taken notice of these compounds in The Locomotive, because we have felt that the proposition that *real ashes* can be burned, either with or without the admixture of coal, provided they are first sprinkled over with a small quantity of solution, is too absurd to be discussed, among engineers or firemen of experience. Our attention has been called, however, to a surprising circular issued by the Department of Education of the city of New York, from which it appears that the said department has taken the matter very seriously; and this leads us to make the following remarks:

Ashes always contain a certain amount of unburned coal, but, with good practice in the fire-room, the proportion of unburned coal that is present should be small. In several analyses that lie before us, the amount ranges from 9 per cent. to 13 per cent., and we are of the opinion that in ordinary practice the proportion will vary between 10 and 12 per cent. There is no doubt but that the unburned coal here referred to can be burned, but to effect its combustion efficiently the coal must be separated from the true ash, either by sifting or otherwise. As we understand the proposition of the men who advocate the ash-burning compounds, however, it is not the coal that has escaped combustion that they propose to burn, but the actual ash, which constitutes what is ordinarily regarded as the incombustible residue; and it is with this understanding that we are writing the present article.

Barr, in his "Practical Treatise on the Combustion of Coal," gives several analyses of the true "ash" resulting from the combustion of coal, — that is, of the part that remains after the unburned coal that may be present has been removed. In an analysis of ash from Pennsylvania anthracite the composition was found to be, approximately, silica, 54 per cent.; alumina, 37 per cent.; sesquioxide of iron, 5 per cent.; lime, 3 per cent.; magnesia, 1 per cent.; oxide of manganese, a trace. An analysis of Ohio bituminous coal ash gave, approximately, silica, 59 per cent.; alumina, 35 per cent.; sesquioxide of iron, 2 per cent.; lime, 1 per cent.; magnesia, 1 per cent.; potash and soda, 1 per cent.; phosphoric acid, sulphuric acid, and combined sulphur, a trace of each.

An attempt to burn a mixture similar to either of the foregoing is like trying to burn a lot of quartz rock and clay. When we "burn" a thing, we merely cause the oxygen gas of the air to combine with it, the production of heat being an incidental result of the act of combination. But silica is the oxide of silicon, alumina is the oxide of aluminum, lime is the oxide of calcium, and magnesia is the oxide of magnesium. Each of these substances, in other words, has already combined with all the oxygen it can take up; and hence the ash cannot be further burned, either by the use of a compound, or otherwise.

Salt is an almost universal constituent of these so-called "ash-burning" compounds, and we have no doubt but that the inventors of the compounds are deceived, by the color-effects produced when salt is thrown upon a fire, into a belief that the combustion is greatly promoted by the addition of the salt. This is not the case, however. Our forefathers, burning wood in big open fireplaces, were often troubled with chimney fires, and the most approved procedure in such cases was to go up on the roof and throw salt down the chimney, to *check* the flames. If the unburned and more or less completely coked fragments of coal that fall through the grate of a modern fire are raked out of the ashes and returned to the fire, they will burn, of course, and often with little or no flame. But by moistening the fragments with a salt solution, they may be made to burn with a considerable flame, due principally to the "sodium color" produced by the volatilization of the salt. The addition of the salt does not cause the evolution of more heat, however, nor does it facilitate the combustion.

Oxalic acid is also a common constitutent of the more recent "ash-burning" compounds, and a year or so ago the market price of oxalic acid went up, coincidently with the somewhat extensive experimenting that was done with them. This led to a suggestion that the manufacturers of oxalic acid were at the bottom of the matter. It would certainly be an astute business move for them to agitate the subject, and so increase the sale of their product; but we regard this explanation as highly improbable. We do not know just what the action of oxalic acid is, when thrown into a furnace. Some authorities assert that when heated in this way it gives rise to acetylene gas, which would burn, of course, with a brilliant flame, and so lead to the belief that the combustion was accelerated in the furnace. Other good authorities deny that acetylene is produced under such circumstances.

The circular issued by the Department of Education of New York City, which serves as the text for the present article, is reproduced below. (We take it from the January issue of *Power*.)

DEPARTMENT OF EDUCATION.

The City of New York.

Special Instructions Relative to the Use of Waste Coal and Ashes, Moistened with a Solution of Oxalic Acid, Salt, and Water.

To the Janitors, Engineers, Firemen, etc., of the Public Schools of the City of New York:

Dear Sir or Madam:

The Committee on Supplies, in conjunction with the Committee on Care of Buildings, has been experimenting with great success for almost a year with the solution above mentioned, with a view of utilizing waste coal and ashes.

So as to find out if the janitors or others had been using the solution on their own account, a letter was sent to each, requesting information regarding same.

Since that time more extended and complete experiments have been made, with the result that it has been determined by the representatives of the Committee on Supplies and the Committee on Care of Buildings that, not alone is it feasible to use in stoves, furnaces, low-pressure and high-pressure boilers waste coal and ashes moistened with a solution of oxalic acid, salt, and water, but by the use of said solution a remarkable saving can be effected.

Because of these facts, you are hereby instructed to use all waste coal and ashes in so far as possible, instead of putting it out in ash cans, and in doing so, observe strictly the following rules:

Proper Solution.

Practical demonstrations have shown that the proper solution is composed of the following:

Hot water must be used in dissolving the acid and rock salt, because better results are obtainable. To every gallon of water add two (2) ounces of oxalic acid and one (1) pound of rock salt.

How to Use Waste Coal and Ashes, Moistened with Solution, with Various Sizes of Coal.

In schools where broken coal, or similar sizes, are used, ashes can be pulled to the door of the ash-pit, dampened with the solution, and re-fired.

In schools where pea coal is used, the coal can be mixed with the ashes in the proportion of one part coal to two parts ashes.

After you have used the ashes once, it may be re-used again by moistening same with the solution.

After fires are cleaned in the morning enough coal should be put on to form a good body. When it becomes necessary to re-fire, moisten any waste coal or ashes you may have with the solution above mentioned. Of course, it will be necessary to make as many gallons of the solution as may be required to moisten the waste coal and ashes you may have on hand, or that you contemplate using. Care must be taken not to saturate the mixture, as it mars its efficiency. A sprinkling-can should be used when moistening the waste coal and ashes, as it is the best means of spreading the solution evenly. When it becomes necessary to re-fire, spread the mixture evenly over the entire surface to the extent of about one and one-half to two inches. Should the fire become low during the day, a fresh body of coal can be formed over the mixture, after you have pushed the slice-bar under it. Fresh coal should be used in the last covering for the day, so that when banking for the night with the mixture, a sufficient body of fire will be left after cleaning to start the next morning. By observing this rule strictly, you will save at least two coverings a day in firing. At the same time, you can generate steam much more quickly under the new method than with the old.

Care of Fire.

When firing with the mixture, care should be taken to fire under a good head of steam. Water must be at proper level in the boiler at all times so as to prevent damage on account of intense heat. Janitors, engineers, firemen, and others responsible for the care of stoves, boilers, machinery, etc., will be held to a strict accountability, and the statement that any damage has been caused by the use of this solution will not be taken as satisfactory, as experiments, extending over a period of one year, have shown that the waste coal and ashes, moistened with the solution mentioned, can be used without detriment to boilers and connections, which contention is sustained by competent authorities.

Clinker Formation.

Any clinker formation that may appear on the surface of the fire in the morning can easily be broken with slice bar and removed, same being much softer than the coal clinkers. Experience has shown that the percentage of clinkers that stick to the sides of fire-box under the new method is less than the clinkers formed by the use of coal alone.

Saving Effected.

The Committee on Supplies and the Committee on Care of Buildings have reached the conclusion that the saving should be not less than 25 per cent. and should reach as high as 70 per cent. We expect some of the experienced men to reach the high-water mark.

Advantages to Janitors, Engineers, Firemen, etc.

There will be less coal to handle; the ashes to be put out will be reduced to a minimum; it will save at least two coverings a day; it will do away with a large number of ash-cans, thereby leaving more money for other supplies, and it will mean a saving of considerable coal to the system.

Discretionary Power of Janitors, Engineers, Firemen, etc.

In using waste coal and ashes moistened with the solution mentioned, it may be that a better method can be presented by some janitor, engineer, or fireman. If any person should devise a better method than the foregoing, he is at liberty to send same to the Superintendent of School Supplies or Supervisor of Janitors, who will look carefully into the matter. On the other hand, if any janitor, engineer, or fireman is not able to use the waste coal and ashes, moistened with the solution mentioned, and produce the results anticipated, he must not experiment, but notify the Supervisor of Janitors or Superintendent of School Supplies, who will see to it that a competent person is sent to give instructions. Under no circumstances must a school be permitted to close or become chilly for lack of heat, and the excuse that you were experimenting will not be accepted as a valid one. The process is so simple there ought to be no difficulty in producing the desired result, but, as before stated, if you find any difficulty in using the solution do not experiment but send a notification, as instructed, and a person will be sent to show you how results may be obtained.

Special Note.

Engineers, janitors, firemen, and others in charge of stoves, furnaces, low-pressure and high-pressure boilers, are hereby notified that comparisons will be made of the saving in each school, and a record kept in the Bureau of Supplies and in the office of the Supervisor of Janitors, and such records will be taken into consideration when promotions are being made. All might as well realize that the committee on Supplies and the Committee on Care of Buildings are convinced that money can be saved by this method, with your coöperation. We, however, do not want to save money in coal and waste it in repairs to boilers and connections. Do not waste your time writing letters criticising the matter, but carry out the instructions set forth, because the formula has been tested and found satisfactory and feasible. Such being the case, you are expected to coöperate with the department, because it will be to your advantage to do so.

A. J. Maguire,
Supervisor of Janitors.
Patrick Jones,
Superintendent of School Supplies.

Approved:
Thomas J. Higgins,
Chairman Committee on Care of Buildings.
Nicholas J. Barrett,
Chairman Committee on Supplies.

The Locomotive.

A. D. Risteen, Ph.D., Editor.

HARTFORD, APRIL 25, 1908.

The Locomotive *can be obtained free by calling at any of the company's agencies.*
Subscription price 50 cents per year when mailed from this office.
Bound volumes one dollar each. (*Any volume can be supplied.*)

Obituary.

Henry Wells Myers.

We record, with deep regret, the death of Mr. Henry Wells Myers, who passed away in this city on January 21, 1908.

Mr. Myers was born at Hartford, Connecticut, in 1842. He was a machinist in the early part of his life, and served his apprenticeship at that trade in the Phœnix Iron Works, on Arch Street, Hartford. Shortly after the expiration of the period of his apprenticeship, in 1864, he entered the employ of the Colt's Patent Firearms Manufacturing Company, where he worked as a machinist continuously for over twenty years. In June, 1889, he became associated with the Hartford Steam Boiler Inspection and Insurance Company, as inspector in its Home Department; and at the time of his death he had served in that capacity for over eighteen years.

Mr. Myers was an excellent mechanic and a highly respected man, and was one of the oldest inspectors in the home office, in point of service. He was widely acquainted throughout the territory covered by his work, and was held in esteem by a large circle of friends. He had been ill for a considerable time, and his health had been especially poor for some three months prior to his death. Mr. Myers' wife survives him, and he also leaves two daughters, the elder of whom, Mrs. George Wismer, lives in Montclair, New Jersey, while the younger, Miss Rachel, resides in Hartford.

Joseph Meade Gleason.

Joseph Meade Gleason, for many years special agent of the Hartford Steam Boiler Inspection and Insurance Company at Cincinnati, Ohio, was born at Austerlitz, Columbia County, New York, on September 15, 1843, and was a son of Lyman C. and Harriet Tyler Gleason. He received a common-school education in his native place, and when sixteen years old he went to Louisville, Kentucky, to seek his fortune, living there until 1886. For a short time he was a clerk in a drug store, after which he lived for a few months at Murfreesboro, Tennessee, but returned to Louisville and secured a situation in the office of James E. Tyler & Company, insurance agents, of that city. He became secretary of the Louisville Insurance & Banking Company, and occupied that position for five years, or until 1872, when he assumed the responsibilities of a general insurance agency, continuing in this work until 1886, when he sold out his interests and assumed charge of the business of the Hartford Steam Boiler

Inspection and Insurance Company for the territory embraced by about half of Ohio, Kentucky, and Indiana, with headquarters at Cincinnati. This position he held up to the time of his death.

Mr. Gleason was a Republican in politics, but had never held nor sought any office. During the Civil War he served as a volunteer in Louisville at the time General Buckner threatened that city, and he was regularly mustered in the United States Army in the organization known as the National Home Guard, of Louisville. A very notable thing about this particular military body was, that it received compensation from the United States Government for services rendered, and then had the patriotism to turn the entire sum so received back into the United States treasury.

On June 1, 1865, Mr. Gleason was married to Mary A. Miles, daughter of A. Duffield and Caroline Miles. Their surviving children are Henry K., Howard S., Edward H., and Ethel H. Gleason.

Mr. Gleason was a man of high character, and was an excellent business man, just and firm in all his dealings. He possessed a spirit of broad charity, which endeared him to all who knew him; and he was a man of religious nature, and an earnest and consistent member of the Baptist church.

The first signs of his failing health came in August last, but his untiring devotion to his work kept him at his desk until about two months ago. His infirmities increased, and he was forced to enter Seton Hospital, Cincinnati, on April 4. Uræmic poisoning subsequently developed, and he passed away, peacefully and painlessly, on April 14.

Changes in our Personnel.

Mr. E. Sidney Berry has been appointed Counsel to the Hartford Steam Boiler Inspection and Insurance Company, with headquarters at the home office at Hartford. The volume of business transacted by this company is now so large that it practically requires the entire time and attention of one person to consider the claims for personal injuries and deaths, and to review the facts, and effect settlements promptly and properly. Mr. Berry, who will have charge of this part of the work, has had an extensive experience in work of this character. He was graduated from Harvard University and from the Harvard Law School, subsequently practicing law in Boston, where, for a period of thirteen years, he assisted in the local and general work of the United States branch of the Employers' Liability Assurance Corporation of London. In June, 1903, he removed to New York City, where he represented the Ætna Life Insurance Company for five years as attorney and counsel.

Mr. A. S. Wickham has also been appointed Superintendent of Agencies of the company. Mr. Wickham has been a special agent in our New York Department for nearly nine years, six of which were spent in New York City. The success which attended his work as a special agent assures us that in his new position he will be a welcome and helpful counselor in every department.

Mr. Alexander H. Cunningham has been appointed special agent at the Minneapolis, Minn., branch office of the company, succeeding its late special agent in that city, Mr. Aid Collins, deceased. Educated as a machinist, Mr. Cunningham subsequently served as a marine engineer for a period of ten years, and entered the employ of this company as an inspector, in February, 1893. Since that date he has been associated with us continuously, not only in the work of inspection, but also in various semi-executive positions in several of our departments. In June, 1906, he was transferred to our Boston Department, where he continued as a special agent until appointed to his present position in Minneapolis.

A Color Scheme for Pipe Lines.

The multiplicity of pipe lines in the modern power plant is confusing, to say the least. Some simple method of easy and certain identification, universally adopted, would be a welcome step in advance. It would not only facilitate the regular work of the attendants in charge, but would also reduce the probability of mistakes in handling valves, and in times of emergency it might prevent serious accidents. Furthermore, when a change of engineers is made, the new man would grasp the situation quicker, and there need be no interruption of the service, or even a drop in the efficiency. Such a system would also be of decided advantage to inspectors when making their regular visits, — whether for the municipal, insurance, or other authorities.

Some attempts in this direction have been made by attaching labels or tags to valves. The United States Government requires all pipe lines in distilleries to be painted in colors, in accordance with an established system. Something has been done also in power plants in this direction, but so far as the writer knows, no complete scheme has as yet been worked out, or proposed, for general adoption.

The writer was confronted with this problem recently, when designing the power and service plant of the new Hamburger Department Store at Los Angeles, Cal., of some 1,600 horse-power capacity. Here there were not only the usual steam, exhaust, and feed lines, but a sprinkler system, iced-water distribution, air lines (both compressed and vacuum), ammonia and brine lines for refrigeration, and oil, both fuel and for lubrication. The solution finally worked out was as follows, previous color schemes being adopted as far as possible:

Steam:

- High and medium-pressure, ... White
- Low-pressure heating lines, ... Aluminum bronze
- Exhaust lines, ... Gray

Hot Water:

- Returns from heating system, ... Aluminum bronze
- House supply, ... Maroon
- Boiler feed, ... Bright red
- Pure drains from high-pressure and exhaust head drips, ... Pink
- Impure drips, overflows, and boiler blowoffs, to blowoff tank, ... Black

Cold Water:

- From city mains or deep well, and general house distribution, ... Light blue
- Sprinkler lines, including tank, excess pressure, and draining systems, Blue

Iced Water:

- Drinking water lines, ... Dark or navy blue

Air:

- Vacuum heating and house-cleaning lines, ... Light green
- Compressed, ... Dark green

Refrigerating:

Ammonia, gas, ... Yellow
Ammonia, liquid, ... Bronze
Brine, ... Orange

Oil:

Lubricating system, ... Light brown
Boiler supply, ... Dark brown

These colors are to be applied to the pipe lines after completion and test. They will be applied directly to the pipes themselves where they are left bare, and on top of the finished covering for all others.

The pneumatic-tube cash system, being of polished brass pipe, was not thought to need special coloring.

Pipe lines for hydraulic elevators, when installed, might be violet. Still further differentiation, if desired, could be secured by painting the valves and fittings a different color from the pipe itself.

Gas pipes, where exposed, might be left black, as there would be no danger of confusing them with impure drains.

Care must be taken, of course, to secure colors that will not fade under heat.

The foregoing plan is believed to be consistent and reasonably complete, and is recommended for general adoption. — William H. Bryan, in *Steam.*

The Properties of Steam.

Sixth Paper.— Juhlin's Experiments on the Pressure of Saturated Steam at Low Temperatures.

Julius Juhlin has made a valuable series of experiments upon the pressures of saturated steam at low temperatures; but his memoir is less familiar to physicists in general than it should be, because it was printed in the Swedish language, and has never been translated, so far as we have been able to learn, into any other. It was epitomized, it is true, in the German annual, *Fortschritte der Physik* ("Progress of Physics"), for 1891, Vol. 2, page 351; but a proper appreciation of the care with which the work was done cannot be had without recourse to the original paper. We have therefore considered it advisable to describe Juhlin's apparatus and experimental methods in some considerable detail.

The title of the original paper is "Bestämning af Vattenångans Maximi-Spänstighet öfver Is mellan 0° och — 50° C., samt öfver Flytande Vatten mellan + 20° och — 13° C." ("Determination of the Maximum Vapor-Pressure over Ice between 0° and — 50° C., and over Liquid Water between + 20° and — 13° C.") It is printed in the "Bihang till Kongl. Svenska Vetenskaps-Akademiens Handlingar" ("Appendix to the Transactions of the Royal Swedish Academy of Sciences"), Vol. 17, Part 1, No. 1, Stockholm, 1891.

As will be inferred from the title, Juhlin measures the vapor-pressure over ice, as well as that over water. The fact that ice is capable of evaporation, without first melting, is familiar to the housewife, who knows that when the wash is hung out upon the line it will dry, even though frozen. Physicists, too, have long known that when ice is placed in a closed space that is otherwise vacuous, evaporation from the ice will proceed only until the pressure of the vapor attains a certain definite value, which depends upon the temperature to which the ice and its vapor are subjected. In other words, they have long known that the pressure of saturated ice-vapor depends simply upon the temperature, just as the pressure of saturated *water*-vapor does.

Now water that is very pure, and quite free from air, may be cooled to some considerable distance below the normal freezing point, without solidifying; and when in this anomalous condition it is said to be "supercooled". It is natural to inquire whether the pressure of the saturated vapor of supercooled water is identical with that of the saturated vapor of ice of the same temperature. Regnault, judging from his own experiments, was of the opinion that the two pressures are identical, so that at any given temperature the saturated vapor has identically the same pressure, whether it arises from ice or from supercooled water. Kirchhoff and Clausius subsequently showed, by means of the mechanical theory of heat, that he was wrong on this point; and in 1886 W. Fischer published a series of observations (Wiedemann's *Annalen*, Vol. 28, page 400) by which, for the first time, the vapor-pressures of ice and of supercooled water of the same temperature were experimentally proved to be different, and the difference was shown to agree with that predicted by theory.

We make this long digression because one of Juhlin's main objects was to investigate this same point with greater accuracy than Fischer had attained. In carrying out his experiments, Juhlin first measured, directly, the difference between the vapor-pressures of ice and of water, when the two stand side by side, in the same apparatus and at the same temperature; and afterwards, by giving a slightly different form to the apparatus, he measured the pressures of saturation of ice-vapor and of water-vapor, separately, and compared the differences of the values so obtained with the corresponding differences, as observed directly in the first form of the apparatus.

As we are now interested more particularly in the properties of liquid water, we shall, for the present, omit all further mention of Juhlin's work upon ice, and confine our attention exclusively to his results in connection with the saturated vapor of water in the liquid state. These, as the title of his memoir indicates, extended over the temperature interval comprised between — 13° C. and + 20° C. (or between + 9° Fahr. and + 68° Fahr.).

The tube in which the water to be investigated was confined (and which we may conveniently call the "experimental tube") was made of glass, and had the general form shown in Fig. 1, which is reproduced from an engraving given in the original memoir. The water to be investigated was contained in the curved arm, *ED*, which was nearly horizontal,— the saturated vapor filling the space *ECG*, while the pressure was measured by means of mercury enclosed in the U-shaped portion of the tube, *GFK*. Juhlin gives no illustration of his apparatus as a whole, but from his description we have prepared the view shown in Fig. 2, which is as nearly correct as it can be made, from the data that he gives. The details shown in Fig. 2 will be explained presently; but we shall first describe the preparation and filling of the experimental tube itself.

The glass tubing of which this tube (Fig. 1) was constructed was very thin, and care was exercised to have it as perfect as possible, in all respects. Its internal surface was carefully cleaned by rubbing with cotton, and by subsequent treatment with acids, alkalis, and alcohol, and a final thorough washing with distilled water. The internal diameter of the experimental tube (save at *A*, *B* and *F*) was everywhere 18 millimeters (0.71 in.), and the general dimensions of the tube are indicated, in centimeters, in Fig. 1, which is drawn to scale, and is about one-fourth of the actual size. The lower part of the U-tube that served as the pressure-gage was constricted, as shown at *F*, and two auxiliary branch-tubes, each 3 millimeters (0.12 in.) in diameter internally, were fused to the main tube at *A* and *B*, for use in connection with the filling of the apparatus, as will be presently described. Especial pains were taken to have the two arms of the siphon gage (*KF* and *GF*) made of as good glass as could be obtained, and to have them of the same diameter in all parts. These arms were separated from each other by a space of 7 millimeters (0.28 in.), for their entire length.

After the interior surface of the experimental tube had been carefully cleaned, as described above, the mercury to be used in the pressure-gage, *KFG*, was introduced. (To ensure its purity, the mercury had been previously treated with fuming nitric acid, and then carefully washed with distilled water.) The

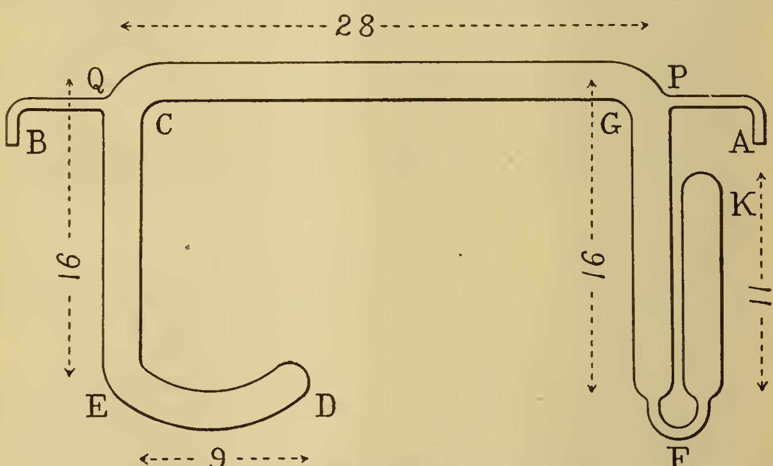


Fig. 1.—Juhlin's Experimental Tube.
(The dimensions are in centimeters.)

experimental tube was tipped up so that *PQ* was vertical, with the end *Q* uppermost, and the auxiliary tube *B* was connected with an aspirator, so that air could be withdrawn from the apparatus while *A* was submerged in a vessel of mercury. In this manner mercury was drawn into the tube until the part *KF* was completely filled. With *KF* still horizontal, the tube A was next closed with a cork, and with the aspirator still attached to *B*, and still in action, heat was applied to *KF*, in order to expel any moisture or air that the mercury within it might contain. More of the purified mercury was then introduced, in the same way as before, until the siphon *KFG* was completely filled, up to *G*; and after this the mercury in the tube was boiled, in order to complete the expulsion of air and moisture from it. The experimental tube was then placed in the position shown in Fig. 1, the siphon gage, *KFG*, being now completely filled, up to *G*, with pure mercury, free from air and moisture.

The tube *A* was next connected with the aspirator, and water, previously purified by two distillations, was drawn into the experimental tube through *B*, until *DE* was filled, and the water extended well up into *EC*. The tube *B* was then sealed off with a blow-pipe.

The experimental tube now contained both mercury and water (each in larger quantity than was desired), and also air; and it remained to expel the air and the excess of water and mercury, and, finally, to seal the apparatus hermetically.

With the apparatus in the position shown in Fig. 1, the tube *A* was placed in communication with a dry flask, which, in its turn, was connected with the aspirator. (Juhlin does not describe the aspirator that he used, but calls it a "water air-pump", from which we infer that it was one of the forms of air-pump in which the suction is produced by the flow of water through a nozzle, as in the Bunsen filter-pump, familiar to the chemist.) When the aspirator was set in action, the pressure in the flask, and in the experimental tube that was connected with it, fell to about 40 millimeters of mercury, so that by this means nearly nineteen-twentieths of the air in the tube was removed, at the start. The remainder was then expelled by boiling the water in the tube, the vapor that passed out through the auxiliary tube *A* sweeping the air before it. Under the pressure (40 millimeters of mercury) prevailing in the experimental tube when the aspirator was at work, water boils at about 35° C. (95° Fahr.); and in the actual operation of evaporating the water in the tube, the heat required was furnished by pouring a continuous stream of warm water over the part *CED*, the part *CG* being meanwhile heated by a Bunsen burner, in order to prevent the vapor from condensing in that section of the apparatus. This process must have been very tedious, for Juhlin states that it occupied two hours in the case of the apparatus that he used for the direct comparison of the vapor-pressures of water and of ice; and as the apparatus here described contained somewhat more than half as much water, we may infer that the boiling operation, in the tube shown in Fig. 1, occupied upwards of an hour. It must have been very effective, however, for it was continued until the water in *DEC* was nearly all evaporated; and a rough calculation shows that the entire volume of vapor that was produced (under the reduced pressure prevailing in the apparatus) must have been about 7,000 times the volume of the section (*DECG*) containing the air in the experimental tube. There can be little doubt, therefore, but that the air was effectually removed from the tube by the time the boiling-out process was completed.

At the close of the evaporation, but while it was still proceeding, the experimental tube was tilted so as to permit a considerable part of the mercury, which had all this while filled both arms of the siphon gage completely, to escape through the tube *A*, into the flask with which this tube communicated; the outflow being permitted to proceed until the quantity of mercury remaining was considered to be sufficient to fill the two arms of the U-gage to a convenient level. Then the experimental tube was restored to its original position, with *CG* horizontal, and the auxiliary tube, *A*, was sealed off by the blow-pipe, while water-vapor was still actively escaping through it, under the action of the aspirator. The experimental tube was then ready for use.

It must be remembered that Juhlin's apparatus was used for the study of supercooled water, as well as for the study of water having a temperature higher than the normal freezing point. When the water in Fig. 1 was cooled below the normal freezing point, it remained fluid until its temperature had fallen to a point which varied in the different series of experiments; but always, if the temperature was carried low enough, the water in the tube eventually froze. It was therefore necessary to give the apparatus a form that would permit of the freezing, without the experimental tube being thereby destroyed. With this object in view, the part *ED*, containing the water, was bent into a horizontal position, and the quantity of water present was kept small, so that *ED* should be less than half filled. It was believed that by this means the safety of the tube would be assured; but in the course of the work it was found that breakages would still occasionally occur, unless a slightly curved form were given to the arm *ED*, as shown in Fig. 1.

In carrying out the measurements, the experimental tube was arranged so that the end containing the water could be maintained at a known temperature, while the mercury siphon-gage could be observed and read at the same time.

In Fig. 2 the experimental tube is shown at *DECGF*. The arm *ED*, containing the water, was placed within a sheet-iron vessel, *LL*, having a capacity of about 10 liters (10½ quarts). This, in turn, was set in a larger wooden vessel, *MM*, and held in position by means of corks, *NN*, so that there was a space of about 4.5 centimeters (1¾ in.) between the two vessels, at the bottom and sides; this space being filled with cow-hair, which served as a non-conductor of heat. In the experiments that were carried out below the normal freezing point (0° C.), the sheet-iron vessel, *LL*, contained a cooling mixture composed of snow and common salt, or (in the experiments upon the vapor of ice) of snow and calcium chloride.

Through two small holes in the cover of the vessel *LL*, two stout steel wires passed down, to whose respective lower ends there were attached two crescent-shaped stirrers, *SS*, made of sheet-iron, and heavily weighted with lead. The upper ends of the steel wires were secured to a horizontal cross-piece, which could be raised and lowered by means of cords passing over pulleys. By this arrangement the fluid contents of the vessel *LL* could be kept well stirred, so as to be of sensibly uniform temperature throughout; and it was found that the temperature of the bath could easily be kept constant for from two to three minutes.

The temperature of the water in the experimental tube was read by means of a pair of thermometers, *TT*, which were placed vertically, as shown, and about 6 centimeters (2.4 in.) apart, with their bulbs as near to *ED* as possible.

The pressure-gage, *KFG*, of the experimental tube was outside of the vessels *LL* and *MM*, so that its indications could be easily seen; and the temperature of the gage was read by means of a thermometer, *V*. This was placed close to the U-tube, *KFG*, and cotton was loosely packed around the lower parts of both, to ensure equality in their temperatures.

It will be apparent, from the way in which the experimental tube was filled, that the space *K*, above the mercury in the short arm of the gage, was entirely vacuous, save for the presence of an insignificant amount of mercury vapor. The difference in level between the columns of mercury in the two arms of the U-gage, therefore, gave the pressure of the vapor in *ECG;* and the thermometers *TT* gave the corresponding temperature. (To guard against misunderstanding, it may be well to explain that although the experimental tube had different temperatures in its different parts, yet the pressure of the vapor, so long as no air was present, and so long as *ED* was the *coldest* part of the tube, depended solely upon the temperature at *ED*. When *G* is warmer than *E*, the vapor at *G* is superheated, while that at *E* is just saturated; but the *pressure* is the same throughout the tube, and is determined by the temperature at *ED*.)

The readings of the gage, *KFG*, were taken by means of a telescope, which was rigidly fixed, and placed so that the upper ends, or meniscuses, of the two mercury columns could both be seen in the field of view of the telescope at the same time. The telescope was provided with a micrometer eyepiece, whose errors were carefully investigated, and whose screw had been standardized by observations made upon a standard centimeter scale, placed in the exact position subsequently occupied by the mercury gage. The difference in level of the

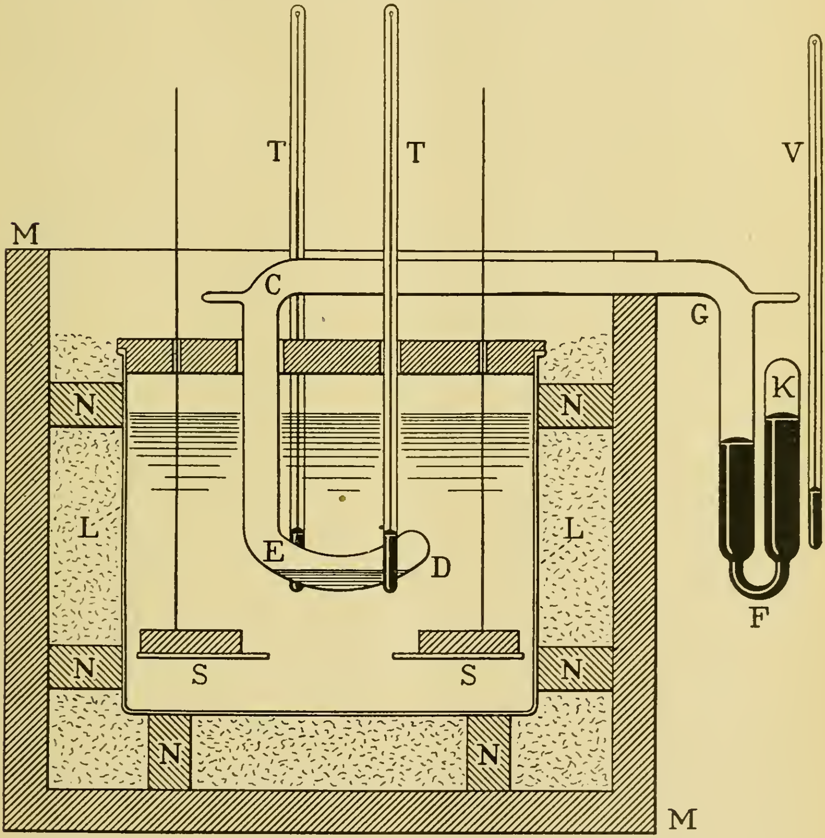


FIG. 2. — SHOWING THE EXPERIMENTAL TUBE FILLED AND IN POSITION.

mercury in the two arms of the gage was obtained by turning the screw of the micrometer eyepiece so that the cross-hair rested first on one of the meniscuses, and then on the other. By the side of this telescope there was a second one, through which the readings of the thermometers *TT* were taken.

Juhlin considered the possible errors of his apparatus with much care. For example, he constructed a separate apparatus, with which he made numerous observations to see if any correction was needed on account of the difference in the pressure of the mercury vapor in *K* and in *ECG*, due to the fact that the temperature at E is lower than that at K; but we do not need to discuss this part of the research, because he found that the error arising from omitting this correction was insignificant. He applied the usual correction, however, to reduce the readings of the mercury gage to the values they would have had if the mercury in the gage had had the temperature 0° C. He also determined the specific gravity of the mercury that he used, and found it to be 13.587. This indicated that it was not quite pure, although it was very brilliant, and showed no tendency to adhere to the glass; for the density of pure mercury is known to be 13.596. He, therefore, applied a correction to reduce his gage readings to the values they would have had if the mercury had been absolutely pure. Finally, he applied a correction to reduce the observed pressure-readings to the values they would have had, if the experiments had been made at sea-level, in latitude 45°. (This last correction was applied because the intensity of gravity varies somewhat in different latitudes and at different elevations above the sea, so that the pressure that is produced by a column of ice-cold mercury of a given height varies to a certain extent, according to the locality. Physicists engaged in making exact measurements commonly follow the practice of the International Bureau of Weights and Measures, and reduce their pressures to sea-level and latitude 45°, so that all such measures, wheresoever made, may be strictly comparable.)

It is well known that when a tube, open at both ends, is set vertically in a large vessel of water, so that part of the tube is in the air and part is submerged, the water within the tube will stand at a higher level than that in the vessel outside; the difference in the two levels being greater the smaller the diameter of the tube. This phenomenon is due to what is termed "capillary action," and it is also observed when the vessel and the tube contain mercury instead of water, only in that case the level of the mercury in the tube is *depressed,* instead of being elevated. In the accurate determination of the pressure of the atmosphere by means of the mercury barometer, the capillary depression of the mercury in the tube must be considered, and proper allowance must be made for it; and, in fact, in all cases in which we have to deal with the height of mercury in a tube, we have to consider whether the tendency of capillary action to depress the level of the mercury has any sensible effect or not. In Juhlin's experiments, care was taken to have the two arms of the gage tube, KF and FG, of the same diameter, as nearly as possible, in order that the capillary action, so far as it depended upon the diameter of the tubing, might be the same in both arms, and hence have no resultant effect upon the reading of the gage. Furthermore, the gage tube was of large diameter (0.71 in.), so that the capillary depression would be small in any event, and any lack of equality in the two arms would have a correspondingly small effect upon the result. The capillary action in a tube depends to a certain extent, however, upon the nature and physical condition of the substance that may be within the tube, above the surface of the mercury; and here we find a possible source of error in Juhlin's work, because the space K (in Fig. 2) was a Torricellian vacuum, while G contained water-vapor. Hence there might be a small difference in the capillary action in the two branches of the gage. Juhlin admits the possible existence of this kind of an error, but says that he could find no way of eliminating it, nor of finding its magnitude, so as to apply a suitable correction. He was of the opinion, however, that this error "could not have had any very marked effect," on account of the large diameter of the tubing. He is probably right in this opinion, and yet we cannot admit that the error was really *insensible*. The subject will be considered further in a subsequent article in the present series.

In a research of this character, the thermometry is of paramount importance; and Juhlin appears to have been keenly alive to this fact. In his work upon the vapor-pressure of liquid water, he made use of four mercury thermometers, which were made by Ådermann, of Stockholm, Sweden. (Juhlin's experiments were made at Upsala.) The zero-point corrections of these thermometers were repeatedly determined, and were found to be constant during the entire period covered by the observations. He compared his thermometers, too, with the standard thermometers in the physical laboratory of the Stockholm Academy of Sciences, which were made by Tonnelot in Paris, and verified at the International Bureau of Weights and Measures at Breteuil, France, and presented to the Academy of Sciences by Professor O. J. Broch, director of the International Bureau. The comparisons made by Juhlin in this way covered the interval from 0° C. up to +33° C. Below 0° C. a different procedure was adopted, because the standard thermometers at Stockholm were not graduated below —7° C., and they could not be conveniently used below 0° C. To obtain the corrections to his thermometers at temperatures below 0°, Juhlin compared them with an air-thermometer, constructed according to Jolly's design; the comparisons by this method extending from +3° C. down to —35° C. Hence (if we understand the facts correctly) Juhlin's temperature scale *above* the freezing point is supposed to be that of the constant-volume *hydrogen*-thermometer, while *below* the freezing point it is that of the constant-volume *air*-thermometer. Within the range of his experiments, however, these two scales agree very closely, and the error introduced by assuming the scale to be that of the hydrogen-thermometer, below zero as well as above, will not exceed 0.01° C. The difference will be even less than this, except at —13° C.; and hence we may safely consider Juhlin's temperature scale to be that of the hydrogen thermometer, throughout his entire range.

The mercury thermometers used by Juhlin were graduated to fifths of a degree, and, therefore, they could be read to fiftieths of a degree (or to 0.02° C.) by the usual process of estimating the tenths of a division. The length of that part of the mercury column which projected into the air was recorded for each of the thermometers *TT*, and Juhlin says that he corrected the observed temperatures for the error due to the fact that this emergent part of the mercury column was warmer than the contents of the vessel *LL*. We do not know whether he did or did not investigate the error due to the hydrostatic pressure of the contents of the vessel *LL* upon the bulbs of the thermometers; but if we may judge from the thermometers made by Tonnelot, the error due to this cause did not materially exceed 0.002° C., and hence could be safely neglected.

In all, Juhlin made 124 measurements of the pressure of the saturated vapor of water, at temperatures ranging from —13° C. to about +20° C. For convenience in the subsequent calculations, he then combined the entire 124 into sixteen groups, corresponding to the sixteen temperatures given in the first column of the table presented herewith. The way in which this combination was effected will be best understood by considering a particular case,—say that corresponding to the temperature +12°. A formula was first found which would express the various pressures in terms of the corresponding temperatures with a considerable degree of accuracy, and over the entire range covered by these experiments. There happened to be seven observations made at temperatures quite near to +12°, and for each experiment in this little group of seven the approximate pressure was calculated by the formula. The average difference between the formula and the observations was then taken for the group, and it was assumed that if an observation had been made at exactly +12°, it would depart from the formula by an amount equal to the average departure of this group of seven. The pressure as calculated by the formula for the temperature +12° was corrected accordingly, and the result (10.5677 millimeters, in this particular case) was treated as though it were an actual observation, made at precisely +12°.

The first column of the table gives the temperatures that were selected for the application of this process, the second column gives the number of observations in each of the corresponding groups, and the third gives the "observed pressures," as deduced by the method we have described.

After having summarized his observations in this way, Juhlin proceeded to find another formula, much more accurate than the one first employed; the object now being to represent, with all the precision possible, the data given in the third column of our table. Having found such a formula, he calculated from it a final table, giving the pressures corresponding to the various temperatures within his range to every tenth of a degree. We do not reprint this table in full, but in Column 4 we reproduce the pressures that his final table gives, for the sixteen temperatures in Column 1. Finally, in the last column of the table, we show the differences between Juhlin's final tabulated results, and the separate observations upon which his table is based.

Condensed Table Giving Juhlin's Results for Liquid Water.

(Pressures are expressed in millimeters of mercury.)

Temperature.	Number of observations.	Observed pressure. (mm.)	Pressure by final table. (mm.)	Observed pressure minus pressure by table. (mm.)
—12° C.	5	1.8750	1.884	—0.0090
—10°	5	2.1952	2.197	—0.0018
— 8	9	2.5549	2.558	—0.0031
— 6	9	2.9760	2.973	+0.0030
— 4	10	3.4667	3.450	+0.0167
— 2	10	4.0084	3.995	+0.0134
0	12	4.6074	4.618	—0.0106
+ 2	10	5.3063	5.328	—0.0217
+ 4	9	6.1291	6.135	—0.0059
+ 6	8	7.0597	7.048	+0.0117
+ 8	7	8.0826	8.080	+0.0026
+10	7	9.2512	9.242	+0.0092
+12	7	10.5677	10.548	+0.0197
+14	7	11.9841	12.009	—0.0249
+16	3	13.6356	13.639	—0.0034
+18	6	15.4566	15.451	0.0056

Hartford Steam Boiler Inspection and Insurance Company.

ABSTRACT OF STATEMENT, JANUARY 1, 1908.

Capital Stock, . . . $1,000,000.00.

ASSETS.

	Par Value.	Market Value.
Cash in office and in Bank, ...		$115,831.34
Premiums in course of collection (since Oct. 1, 1907),		203,819.78
Agents' cash balances, ...		9,846.14
Interest accrued on Mortgage Loans, . . .		26,224.54
Loaned on Bond and Mortgage, ...		1,041,950.00
Real Estate, ...		97,000.00
State of Massachusetts Bonds, ...	$100,000.00	88,000.00
County, City, and Town Bonds, ...	337,000.00	341,830.00
Board of Education and School District Bonds,	34,000.00	35,000.00
Railroad Bonds, ...	1,556,000.00	1,580,760.00
Street Railway Bonds, ...	55,000.00	51,900.00
Miscellaneous Bonds, ...	87,500.00	75,475.00
National Bank Stocks, ...	43,300.00	62,250.00
Railroad Stocks, ...	201,700.00	209,583.00
Miscellaneous Stocks, ...	165,600.00	120,725.00
	$2,580,100.00	
Total Assets, ...		$4,060,194.80

LIABILITIES.

Re-insurance Reserve, ...		$1,933,139.74
Commissions and brokerage, ...		40,763.95
State, County, and Municipal Taxes, due and accrued, ...		8,500.00
Losses unadjusted, ...		70,923.05
Surplus, ...	$1,006,868.06	
Capital Stock, ...	1,000,000.00	
Surplus as regards Policy-holders, .	**$2,006,868.06**	2,006,868.06
Total Liabilities, ...		$4,060,194.80

On December 31, 1906, the Hartford Steam Boiler Inspection and Insurance Company had **98,287** steam boilers under insurance.

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C. S. BLAKE, Secretary. L. F. MIDDLEBROOK, Asst. Sec.

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The Locomotive

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Diagonal Joints and Tube-Hole Rows.

In the issue of The Locomotive for July, 1897, page 97, we published an article on the diagonal riveted joint, in which the principles involved in the calculations of such joints were discussed at some length. Since that article appeared we have had considerable correspondence on this and closely allied subjects, from which it appears that a certain amount of misunderstanding still exists with respect to the diagonal joint. We have therefore prepared the present still more extensive article, which it is hoped will be found satisfactorily complete, and as simple as is consistent with the inherent complexity of the subject.

In boilers of certain types, holes for the reception of tubes are cut through drums or shells, so that the perforations constitute lines of weakness in the plate. When these perforations are so disposed that the line of probable (or

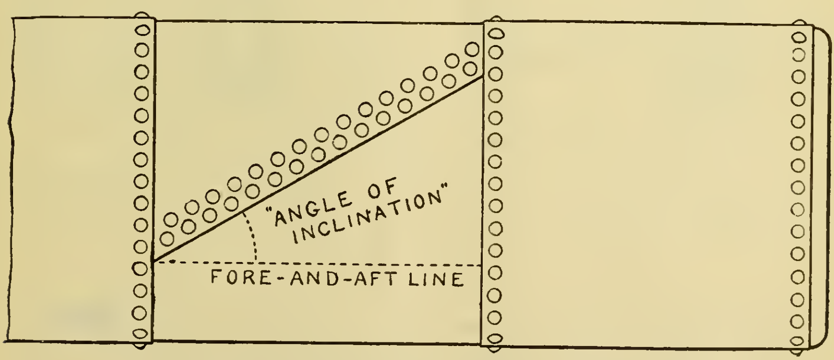

Fig. 1. — Illustrating the Diagonal Riveted Joint.

possible) fracture runs parallel to the length of the shell or drum, or circularly around it, there appears to be no misunderstanding as to the method to be followed in investigating the effect of such perforations upon the pressure to be allowed upon the boiler. On the other hand, when the line of possible fracture follows a diagonal or oblique course, so as to make an acute angle both with the longitudinal joint and with the girth joints, we find much the same confusion as to the effect of such holes upon the safe working pressure in the boiler that exists in the case of the diagonal joint. In the present article, therefore, we shall dwell not only upon the diagonal riveted joint, but also upon the lines of weakness caused by the presence of tube-holes in a drum or shell. In explaining the principles of the subject, however, we shall speak merely of the riveted joint, taking up the application to tube-holes subsequently.

Meaning of the Term "Unit of a Joint."

In calculations relating to riveted joints, it is often convenient to confine our attention to a single "unit" of the joint; a "unit" being a section of the joint of such length that the whole joint can be regarded as made up by a repetition of such units, or sections, by placing them end to end. In Fig. 2, for example, the shaded sections show "units" of the respective types of joint there illustrated, and it will be plain that each joint may be regarded as made up by merely repeating these shaded sections, as indicated by the numerals 1, 2, 3, 4, etc. If the joint is of indefinite length, it is also evident that a section two, three, four, or any integral number of times as long as one of the shaded sections might also be regarded as a "unit," inasmuch as the entire joint could still be considered to be made up by a repetition of these longer sections, or units. But it is usual to use the word "unit" to signify the smallest portion of the joint that fulfills the given condition of being sufficient, by continued repetition of itself, to make up the whole joint.

The advantage of dealing with a unit of a joint, instead of with the entire joint, consists in the fact that the efficiency of the whole joint is the

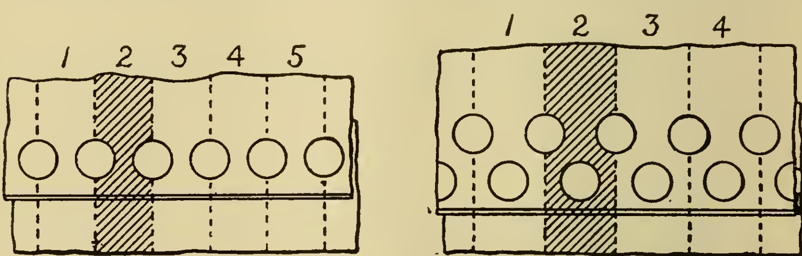

Fig. 2. — Illustrating the Term "Unit of a Joint."

same as the efficiency of any one of its units; and we therefore do not need to know anything about the total length of the joint, in calculations relating to efficiency.

Ambiguity of the Term "Efficiency of a Joint."

One of the chief difficulties encountered in connection with explaining the principles involved in the diagonal joint consists in the fact that the term "efficiency" is used in two different senses. The commonest way to define the word is to say that the "efficiency" of a joint is a fraction which expresses the strength of a unit of the actual joint, in terms of the strength of an equal section of the solid plate, before it is perforated by rivet holes. Expressed in other words, this definition says that the "efficiency" of the joint is the fraction, or percentage, by which we must multiply the strength of the solid, unperforated plate, in order to obtain the strength of a section of the joint of equal length. This is perhaps the commonest point of view respecting riveted joints, and it is quite satisfactory when applied to fore-and-aft joints in a boiler shell or drum, or to joints in any position whatever in a metal plate in which the tension is the same in all directions. We shall call the efficiency, as so defined, the "ordinary efficiency" of the joint.

There is another sense in which the word "efficiency" is used in connection with riveted joints, however. This may best be explained in the following way:

Let us first calculate the internal pressure that would have to be applied to the boiler in order to produce rupture of the shell, if the shell were solid, and had no riveted joints whatever. Now the actual shell, since it *has* riveted joints, is presumably weaker than this, and fracture would presumably occur at a joint, before the shell itself gave way.* The fraction by which we must multiply the pressure that would rupture the solid shell, in order to obtain the pressure that would produce fracture at the joint, may also be called the "efficiency" of the joint; and this is the definition that is actually used, in dealing with diagonal joints. We shall call this kind of efficiency the "effective efficiency" of the joint (scholars will please pardon the unlovely name), because it is upon this efficiency that the effective strength of the boiler or drum directly depends. The "ordinary" and "effective" efficiencies are identically the same thing in the case of a longitudinal (or fore-and-aft) joint in a boiler shell, but they are quite different in the case of a diagonal joint, or a girth joint. As a perfectly clear understanding of the difference between these two kinds of efficiency is essential to a correct treatment of the problem of the diagonal joint, we shall discuss the matter at some length before proceeding further.

The "Ordinary" Efficiency of a Longitudinal Joint.

In determining the "ordinary" efficiency of a longitudinal (or fore-and-aft) joint, we begin by considering the various ways in which the joint can fail (as, for example, by shearing the rivets, or by breaking the ligaments between the rivet holes). Fixing our attention upon some one of these possible modes of failure, we then calculate the tension that would have to be exerted upon one unit of the joint, in order to cause it to fail in the proposed manner. We then calculate the tensile stress that would have to be exerted upon a strip of the solid, unperforated plate, of a width equal to the length of a unit of the joint, in order to cause the fracture of the solid plate. The stress that would have to be applied in order to cause the failure of the joint in the proposed manner, divided by the stress that would have to be applied to the plate itself in order to rupture it, gives the "ordinary efficiency" of the joint, so far as failure in the proposed manner is concerned.

We next proceed to consider, in the same way, every other mode of failure that appears probable, or possible, and for each we compute the "ordinary" efficiency as regards failure by that particular method; so that for every method by which failure might conceivably occur, the joint has a corresponding "ordinary efficiency." Some of these various efficiencies may happen to be equal to one another, but in general they will all be different, and we then take, as our final estimate of the "ordinary efficiency" of the joint, the lowest value obtained in these various calculations; for the joint will fail, presumably, by that mode for which the calculated efficiency is least. (For details concerning the determination of "ordinary" efficiencies, see The Locomotive for July, 1891, page 97, and for November, 1896, page 161.)

The "Effective" Efficiency of Any Joint.

Our definition of the "effective efficiency" of a joint does not throw any light, directly, upon the way in which the *numerical value* of that efficiency

* This is not necessarily the case with a *diagonal* joint, if its obliquity is large; but for the sake of simplicity we do not refer to this exception in the text.

is to be obtained, in practice. It merely fixes the meaning of the term "effective efficiency," so that when we go about the actual work of calculating that numerical value, we may do so with a clear understanding of the nature of the thing we are after.

To make the matter clear, let us look at the case from the following point of view: First, let us suppose that the boiler containing the joint whose "effective efficiency" we are seeking is so strong in all other respects, that if we expose it to a hydrostatic pressure until it bursts, the failure will consist either in the rupture of the joint, or in the development of a fracture elsewhere, running fore and aft through the solid metal of the shell; the heads and other parts being assumed (for the sake of the illustration we are about to give) to be stronger than any part of the shell. The hydrostatic pressure being applied until the boiler gives way, let us further suppose that the rupture occurs at the joint. (This would necessarily happen if the joint were a longitudinal one, and the plate had everywhere the same thickness and strength; but, as we shall see subsequently, it would not necessarily be the case if the joint were a diagonal one, and inclined to the fore-and-aft line at a sufficiently high angle. As we have already remarked, diagonal joints of these high inclinations are left out of consideration, for the moment, for the sake of clearness and simplicity.) The failure may occur by a fracture running from rivet-hole to rivet-hole, or by the rivets shearing, or perhaps by the edges of the plate giving way so that the rivets tear out directly; or two or more of these possible modes of failure may occur simultaneously, in different parts of the joint. Whatever the manner in which the rupture at the joint occurs, let us call the corresponding pressure the "bursting pressure *with* a joint."

Now consider a shell made up of exactly the same material as before, and identical with the previous one in every respect, except that it has no joint whatever, but is a mere cylindrical sheet, everywhere uniform in strength and thickness, and provided with heads so stiff and strong that failure must occur in the shell itself. If hydrostatic pressure be applied to this shell until it ruptures, then (since the stress in such a structure is greatest in the girthwise direction) failure will take place by the formation of a fracture running through the solid metal of the shell, in a direction parallel to the length of the boiler. Let us call the bursting pressure, in this case, the "bursting pressure *without* a joint."

If, now, we divide the "bursting pressure *with* a joint" by the "bursting pressure *without* a joint," the quotient will be what we have called the "effective efficiency" of the joint. Conversely, if we knew the "effective efficiency" of the joint, and we wanted to find the pressure at which a boiler shell, provided with such a joint, would give way, we should first determine the pressure at which the shell would burst if it were continuous, or jointless, and we should then multiply this pressure by the known "effective efficiency" of the joint, and the product would be the pressure under which the joint might be expected to fail.

Cause of the Difference Between the Two Kinds of Efficiency.

If the tensile stress in a boiler shell were the same in all directions, the two kinds of efficiency, as defined above, would be identically the same. It is known, however, that when a boiler is subjected to an internal pressure which acts both upon the shell and upon the heads, the shell is (in general) subjected to a state of stress such that the tension, at any given point, is different in different directions. If the heads of the shell are not braced in any way, but are capable of resisting the pressure simply by reason of their thickness, or by reason of their being bumped, then the tension per square inch on the metal of the shell is exactly twice as great in the round-about direction as it is in the lengthwise direction. (On this point, see THE LOCOMOTIVE for September, 1890, page 139, and for November, 1891, page 161.) In actual boilers, however, the stress, lengthwise of the shell, is often much less than half of the girthwise stress. In the horizontal tubular boiler, for example, the two heads are connected, in the lower part of the shell, by tubes, which reduce the stress upon the shell in two ways: (1) by diminishing the area on the head that is exposed to pressure, and (2) by supporting the entire steam load that comes upon the ligaments between the tube-holes, as well as that upon a certain fraction of the remaining portion of each head. In some boilers the upper parts of the heads are stayed by through braces, running from head to head, so that a considerable part of the steam load upon the heads is directly transmitted from one end of the boiler to the other, through these braces, without influencing the shell in the least. In such cases the action of the tubes and of the through braces reduces the endwise tension on the shell so materially that we may approach (though we could not actually attain) a condition in which the endwise tension on the shell is zero.

When, as in the commonest form of the horizontal tubular boiler, the heads, above the tubes, are supported by oblique braces running to the shell, the lengthwise stress in the middle of the upper part of the shell, between the points of attachment of the two sets of braces running to the respective heads, will be nearly equal to half of the girthwise stress. In the upper part of the shell of this same form of boiler, between either head and the points of attachment of the braces running from that head, the lengthwise stress will be somewhat less than in the middle of the boiler,—*how much* less depends upon the number, disposition, and effectiveness of the braces. To attempt to take account of all these points in any general or systematic way would lead to a long discussion that would doubtless, in the end, be of little or no practical value. We mention these various details, however, to emphasize the fact that in the case of an actual boiler the lengthwise stress in the shell may have any value, from almost nothing, up to one-half of the girthwise stress. Now in our first definition of efficiency (*i. e.*, in the case of "ordinary efficiency"), there is nothing said about the *position* of the joint in the boiler shell; and hence we should obtain the same result, in following out that definition, whether the joint had to resist the full girthwise stress in the shell, or only the lengthwise stress, which has a very different value, as we have just seen. A joint having an "ordinary efficiency" of 50 per cent. would give way, if it were placed longitudinally on a boiler, when the test pressure became equal to one-half of the pressure that would be required to burst the solid shell; but a joint of identically the same design, if placed girthwise of the boiler, would not give way until the test pressure became great enough to fracture the shell itself in a lengthwise direction, even if the boiler had no tubes nor braces, so that the longitudinal stress in the shell had the greatest value possible. Such a girth joint would therefore have an "ordinary efficiency" of 50 per cent., while its "effective efficiency" would be 100 per cent. or more.

In longitudinal and girth joints, the two definitions of "efficiency" do not give rise to any confusion, because the facts are well understood in these cases; but when we come to deal with the less familiar diagonal joint, we have to proceed with considerable care.

Derivation of the Rules for Diagonal Joints.

On account of the apparent difference of opinion among engineers respecting the proper method of calculating the efficiency of a diagonal joint, or that of a diagonally disposed row of tube holes, we have thought it best to explain the theoretical principles that underlie the rules that are given in the present article; but as it appears to be desirable to avoid algebraical symbols in stating and explaining these rules, we shall give the mathematical part of the reasoning in a separate section, or appendix, and in the present place we shall give only a general statement of the principles upon which this reasoning depends.

As we have already pointed out, the stress in a boiler shell is greater, girthwise, than it is lengthwise; and hence the weakening of a boiler shell due to the presence of a riveted joint depends not only upon the design of the joint, but also upon the angle that the joint makes with a line running lengthwise of the boiler. Let us now picture to ourselves a boiler shell, built all in one piece, so that it is simply a thin steel cylinder, without any joints whatever, except where it is fastened to the heads; and let us assume that this shell is exposed to a steady hydrostatic pressure, of such intensity that the shell is strained to a point just short of its breaking strength. Next, let us draw upon this shell a line, say one foot in length, and making a definite angle with the fore-and-aft direction, and let us consider the condition of stress that the metal of the shell is in, immediately under this line. That is, let us consider what the stress is, which acts upon the shell so as to tend to fracture it along the line we have marked out. If this line is parallel to the length of the boiler, the metal under it will be strained to a point just short of its breaking strength; but if it runs at right angles to this direction (that is, if it runs girthwise), the tension acting in the shell in a direction perpendicular to the line will not exceed half of the breaking strength, and it may be much less than this, as we have already pointed out in discussing the effect of tubes and bracing, in the preceding section of this article. It is easy to infer (and the mathematical investigation given below bears out this inference fully) that if the line is neither parallel to the length of the shell nor perpendicular to it, but lies at an oblique angle between those two positions, the stress acting perpendicularly to the line, and tending to produce fracture along it, will have a value intermediate between the full tensile strength of the plate and the tension experienced by the same line when lying in the girthwise position. In fact, if the shell upon which the line is drawn is provided with heads that are not braced in any way, nor connected by tubes (the lengthwise stress in the metal being then one-half of the girthwise stress), it may be shown that when the line we have marked out makes an angle of 30° with the length of the boiler, the tension acting perpendicularly to the line, and tending to produce fracture along it, will be 0.875 of the strength of the plate; and that when the line makes an angle of 45° with the length of the boiler, the corresponding tension will be 0.75 of the strength of the plate; and that when it makes an angle of 60° with the length of the boiler, the tension tending to produce rupture along the line will be 0.625 of the strength of the plate. The stress in the plate perpendicularly to any given line, in other words, varies in a perfectly definite manner as the inclination of the line to the length of the boiler varies, and is greatest when that inclination is least.

To find the "effective efficiency" of a diagonal joint making a given angle with the length of the boiler, we therefore calculate the "ordinary efficiency" first, in the usual way. This would be the efficiency to be used in calculating the strength of the boiler, if the joint were placed parallel to the length of the boiler; but inasmuch as the actual joint is inclined to the length of the boiler, and is therefore not subjected to so great a stress as would come upon it if it lay in a fore-and-aft position, it does not reduce the strength of the boiler by the amount corresponding to the "ordinary efficiency" as so calculated; and to find the efficiency that is to be assigned to such a joint in calculating the resistance of the boiler to internal pressure (*i. e.,* the "effective efficiency"), we therefore have to increase the efficiency as calculated for a fore-and-aft joint, by an amount which depends upon the position of the diagonal joint, and upon the way in which the heads of the boiler are braced. The numbers by which the efficiencies of longitudinal joints must be multiplied, in order to obtain the corresponding efficiencies of diagonal joints of a like design, are given in the accompanying table, and the use of the table is explained by the following rules, and the illustrative example. The reader must consult the appendix to the present article, however, if he wishes to know how the numbers that are given in the table are calculated.

Limitations of the Rules and of the Table.

The rules that are given below apply only to *lap joints,* which fail either by the breaking of the ligaments between the rivet-holes, or else by the shearing of the rivets. In a butt strap joint, or in any kind of a joint in which failure may occur partly in one way and partly in another (as by the shearing of certain rivets and the simultaneous fracture of the plate elsewhere), the same rules apply, for finding the effective efficiency of the diagonal joint with respect to modes of failure consisting solely in the shear of the rivets, or solely in the breakage of the plate; but the rules no longer hold true, in such butt joints, for other modes of failure, consisting in simultaneous rivet-shear and plate-failure. This is because the tabular factor for finding the effective efficiency as respects the shearing of the rivets is different from the corresponding factor for finding the effective efficiency as respects fracture of the plate. A rule that would apply accurately to butt strap joints (or to other joints of a similarly complex design), for any mode of failure whatever, would be quite complicated; and as such joints are seldom used in the oblique position, we have not thought it necessary to discuss them. In any case of this sort that may arise, we shall err on the safe side if we calculate the efficiency, first, as though the joint were a longitudinal one, and then multiply the result, *whatever the probable mode of failure,* by the "factor for rivet efficiency" in the table; because, in any given joint, the factor for rivet efficiency (for a given inclination of the joint) is never greater than the factor as regards plate-fracture; and hence if a diagonal butt strap joint is safe when this factor is used for all modes of failure, we may be assured that it would be safe if we used the mathematically correct factor, for each mode of failure separately.

THE ARRANGEMENT AND USE OF THE TABLE.

For convenience of reference, each column of the table has been provided not only with its own proper head-line, but also with a black-faced letter, **A**, **B**, **C**, etc., by which the column may be designated.

The angle that a given diagonal joint makes with a line running length-wise of the boiler is called the "inclination" of the joint, as indicated in Fig. 1*; and in our earlier article on the diagonal joint (THE LOCOMOTIVE, July, 1897, page 97) the table was arranged so that in using it we had to know the inclination, in degrees, in order to make the necessary calculations. It is much more convenient in practice, however, to designate the obliquity of the joint by giving what is called the *sine* of the inclination, instead of the inclination itself, in degrees. Fig. 3 shows what is meant by the "sine of the inclination" of the joint. To determine it we mark off a convenient number of units of the joint, and measure the total length (AB) of this selected number of units. In the illustration we have supposed that the inspector has chosen to measure the length of eight units of the joint, and that he has found the total length of these eight units to be exactly 20 in. Next, we measure the amount (BC) by which the diagonal joint departs, in a girthwise direction, from a straight fore-and-aft line, in eight units of its own length. In the illustration we have supposed that this girthwise departure, or travel, of the diagonal joint is 9½ in., for eight units of length of the joint. If we now divide BC by AB, we obtain what is called the "sine of the inclination" of the joint. Thus in the case we have illustrated in Fig. 3, the "sine of the inclination" is $9.5 \div 20 = 0.475$.

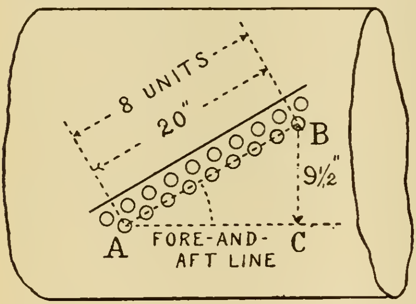

FIG. 3. — ILLUSTRATING THE "SINE OF THE INCLINATION."

In using the table in accordance with the rules presently to be given, we take the "sine of the inclination" of the joint as the measure of the obliquity of the joint; and Column **A** gives the values of the sine of the inclination, for every hundredth, and for all possible angles of obliquity, from the position where the joint is a true fore-and-aft joint, to where it becomes a true girth joint.† As cases may arise in which it is more convenient to use the actual angle of inclination (BAC in Fig. 3) instead of the sine of that angle, we have given, in Column **F**, the angles corresponding to the respective sines in Column **A**.

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* The reader should observe that in the article in *The Locomotive* for July, 1897, the angle between the diagonal joint and the *girth joint* was taken as measuring the obliquity, while in the present article we have adopted the angle between the diagonal joint and a *fore-and-aft* line.

† Objection may be made to this table, on the ground that it is extensive, even to the point of absurdity. In reply to this possible criticism we would say that when, in the past, we have tried to limit the scope of our tables so as to include only the cases that arise in practice we have often had occasion to regret, subsequently, that they were not calculated for a wider range of values; and so in this table we have included every possible position of the diagonal joint.

Before passing to the rules governing the use of the table, it may be well to say a word about finding the values of the factors in the table, corresponding to values of the "sine of the inclination" that are intermediate between those given in Column **A**. For example, suppose that in a given diagonal joint the "sine of the inclination" is found to be 0.663; and suppose we want to find the value of the factor tabulated in Column **B**, corresponding to this value of the "sine of the inclination." We do not find 0.663 in Column **A**, but we do find 0.66 and 0.67; and in Column **B** we find 1.278 opposite 0.66, and 1.289 opposite 0.67. In a practical calculation it might suffice to adopt the lesser of these (namely, 1.278) as a satisfactory approximation to the desired factor; or it might even be sufficient to preserve only two decimal places in this factor, and call it 1.28 instead of 1.278. But if we wish for a considerable degree of precision for any reason, we may adopt a value of the factor in Column **B** that is intermediate between 1.278 and 1.289, just as the given value, 0.663, of the sine of the inclination, is intermediate between 0.66 and 0.67. The easiest way to proceed is as follows: The given value, 0.663, of the sine of the inclination, is 3/10 of the way from 0.66 to 0.67; and hence the value to be adopted for the corresponding factor in Column **B** should be 3/10 of the way from 1.278 to 1.289. Now $1.289 - 1.278 = 0.011$, and 3/10 of this is 0.0033, or 0.003, if we retain the result to the nearest unit in the third decimal place. Then $1.278 + 0.003 = 1.281$, which is the value to be adopted for the factor in Column **B**, corresponding to 0.663 in Column **A**, when we wish a very precise result. This process of obtaining a number from a table, intermediate between two successive given numbers, is called "interpolation."

Rules for Finding the "Effective Efficiency" of a Lap-Riveted Diagonal Joint.

Rule 1. To find the "effective" ligament efficiency; that is, the "effective" efficiency with respect to the breakage of the plate through the rivet-holes:

First find the ordinary efficiency of the joint, in the usual way, so far as concerns the tendency to break the ligaments of the plate between the rivet-holes. Then, in Column **B** or Column **D** of the table, find the factor corresponding to the sine of the inclination of the joint, and multiply the ordinary efficiency, as just found, by this factor. The result is the effective efficiency which is to be assigned to the joint, so far as fracture of the ligaments between the rivet-holes is concerned. The tabular factor is to be taken from Column **B**, if the joint occurs on a shell whose heads are not braced, and not connected by tubes; and it is to be taken from Column **D** if the shell is entirely free from lengthwise stress, by reason of the heads being united by braces or tubes, in such a manner that the load on the heads is directly transmitted from one head to the other, without any part of it coming upon the shell. For cases in which the support of the heads is such that the stress, lengthwise on the shell, is intermediate between zero and the greatest value that is possible, a value for the efficiency should be selected, intermediate between the two values obtained as here described; the selection of this intermediate value being made with due reference to the actual mode of support of the heads, and to the consequent degree of approximation of the conditions to the two respective extreme cases covered by the table. In a horizontal tubular boiler, fitted with tubes in the usual manner, the efficiency of the

Table of Factors for Diagonal Joints.

A.	Heads entirely unbraced. Endwise stress on shell equal to full load on head.		Heads supported in such a manner that there is no endwise stress on shell.		F.
Sine of the inclination of the joint.	B. Factor for ligament efficiency.	C. Factor for rivet efficiency.	D. Factor for ligament efficiency.	E. Factor for rivet efficiency.	Inclination of joint to fore-and-aft line.
0.51	1.149	1.115	1.352	1.163	30° 40′
.52	1.156	1.120	1.371	1.171	31° 20′
.53	1.163	1.126	1.391	1.179	32° 00′
.54	1.171	1.131	1.412	1.188	32° 41′
.55	1.178	1.137	1.434	1.197	33° 22′
0.56	1.185	1.143	1.457	1 207	34° 03′
.57	1.194	1.150	1.481	1.217	34° 45′
.58	1.202	1.156	1.507	1.228	35° 27′
.59	1.211	1.163	1.534	1.239	36° 09′
.60	1.220	1.170	1.562	1.250	36° 52′
0.61	1.229	1.178	1.593	1.262	37° 35′
.62	1.238	1.185	1.624	1.275	38° 19′
.63	1 248	1.193	1.658	1.288	39° 03′
.64	1.258	1.201	1.694	1.301	39° 48′
.65	1.268	1.210	1.732	1.316	40° 32′
0.66	1.278	1.219	1.772	1.331	41° 18′
.67	1.289	1.228	1.815	1.347	42° 04′
.68	1.301	1.237	1.860	1.364	42° 51′
.69	1.312	1.247	1.909	1.382	43° 38′
.70	1.325	1.257	1.961	1.400	44° 26′
0.71	1.337	1.268	2.017	1.420	45° 14′
.72	1.350	1.279	2.076	1.441	46° 03′
.73	1.363	1.291	2.141	1.463	46° 53′
.74	1.377	1.303	2.210	1.487	47° 44′
.75	1.391	1.315	2.286	1.512	48° 35′
0.76	1.406	1.328	2.367	1.539	49° 28′
.77	1.421	1.342	2.456	1.567	50° 21′
.78	1.437	1.356	2.554	1.598	51° 16′
79	1.454	1.371	2.660	1.631	52° 11′
80	1.471	1.387	2.778	1.667	53° 08′
0.81	1.488	1.403	2.908	1.705	54° 06′
.82	1.506	1.420	3.053	1.747	55° 05′
.83	1.525	1.438	3.214	1.793	56° 06′
.84	1.545	1.457	3.397	1.843	57° 08′
.85	1.566	1.477	3.604	1.898	58° 13′
0.86	1.587	1.499	3.840	1.960	59° 19′
.87	1.609	1.521	4.114	2.028	60° 28′
.88	1.632	1.545	4.433	2.105	61° 39′
.89	1.656	1.570	4.810	2.193	62° 52′
.90	1.681	1.596	5.263	2.294	64° 09′
0.91	1.707	1.625	5.817	2.412	65° 30′
.92	1.734	1.655	6.510	2.552	66° 56′
.93	1.762	1.687	7.402	2.721	68° 26′
.94	1.792	1.722	8.591	2.931	70° 03′
.95	1.822	1.759	10.256	3.203	71° 48′
0.96	1.855	1.800	12.755	3.571	73° 44′
.97	1.888	1.843	16.920	4.114	75° 56′
.98	1.924	1.891	25.253	5.025	78° 31′
.99	1.961	1.943	50.251	7.090	81° 54′
1.00	2.000	2.000	infinite	infinite	90° 00′

Table of Factors for Diagonal Joints.

A.	Heads entirely unbraced. End-wise stress on shell equal to full load on head.		Heads supported in such a manner that there is no end-wise stress on shell.		F.
Sine of the inclination of the joint.	B. Factor for ligament efficiency.	C. Factor for rivet efficiency.	D. Factor for ligament efficiency.	E. Factor for rivet efficiency.	Inclination of joint to fore-and-aft line.
0.01	1.000	1.000	1.000	1.000	0° 34′
.02	1.000	1.000	1.000	1.000	1° 09′
.03	1.000	1.000	1.001	1.000	1° 43′
.04	1.001	1.001	1.002	1.001	2° 18′
.05	1.001	1.001	1.003	1.001	2° 52′
0.06	1.002	1.001	1.004	1.002	3° 26′
.07	1.002	1.002	1.005	1.002	4° 01′
.08	1.003	1.002	1.006	1.003	4° 35′
.09	1.004	1.003	1.008	1.004	5° 10′
.10	1.005	1.004	1.010	1.005	5° 44′
0.11	1.006	1.005	1.012	1.006	6° 19′
.12	1.007	1.005	1.015	1.007	6° 54′
.13	1.009	1.006	1.017	1.009	7° 28′
.14	1.010	1.007	1.020	1.010	8° 03′
.15	1.011	1.009	1.023	1.011	8° 38′
0.16	1.013	1.010	1.026	1.013	9° 12′
.17	1.015	1.011	1.030	1.015	9° 47′
.18	1.016	1.012	1.033	1.017	10° 22′
.19	1.018	1.014	1.037	1.019	10° 57′
.20	1.020	1.015	1.042	1.021	11° 32′
0.21	1.023	1.017	1.046	1.023	12° 07′
.22	1.025	1.019	1.051	1.025	12° 43′
.23	1.027	1.020	1.056	1.028	13° 18′
.24	1.030	1.022	1.061	1.030	13° 53′
.25	1.032	1.024	1.067	1.033	14° 29′
0.26	1.035	1.026	1.073	1.036	15° 04′
.27	1.038	1.028	1.079	1.039	15° 40′
.28	1.041	1.031	1.085	1.042	16° 16′
.29	1.044	1.033	1.092	1.045	16° 51′
.30	1.047	1.036	1.099	1.048	17° 27′
0.31	1.050	1.038	1.106	1.052	18° 04′
.32	1.054	1.041	1.114	1.056	18° 40′
.33	1.058	1.044	1.122	1.059	19° 16′
.34	1.061	1.046	1.131	1.063	19° 53′
.35	1.065	1.049	1.140	1.068	20° 29′
0.36	1.069	1.052	1.149	1.072	21° 06′
.37	1.073	1.056	1.159	1.076	21° 43′
.38	1.078	1.059	1.169	1.081	22° 20′
.39	1.082	1.062	1.179	1.086	22° 57′
.40	1.087	1.066	1.190	1.091	23° 35′
0.41	1.092	1.070	1.202	1.096	24° 12′
.42	1.097	1.074	1.214	1.102	24° 50′
.43	1.102	1.077	1.227	1.108	25° 28′
.44	1.107	1.082	1.240	1.114	26° 06′
.45	1.113	1.086	1.254	1.120	26° 45′
0.46	1.118	1.090	1.268	1.126	27° 23′
.47	1.124	1.095	1.284	1.133	28° 02′
.48	1.130	1.100	1.299	1.140	28° 41′
.49	1.136	1.104	1.316	1.147	29° 20′
.50	1.143	1.109	1.333	1.155	30° 00′

joint will approach that calculated by Column D, when the joint is in the lower part of the shell, and it will approach that calculated by Column B, when the joint is in the upper part of the shell and near the middle of the boiler.

Rule 2. To find the "effective" efficiency as regards the shearing of the rivets:

First find the ordinary efficiency of the joint, in the usual way, so far as concerns the tendency of the rivets to fail by shearing. Then, in Column C or Column E of the table, find the factor corresponding to the sine of the inclination of the joint, and multiply the ordinary efficiency, as just found, by this factor. The result is the effective efficiency that is to be assigned to the joint, so far as the shearing of the rivets is concerned. The tabular factor is to be taken from Column C, if the heads are unsupported by either braces or tubes; and it is to be taken from Column E if the load on the heads is so perfectly supported by tubes, or through braces, or otherwise, that no part of it comes on the shell. In practical cases in which neither of these conditions is accurately fulfilled, a value of the effective efficiency lying between these two extreme values is to be selected, the principles governing the selection being the same as in the preceding rule.

Having determined the effective efficiency as regards breakage of the plate through the rivet-holes, and also the effective efficiency as regards the shearing of the rivets, the lesser of these two efficiencies is to be accepted as the final estimate of the effective efficiency of the joint, for use in computing the strength of the shell upon which the joint occurs.

Example in the Use of the Rules.

To illustrate the application of the foregoing rules to a concrete case, let us consider a double-riveted lap joint of the following proportions: Pitch of rivets, 2⅞ in.; diameter of rivet-hole, $^{13}/_{16}$ in.; thickness of plate ⅜ in. The plate will be assumed to have a tensile strength of 55,000 lbs. per square inch of sectional area, and the rivets will be assumed to be of steel, with a shearing strength of 42,000 lbs. per square inch. The inclination of the joint to the fore-and-aft direction will be assumed to be such that when we measure off eight units of the joint, as shown at *AB* in Fig. 3 (the total length of *AB*, in the present case, being 8 × 2⅞ in. = 23 in.), we find that the distance *BC*, by which this length of the joint departs, in a girthwise direction, from the fore-and-aft line through *A*, is 11½ in.; so that the sine of the inclination of the joint, in this case, is 11½ ÷ 23 = 0.500.

We first find the ordinary efficiencies of the joint in the usual way, with respect both to fracture through the rivet-holes, and to the shearing of the rivets. Thus:

Tensile strength of a strip of solid plate of width equal to the length of one unit of the joint = 55,000 × ⅜″ × 2⅞″ = 59,297 lbs.

Shearing strength of one rivet (see table in The Locomotive for October, 1903, page 150) = 21,776 lbs. As there are two rivets in each unit of the joint, the total strength of the rivets that must be sheared, in each unit, to cause failure of the joint by shearing, is 2 × 21,776 = 43,552 lbs.

Hence we have:

Rivet efficiency = 43,552 ÷ 59,297 = 0.734.

We also have

Ligament efficiency = $(2\frac{7}{8}'' - \frac{13}{16}'') \div 2\frac{7}{8}'' = (2.875'' - 0.8125'') \div 2.875'' = 2.0625'' \div 2.875'' = 0.717$.

Our results therefore are:

"Ordinary efficiency" as regards breakage of the plate through the rivet-holes = 71.7 per cent.

"Ordinary efficiency" as regards the shearing of the rivets = 73.4 per cent.

We have now to take account of the fact that the joint lies in a diagonal, or oblique position, instead of in a true fore-and-aft direction; and we shall do this, *firstly*, for the case in which the heads of the boiler or drum, upon which the joint occurs, are entirely unsupported by braces or tubes, so that the full steam load upon the heads is transmitted to the shell; and *secondly*, we shall do it for the case in which the heads are so perfectly supported, by tubes or through braces or otherwise, that no sensible part of the load upon them is transmitted to that part of the shell where the diagonal joint is located.

When the full load upon the heads is transmitted to the shell, the factors for taking account of the obliquity of the joint are to be sought in Columns **B** and **C** of the table. We found that the sine of the inclination of the joint under consideration is 0.500. We therefore look for this number in Column **A**; and opposite to it, in Columns **B** and **C**, respectively, we find the numbers 1.143 and 1.109. Hence, for this particular joint and for the assumed conditions, we have:

"Effective efficiency" as regards breakage of the plate through the rivet-holes = $71.7 \times 1.143 = 82.0$ per cent.

"Effective efficiency" as regards the shearing of the rivets = $73.4 \times 1.109 = 81.4$ per cent.

It will be noticed that the "ordinary" efficiency of this joint is least with respect to the breakage of the plate through the rivet-holes; while the "effective" efficiency of the actual joint in its oblique position is least with respect to the shearing of the rivets. This change, or reversal, in the point of weakness is due, manifestly, to the fact that the factors in Column **C** are smaller than the corresponding factors in Column **B**; and a similar change, or reversal, will always occur, if the joint is oblique, and the ordinary rivet-efficiency exceeds the ordinary plate-ligament efficiency by a sufficiently small amount.

We pass, next, to the consideration of the case in which the joint has the same proportions as before, and the same degree of obliquity, but where the heads of the shell or drum on which the joint occurs are so perfectly supported by tubes, or through braces, or other equivalent means, that the shell receives none of the steam load upon the heads. In this case the procedure is the same as before, except that the factors must now be taken from Columns **D** and **E**. We find these factors, accordingly, to be 1.333 and 1.155, respectively, for breakage through the rivet-holes, and for shearing of the rivets. Hence, for the conditions here assumed, we have:

"Effective efficiency" as regards the breakage of the plate through the rivet-holes = $71.7 \times 1.333 = 95.6$ per cent.

"Effective efficiency" as regards the shearing of the rivets = $73.4 \times 1.155 = 84.8$ per cent.

Here, also, we find that the rivets have become weaker than the net section of the plate, when the joint is in its oblique position; but the disparity is now much greater than it was before. It is in fact so great as to suggest that in diagonal riveted joints that are to be used on shells in which the endwise tension is very small, it would be well to make the rivets somewhat stronger, relatively to the net section of the plate, than is customary in ordinary longitudinal joints. For example, if the joint is to be used on such a shell, and the materials are the same as are assumed above, then we should have a stronger construction (with the joint in the diagonal position) if we should make the pitch of the rivets 2⅝ in. instead of 2⅞ in., the proportions being otherwise the same as before. Such a joint has a ligament efficiency of 69.0 per cent., and a rivet efficiency of 80.4 per cent., when used as a longitudinal joint; but upon multiplying these values by the tabular factors, 1.333 and 1.155 respectively, we find that the joint, in its diagonal position, would have an "effective" efficiency of 92.0 per cent. with respect to breakage between the rivet-holes, and 92.9 per cent. with respect to the shearing of the rivets.

This, it should be observed, is for the case in which the heads are fully supported, in such a manner that no endwise stress comes on the shell. When the construction is such that the entire load on the heads is transmitted to the shell, it would be better, in the joint here considered, to use the pitch 2⅞ in., as in the first part of this example.

When, as is the case in a horizontal tubular boiler, the heads are connected by tubes (or otherwise) so that a considerable portion of the load upon the heads is transmitted directly from one head to the other, without influencing the shell, while, at the same time, there is also a considerable portion of the load on the heads that is *not* so transmitted, but which must be sustained by the shell, it is practically impossible to give a rule for finding the effective efficiency of a diagonal joint *exactly*. The effective efficiency in such cases will be intermediate, however, between the least value obtained from Columns **B** and **C** of the table, on the one hand, and the least value obtained from Columns **D** and **E** on the other hand; and the best that we can do is to estimate its value, within this range, from our knowledge of the actual mode of support of the heads.

When the joint is so designed that the rivet-efficiency and the ligament-efficiency are approximately equal, as calculated for a longitudinal joint in the ordinary way, there will not be any very wide difference between the effective efficiencies as calculated from Columns **B** and **E**, unless the obliquity of the joint is extreme; so that in many of the practical problems that arise, the assigning of a probable value to the effective efficiency of a diagonal joint in a structure similar to a horizontal tubular boiler is not at all a difficult matter. For example, in the illustrative joint considered above (with a pitch of 2⅞ in.) we obtained the results given in the accompanying short table.

Effective Efficiencies of the Illustrative Joint.

Nature of lengthwise stress on shell.	Ligament efficiency.	Rivet efficiency.
Heads entirely unbraced; lengthwise stress on the shell a maximum.	82.0 %	81.4 %
No lengthwise stress on the shell.	95.6 %	84.8 %

The effective efficiency that we should have to adopt for the diagonal joint, if it were on a structure similar in design to a horizontal tubular boiler, would therefore be intermediate between 81.4 per cent. and 84.8 per cent.; the former being the smaller of the two values obtained for the case of a maximum endwise stress on the shell, while the latter is the smaller of the two values obtained for the case of the entire absence of endwise stress on the shell. If the joint were on the bottom of the shell, where the load on the heads is almost entirely sustained by the tubes, its effective efficiency would approximate closely to 84.0 per cent. (*i. e.*, a little less than 84.8 per cent.); while if it were on the upper part of the shell, towards the middle of the boiler (so as to be between the braces running from the heads to the shell), its effective efficiency would approximate to 82.0 per cent. (*i. e.*, a little more than 81.4 per cent.). We could therefore take the effective efficiency of the joint as equal to (say) 83.0 per cent. for any part of the boiler, unless the computation were being made for the purpose of deciding some very fine point; and in that case the problem in hand would have to be considered on its own merits.

Having determined the "effective efficiency" of a diagonal joint on a cylindrical shell or drum, we proceed to calculate the bursting pressure of the shell in the usual way, except that this "effective" efficiency is to be used for the joint, instead of using the "ordinary" efficiency, as calculated for a longitudinal joint. The rule would therefore be:

Rule for finding the Bursting Pressure of a Shell having a Diagonal Lap-riveted Joint: Multiply the tensile strength of the material of the shell, in pounds per square inch, by the "effective" efficiency of the diagonal joint, and multiply the result by the thickness of the plate, in inches. The product so found is then to be divided by the radius of the shell, in inches, and the result is the bursting pressure of the shell, in pounds per square inch.

Of course if the boiler has joints of other kinds, these must be separately investigated, and the final estimate of the bursting pressure must be based upon the strength of the weakest part of the shell, wherever that may be.

The parts of the table relating to positions of the diagonal joint nearly parallel to the girth joint will seldom be required in practice for calculations relating to the strength of riveted joints. A double-riveted lap joint, whose ordinary efficiency is 72 per cent., has an effective efficiency of 100 per cent. or more, when its angle of inclination to the fore-and-aft line is upwards of 53° on a shell with unbraced heads, or upwards of 44° on a shell which is entirely free from endwise stress. When such a joint has an obliquity greater than these respective values, we therefore do not need to use the table at all, since we do not care what the effective efficiency of the joint may be, so long as we know that it exceeds 100 per cent.

Diagonal Rows of Tube-Holes in a Boiler Shell, or Drum.

In boilers of certain types there are cylindrical shells, or drums, which are perforated with rows of holes for the insertion of tubes, the arrangement of the holes being similar to that suggested in Fig. 4. A shell or drum of this sort might conceivably fracture along a line parallel to the length of the drum, as indicated by the dotted line *AB*, or the fracture might take a diagonal course, as is suggested by the full line, *AC*. The calculation of the efficiency of the shell, so far as fracture along *AB* is concerned, is a simple matter; so that we omit this mode of fracture from present consideration, and confine our attention to the other case, in which fracture may occur along a diagonal line, as shown at *AC*.

In determining the effective efficiency of a drum with respect to diagonal fracture along a line of tube-holes, we may proceed precisely as we did in determining the effective efficiency of a diagonal riveted joint, with respect to possible fracture of the plate through the rivet-holes; and in fact we may apply Rule 1 (given above) directly. It is necessary to exercise a little caution in obtaining the "sine of the inclination," however, because in many of these drums the length of the drum lies vertically, and in such cases the line which we have called the "fore-and-aft line" runs vertically also, instead of running horizontally, as it does in a horizontal tubular boiler. In explaining the application of Rule 1 to the calculation of the "effective efficiency" of a diagonal row of tube-holes, we shall illustrate our remarks by the aid of Fig. 5, which represents, on an enlarged scale, a few of the tube-holes of Fig. 4. The letters

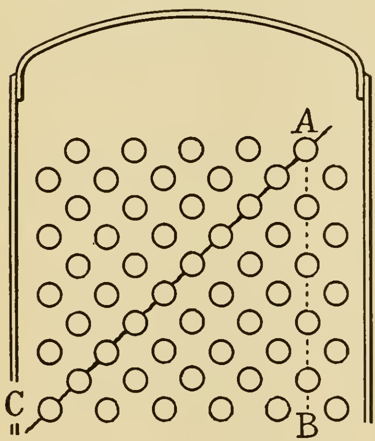


Fig. 4. — Illustrating a Cylindrical Shell perforated with Tube-Holes.

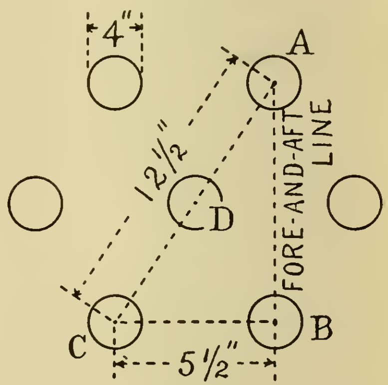


Fig. 5. — A Portion of Fig. 4, on an Enlarged Scale.

A, B, C, and *D* are here to be understood as applying to the *centers* of the holes beside which they stand.

First, as to the calculation of the "sine of the inclination" of the assumed line of diagonal fracture, *AC*. To obtain this, we measure the distance *BC* (in Fig. 5), which is the girthwise pitch of the holes, or the distance from the center of one hole to the center of the one that comes next to it in the roundabout direction. We also measure the distance *AC*, which, as will be seen, is *double* the pitch of the holes, as measured along the diagonal line that we assume the line of fracture may follow. (In other words, *AC* is the distance from the center of one tube-hole to the center of the *second* hole from it, as we pass along the oblique line that the fracture will presumably follow.) We then divide the distance *BC* by the distance *AC*, and the quotient is the "sine of the inclination" of the line of fracture.

Having found, in this way, the "sine of the inclination" of the fracture, we proceed to determine the "ordinary efficiency" of the shell, along this line of fracture. This is done precisely as in an ordinary longitudinal riveted joint.

That is, we measure the pitch, *AD,* of the row of holes along the oblique line of fracture, and from this pitch we subtract the diameter of one tube-hole. The remainder is then to be divided by the pitch, *AD,* and the quotient is the "ordinary efficiency" of the row of tube-holes, along the line of fracture, *AC.*

As we now have the "ordinary efficiency" of the shell along the line of fracture, and also the "sine of the inclination" that the line of fracture makes with the fore-and-aft line (or lengthwise direction) of the shell, we can apply Rule 1 at once. An example will make the procedure clear.

Let us suppose that the various dimensions that are involved in the calculation are those shown in Fig. 5; the diameter of each hole being 4 in., the girthwise pitch (*BC*) being 5.50 in., and the diagonal pitch, *AD,* being 6.25 in. (so that *AC* is equal to 12.50 in.). The "sine of the inclination" of the line of fracture is then equal to $5.50'' \div 12.50'' = 0.440$; and the "ordinary efficiency," along the line of fracture, is $(6.25'' - 4.00'') \div 6.25'' = 0.360$, or 36.0 per cent. Following Rule 1, we find the value 0.440 of the "sine of the inclination" in Column **A** of the table, and opposite to it we find 1.107 in Column **B**, and 1.240 in Column **D**. Then we have $36.0 \times 1.107 = 39.9$, and $36.0 \times 1.240 = 44.6$ (retaining the figures, in each case, to the nearest tenth). Hence the "effective efficiency" of the row of holes, so far as fracture along the diagonal line *AC* (in Fig. 4) is concerned, is 39.9 per cent. if the heads of the drum are entirely unbraced (so that the entire load upon them is transmitted to the shell), and it is 44.6 per cent., if the heads are supported in such a way that none of the load upon them is transmitted to the shell.

Having thus found the "effective efficiency" of the shell, so far as fracture along the diagonal line is concerned, we may proceed to compute the bursting pressure of the drum in the usual way, as has already been explained in connection with diagonal riveted joints.

The Massachusetts Rule for Diagonal Rows of Tube-Holes.

The Massachusetts Board of Boiler Rules has given a formula for calculating the effective efficiency of a diagonal row of uniformly spaced tube-holes, which must be followed in the Commonwealth of Massachusetts, in all boilers which are under the jurisdiction of the State authorities. Expressed in words, the formula is as follows: Subtract the diameter of one tube-hole from the diagonal pitch (*AB* in Fig. 6) of the tube-holes, and divide the result by the distance (*BC* in Fig. 6), measured along a fore-and-aft line of the drum or shell, between two *successive* rows of tube-holes; all measurements being taken in inches. The result is the efficiency of the tube-sheet, so far as concerns fracture along a diagonal line such as *AC* in Fig. 4. It will be observed that this rule takes no account of the way in which the head of the shell is supported, and it therefore cannot be exact under all conditions. It has a very simple form, however, and when applied to the tube-sheets that are of most common occurrence in practice, it gives results that do not differ markedly from those obtained by the more exact

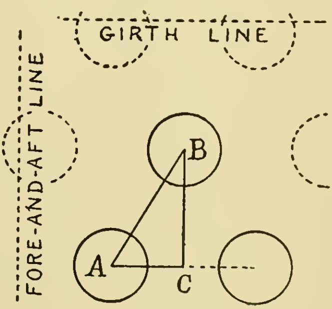


Fig. 6. — Illustrating the Massachusetts Rule.

method of calculation that we have given above, for the case in which the heads of the shell are entirely unsupported by braces or tubes.

The Massachusetts rule, in fact, gives results that are identical with those that would be obtained by the method we have described above, if we should use the factors in Column **E** of the table, instead of those in Columns **B** or **D**. The conditions under which the rule is applicable, outside of Massachusetts, may therefore be judged by comparing those columns in the table. Usually, the drums on which rows of tube-holes occur have bumped heads, so that in our exact rule we should use the factors in Column **B**. It will be seen that for tube-hole rows having a degree of obliquity such as occurs in ordinary practice, the factors in Column **E** are nearly equal to the corresponding ones in Column **B**; and the Massachusetts rule, in such cases, has a degree of precision corresponding to this approximate equality.

Rule of the U. S. Steamboat Inspection Service for Diagonal Tube-Hole Rows.

The rule of the Board of Supervising Inspectors for calculating the pressure allowable upon a shell that is perforated with staggered rows of tube-holes (as in Fig. 4) differs in outward form from the Massachusetts rule, but is in reality identical with it, except that the Supervising Inspectors require a factor of safety of *six* to be used in calculating the working pressure to be allowed upon such shells, whereas the Massachusetts rule does not explicitly specify any particular factor of safety, for use in connection with a construction of this sort.

Case of Two or Three Parallel Staggered Rows of Tube-Holes.

Cylindrical drums, or shells, are often met with, in practice, in which two or three staggered rows of tube-holes occur, as indicated in Fig. 7. There is no difficulty, in such cases, about finding the strength of the drum so far as a straight fracture is concerned, running fore-and-aft through a single row of holes. Fracture may conceivably occur, however, in the zig-zag fashion indicated in the illustration; and hence it is important to know the efficiency of the drum respecting this mode of failure. In the mathematical discussion of a zig-zag fracture of this sort, some rather vexatious difficulties arise, and we are not aware that anyone has given a solution of the problem that is beyond reproach in all respects. It is usual, however, to calculate the efficiency of the shell in such cases as though the plate were perforated all over with regularly spaced holes, as indicated by the dotted circles, and as though fracture took place along the line *AB*. The idea underlying this method of calculation is, that although the successive sections of the actual fracture are turned first one way and then the other, yet they all make the same angle with the fore-and-aft line. Hence it is assumed that the strength of the drum is the same as it would be if all these sections were turned in the same direction, so as to lie along the straight line *AB*. As we have already suggested, this assumption is not altogether beyond criticism, and yet it appears to be the best one that we can make, in the present state of our knowledge.

In calculating the efficiency of a drum perforated with only two or three rows of staggered holes, we should furthermore proceed as though there were no endwise stress on the shell. In other words, in applying our rule for the efficiency of a diagonal row of tube-holes to this case, the factor that we must take from the table should be taken from Column D. This is because any endwise tension that there may be on the shell, in a construction similar to that shown in Fig. 7, does not affect the ligaments between the tubes to nearly so great an extent as it does when the line of possible fracture runs a straight

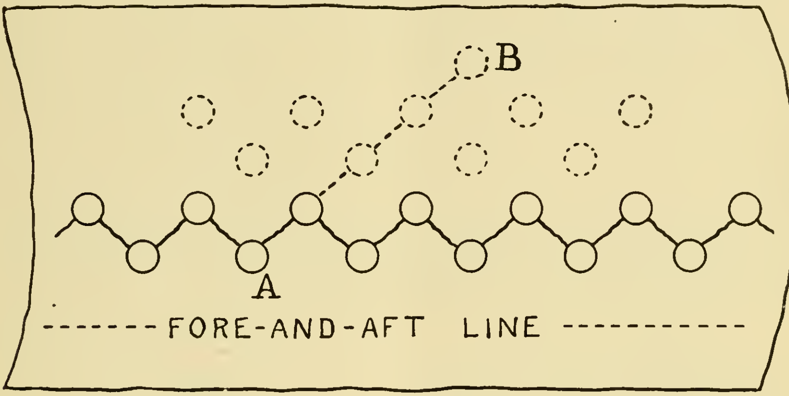


Fig. 7. — Two Parallel Staggered Rows of Tube-Holes.

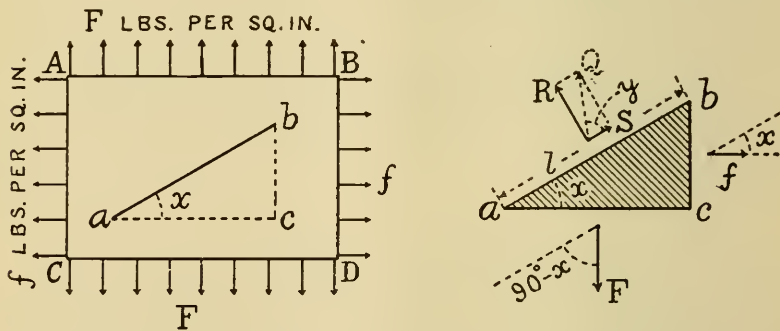
(or helical) course, around a considerable part of the circumference of the shell, as in Figs. 1 or 4.

Mathematical Appendix.

In the investigation of the efficiency of a diagonal riveted joint, it is convenient to begin by considering the stresses in a rectangular plate of uniform thickness, such as is indicated in Fig. 8. We will suppose each edge of the plate to be subjected to a uniform tension, which everywhere lies in the plane of the plate, and is everywhere perpendicular to the edge to which it is applied, as indicated by the arrows. The tension applied to the edge *AB* is equal and opposite to that applied to *CD,* and is of such a magnitude, we will suppose, as to subject the plate all along the edge to a tensile stress of *F* pounds per square inch of its cross section. The tension applied to the edge *AC* is likewise equal and opposite to that applied to *BD*, and is of such an intensity as to subject the plate everywhere along these two edges to a tensile stress of *f* pounds per square inch of cross section.

We shall first consider the nature of the force acting upon an imaginary, straight section of the plate, such as that shown edgewise at *ab;* and as an aid in doing so, we shall also suppose imaginary straight sections of the plate to be made through *a* and *b,* as shown at *ac* and *bc*, the former being parallel to *CD* and the latter to *BD*. Then, since the tensions acting upon the whole plate are uniform along each edge, the forces acting on the triangular piece *abc* will also be uniform along each of the edges *ab, bc,* and *ca.* The force acting on the edge *ac* will in fact consist in a uniform tension of *F* lbs. per square inch, and that acting on the edge *bc* will be a uniform tension of *f* lbs. per square inch. These tensions will be perpendicular to the edges *ac* and *bc*, respectively, and there will be no shearing stress on either *ac* or *bc*. Concerning the force acting on the edge *ab*, we can only assert, for the present, that it will consist in a uniform pull of (say) Q lbs. upon each square inch of that edge; Q being not yet known. We cannot assert that the force Q will be perpendicular to the edge *ab*; and as a matter of fact it will *not* be perpendicular thereto, unless certain special conditions are fulfilled.

But though Q is not perpendicular to *ab*, we may nevertheless resolve it, by means of the parallelogram of forces, into two components, one of these (which we will call R) being perpendicular to *ab*, while the other (S) is parallel to *ab*; the latter component tending to shear the plate along *ab*. An attempt has been made in Fig. 9. to indicate the resolution of Q into the components R and S; but in referring to this diagram it must be remembered that F, f, R, S, and Q are not the *total* forces exerted upon the several edges of the triangle, but that each is the intensity of the force acting in the direction shown, upon each square inch of the sectional area of the corresponding edge. In this diagram l is the length of *ab*, in inches, and x is the angle included between the lines *ab* and *ac*.



FIGS. 8 AND 9.—ILLUSTRATING THE STRESSES IN A SOLID PLATE.

The forces R and S are as yet unknown, and we must determine them from the condition that the triangle is in equilibrium. We proceed, first, to find R, by resolving all the forces acting upon the triangle so as to find the component of each that is perpendicular to *ab*. The total force acting upon the edge *ab* in this direction is Rlt (t being the thickness of the plate). The length of *bc* is $l \sin x$, and hence the total force acting upon *bc*, and perpendicularly to *bc*, is $flt \sin x$; whence it follows that the component, perpendicular to *ab*, of the total force acting on *bc*, is $flt \sin^2 x$. Similarly, the length of *ac* is $l \cos x$, and the total force acting on *ac* (and perpendicularly to it) is $Flt \cos x$; and the component of this, perpendicular to *ab*, is $Flt \cos^2 x$. In order that the triangular piece of plate, *abc*, may be in equilibrium, we must therefore have

$$Rlt = Flt \cos^2 x + flt \sin^2 x, \text{ or}$$
$$R = F \cos^2 x + f \sin^2 x. \quad (1)$$

When we know the forces F and f, and the angle x, this equation gives us the value, R, of the tensile stress in the plate across the line *ab*, and perpendicularly to it.

To find the force S, acting upon each square inch of the section ab, and tending to *shear* the plate along ab, we resolve all the forces acting upon the triangle, so as to obtain their components *parallel* to ab. The total force acting upon ab in this direction is Slt. The total force on bc, and perpendicular to it, is $flt \sin x$, as before; and the component of this, parallel to ab, is $flt \sin x \cos x$, acting in the same direction as S. Similarly, the total normal force on ac is $Flt \cos x$, as before; and the component of this, parallel to ab, is $Flt \cos x \sin x$, acting in a direction opposite to S. Hence, since the triangle abc is in equilibrium, we must have

$$Slt = Flt \cos x \sin x - flt \sin x \cos x, \text{ or}$$

$$S = (F - f) \sin x \cos x. \qquad (2)$$

This equation gives the shearing stress, S, acting upon each square inch of the edge ab, and tending to shear the plate along ab.

To find the total force, Q, acting (obliquely) upon each square inch of the edge ab, we have merely to compound the two component forces, R and S, in accordance with the relation

$$Q^2 = R^2 + S^2.$$

The result, after substituting the values of R and S, as given above, may be brought into the form

$$Q = \sqrt{F^2 \cos^2 x + f^2 \sin^2 x} \qquad (3)$$

We have now completed the investigation of the nature of the stress upon the section ab, except that we have still to determine the obliquity with which the force Q (compounded of R and S) acts upon ab. If F is greater than f, then Q will be more nearly parallel to F than R is; and the angle, y (see Fig. 9), included between the directions of Q and S, may be obtained from the relation

$$\tan y = \frac{R}{S} = \frac{F \cos^2 x + f \sin^2 x}{(F - f) \sin x \cos x} = \frac{F \cot x + f \tan x}{(F - f)}$$

Thus far we have been considering the case of a solid, unperforated plate. When, on the other hand, the plate is perforated by a straight row of equidistant holes, as in Fig. 10, the case becomes much more complicated, if we wish to obtain an absolutely correct solution of the problem. We can no longer assert, for example, that the tension is uniform, everywhere across the line of fracture; and in fact it certainly is *not* absolutely uniform on all parts of the ligaments between the holes, being somewhat less in the middle of each ligament than it is on the parts close to the holes. The difference is not accurately known, but there is reason for believing that it is not very great, and we may therefore follow the usual practice and assume the tension to be uniform throughout each ligament, relying upon a factor of safety to protect us from the results of our ignorance as to the *exact* distribution of the stress.

Making this assumption, the solution of the problem becomes simple; and in seeking it we will consider, first, the effective efficiency of the plate, so far as concerns the breakage of the ligaments between the holes. If D is the pitch of the holes, or the distance from the center of one hole to the center of the next one, and d is the diameter of a hole, then $D - d$ is the width of the ligament of metal between the holes, and the actual tensile stress on the ligament, per square inch of its cross-section, will be $DR \div (D - d)$, where R still represents the intensity of the tension in the unperforated plate, and perpendicular to the line of fracture, as calculated from equation (1). When the ligaments are on the point of failing, this expression must be equal to the tensile strength of the material, which we may represent by T. Hence, substituting for R its value from equation (1), we have, at the moment of failure,

$$\frac{D\,(F \cos^2 x + f \sin^2 x)}{D - d} = T \qquad (4)$$

Now if F is the tension in the solid shell in the *girthwise* direction, and f is the simultaneous tension in the *lengthwise* direction, then when equation (4) is fulfilled, the effective efficiency of the joint, with respect to the breakage of the plate along the line of the holes, is $F \div T$; this being the ratio, at the moment of failure, that the actual girthwise stress in the solid shell bears to the tensile strength of the material of the shell; — that is to the stress that might be exerted upon the shell before it ruptured, if it had no joint at all. Hence

$$\textit{Effective Efficiency} = \frac{F}{T} = \frac{D - d}{D} \times \left(\frac{1}{\cos^2 x + \frac{f}{F} \sin^2 x} \right) \qquad (5$$

But $(D - d) \div D$ is the "ordinary efficiency" of the plate along the row of holes; and hence the quantity in the parenthesis is the factor by which we must multiply the "ordinary efficiency," in order to obtain the "effective efficiency." If $f = 0$, then this factor reduces to $1 \div \cos^2 x$; and Column **D** of the table was computed from this expression. On the other hand if $f = \frac{1}{2} F$ (which is its maximum value, or its value when the heads are entirely unbraced), the factor in the parenthesis of (5) becomes equal to

$$\frac{1}{\cos^2 x + \frac{1}{2} \sin^2 x} = \frac{2}{1 + \cos^2 x}$$

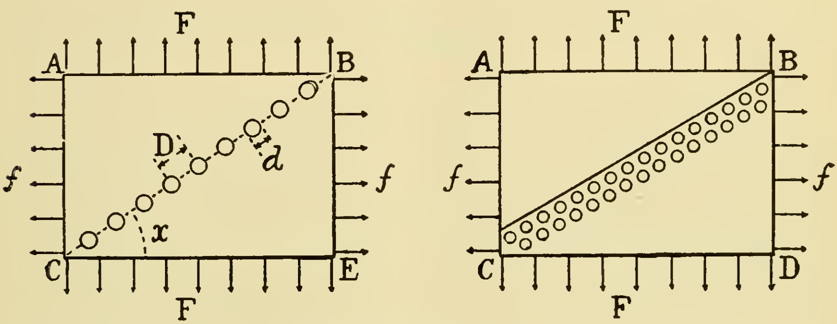
and from this expression Column **B** in the table was calculated.

We proceed, next, to consider the effective efficiency, with respect to the shear of the rivets, of a diagonal joint such as is represented in Fig. 11. In this case the force that has to be resisted by the rivets is the Q of equation (3); that is, it is the *total*, or *resultant* force upon each unit length of the joint. If T (as before) is the ultimate tensile strength of the solid plate, and E is the "ordinary efficiency" of the joint so far as rivet-failure is concerned, then the rivets will be on the point of shearing when Q becomes equal to ET. Let F (as before) be the girthwise stress in the solid plate at this moment. Then $F \div T$ is the "effective efficiency" of the joint so far as rivet-shear is concerned; and hence we have, by the aid of (3),

$$\textit{Effective Efficiency} = \frac{F}{T} = \frac{EF}{Q} = E \times \frac{1}{\sqrt{\cos^2 x + \left(\frac{f}{F}\right)^2 \sin^2 x}}$$

The quantity by which E is multiplied, in this equation, is the factor by which we must multiply the "ordinary efficiency" (*i. e.*, E), in order to obtain the "effective efficiency." If $f = 0$, this factor reduces to $1 \div \cos x$; and if $f = \frac{1}{2} F$, it may be shown to be equal to $2 \div \sqrt{1 + 3 \cos^2 x}$. It was from these expressions that Columns **E** and **C** of the table were calculated, respectively.

In comparing the results given in the present article with those given in the article on diagonal joints in The Locomotive for July, 1897, two things should be borne in mind. Firstly, the degree of obliquity of the joint is measured, in the present article, by the angle, x, included between the direction of the joint and a fore-and-aft line on the shell; so that the angle x, of the



Figs. 10 and 11. — A Perforated Plate and a Plate with a Joint.

present article, is the complement of the angle a, used in the earlier one. Secondly, in the earlier article we based the method of calculation upon the assumptions (1) that the heads of the shell are entirely unbraced, and (2) that the *total* force acting upon the joint, and here represented by Q, has to be withstood both by the rivets and by the ligaments between the rivet-holes. These assumptions were made in the interest of simplicity, and because the rule obtained by adopting them would always err (when it erred at all) on the side of safety. In the present article we have attempted to meet the demand for rules which shall be as accurate as possible in all cases; and this, of course, calls for much more detailed and extended treatment.

One account of explosion No. 203, on page 94 of this issue, says: "When the explosion took place, Mrs. Keelor was in her home near by, and saw the boiler go up into the air. The force of the explosion was so tremendous that Mrs. Keelor had telephoned notice of the explosion to her husband in Kane, and had hung up the receiver, before the main portion of the boiler came to earth. The descending pieces of iron broke the telephone wires." Admitting the truth of this report, and allowing thirty seconds as the total time required for the woman to appreciate what had happened, call up her husband, and transmit the message to him, it follows that the sheet that cut the telephone wires must have been thrown to a vertical height of some 3,600 feet. If the time were a full minute, the corresponding height would be about 14,400 feet.

The Locomotive.

A. D. Risteen, Ph.D., Editor.

HARTFORD, JULY 25, 1908.

The Locomotive *can be obtained free by calling at any of the company's agencies.*
Subscription price 50 cents per year when mailed from this office.
Bound volumes one dollar each.

Obituary.

William Heaford.

It is with profound regret that we record the death of William Heaford, who was for many years in the employ of the Hartford Steam Boiler Inspection and Insurance Company, in its Chicago department. Mr. Heaford was born in the village of Oakbrook, Derbyshire, England, on September 4, 1836, and died at his home in Chicago, on February 24, 1908.

When about eleven years old, he came to America with his parents, who settled at Albany, New York. He early developed a liking for the science of mechanics, served an apprenticeship in a machine shop, and at the age of twenty moved to Brooklyn. Shortly afterwards he was offered and accepted a position in his chosen business, which took him south. He remained there until the end of the Civil War, at which time he was much broken in health, having suffered greatly from malaria. His physician then advised him to return to the north, and he accordingly went to Chicago, where his brother, H. H. Heaford, resided. At this time the personnel of the Chicago department of the Hartford Steam Boiler Inspection and Insurance Company consisted in a general agent (then Mr. H. D. P. Bigelow), and an inspector named Hale. Mr. Hale being taken ill, at a time when certain inspections were urgently needed, Mr. Heaford undertook to do the work in his place; and while he had had no previous experience as an inspector, his general knowledge of mechanics and steam engineering served him in good stead, and his work on this temporary assignment was so eminently satisfactory that he was at once permanently employed as an inspector. He had been an honored member of the inspection staff from that time up to his death; and he also served as chief inspector for the department, from February, 1893, to March, 1897.

Boiler Explosions.

April, 1908.

(134.)— A boiler exploded, April 1, in Garmen & Emmons' shingle mill, Everett, Wash. A. O. Garmen, T. B. Ambuhl, James Hopkins, and Edward Olson were killed almost instantly, and Charles Larson died in the hospital, shortly afterwards. Peter Carlson was injured badly, but not fatally. The mill was wrecked.

(135.)—A tube ruptured, April 1, in a water-tube boiler at the Bath Portland Cement Co.'s plant, Bath, Pa. Fireman Paul Bolows was injured.

(136.)—The boiler of locomotive No. 628, on the Spartanburg branch of the Southern Railway, exploded, April 4, at Hillgirt, near Asheville, N. C. Engineer George Lauderback and fireman W. M. Kemp were killed. The locomotive was demolished.

(137.)—The boiler of a Big Four locomotive exploded, April 4, at Durbin, Ohio. Fireman G. W. Hickey was scalded so badly that he died a few days later.

(138.)—A digester exploded, April 4, at the plant of the Menominee & Marinette Paper Co., Menominee, Mich. One man was killed, and two others seriously injured.

(139.)—On April 5 several sections fractured in a cast-iron heating boiler, in the Hotel Woodcock, managed by W. P. Ruisseau & Son, Washington St., Boston, Mass.

(140.)—The boiler of locomotive No. 1668, of the New York Central railroad, exploded, April 7, on the Adirondack division, at White Rock cut, between Saranac Inn and Floodwood, N. Y. Five men were severely injured, and three others were injured less seriously. The explosion consisted in the failure of the crown sheet.

(141.)—A small boiler owned by Mr. R. D. Ross and formerly used in cooking food for stock, exploded, April 9, on Twelfth street, Columbus, Ga. Clyde Higgins was scalded.

(142.)—The boiler of locomotive No. 463 exploded, April 9, on the Naugatuck division of the New York, New Haven & Hartford railroad, at Wheeler's Farms, about three miles from Derby, Conn. Three men were injured, and the locomotive was wrecked.

(143.)—A slight boiler accident occurred April 10, in the Pacific Iron Works, Bridgeport, Conn.

(144.)—On April 12 a header fractured on an economizer in the power house of the Brooklyn Rapid Transit Co., Kent and Division avenues, Williamsburg, Brooklyn, N. Y. Thomas Milne and George Tieman were seriously injured. We are informed that the accident occurred while the men were tightening up nuts, under pressure.

(145.)—On April 13 a boiler exploded in J. M. Beal & Co.'s tile factory, Paw Paw, Ill. Frank Boyers was killed instantly, and Arthur Boyers was injured so badly that he died two hours later. Leslie Elliot, Lewis Burnett, and Earl Marks were also injured less seriously.

(146.)—A boiler exploded, April 13, in Peter Fraley's feed and sawmill, three miles south of Cape Vincent, N. Y. Christopher Fraley, a son of the owner, was the only person in the mill at the time. He was badly injured.

(147.)— An upright boiler exploded, April 13, at the Big Four pumping station, Grafton, Ohio. Engineer Stacy Diska was killed, and the pumping station was wrecked.

(148.)— A blowoff pipe failed, April 15, at the Southwestern Packing Co.'s plant, Sentous Station, near Los Angeles, Cal. Engineer A. G. Gum was severely scalded.

(149.)— A tube ruptured, April 15, in a water-tube boiler at the electric station of the Public Service Corporation of New Jersey, Paterson, N. J. Firemen John Serrapin and George Rockwell were scalded.

(150.)— A feed-water heater exploded, April 16, in the basement of the West End Hotel, St. Louis, Mo. Nobody was injured. The property loss was estimated at $5,000.

(151.)— A water-tube boiler exploded, April 16, at the blast furnace of the Ivanhoe Furnace Co., Ivanhoe, Va.

(152.)— On April 16 a boiler ruptured in the woolen mill of the Forest Mills Co., Bridgton, Me.

(153.)— A tube ruptured, April 17, in a water-tube boiler at the Columbia Ave. and Passaic street station of the Public Service Corporation of New Jersey, Passaic, N. J. Henry Dulmar and engineer John W. Stokes were fatally injured, the former dying within a few hours, while the latter lived a week after the explosion. Fireman John Serokary was also burned severely, but not fatally.

(154.)— A boiler exploded, April 17, in the R. J. & B. T. Camp Co.'s lumber mill, at Carrabelle, near Pensacola, Fla. Engineer William Roberts was killed, and Oscar Powers was badly and perhaps fatally injured. Several other persons also received lesser injuries. The property loss was estimated at $4,000.

(155.)— On April 19 a boiler exploded in J. N. Russell's ice manufactory, Tipton, Ind. Engineer Charles Covert was badly injured, and the building was destroyed, together with a large part of the machinery. The property loss was believed to be more than $12,000.

(156.)— A tube ruptured, April 19, in a water-tube boiler at the Remington Salt Co.'s plant, Ithaca, N. Y. James Williamson was injured.

(157.)— A tube ruptured, April 20, in the Edison Electric Light Co.'s power house, at the foot of Gold street, Brooklyn, N. Y. John Skinner, Michael Brennon, and George Ryan were seriously scalded, and it was thought that Ryan might not live.

(158.)— On April 25 a boiler accident occurred at the Leyden Coal Co.'s mine, Leyden, Colo.

(159.)— On April 26 a piece of tube blew out of a boiler at the plant of the Washington Light & Water Co., Washington, Ind.

(160.)—A boiler accident occurred, April 27, at the Washington Coal & Coke Co.'s plant, Star Junction, Pa.

(161.)—A boiler ruptured, April 28, in St. Mary's Training School, at Feehanville, Ill., a small place near Chicago.

(162.)—On April 28 a slight boiler accident occurred at the Cleveland Protestant Orphan Asylum, Cleveland, Ohio.

(163.)—A tube ruptured, April 28, in a water-tube boiler at the plant of The B. F. Goodrich Co., Akron, Ohio.

(164.)—A tube ruptured, April 29, in a boiler at the Crystal Ice Co.'s plant, Chattanooga, Tenn.

May, 1908.

(165.)—On May 2 a boiler exploded on Commander Benson's launch, at Annapolis, Md. Five persons were injured.

(166.)—A boiler exploded, May 2, in the fire department's engine house No. 4, New Haven, Conn. Lieutenant Frank Conlan was fatally injured, and died soon afterwards. John J. Falsey and James Mortell also received lesser injuries.

(167.)—On May 4 a steam pipe failed at the valve next to the boiler, in the plant of S. T. Alcus & Co., New Orleans, La.

(168.)—On May 5 a blowoff pipe failed at the Scott Logan Milling Co.'s flouring mill, Sheldon, Iowa.

(169.)—The boiler of a flying machine exploded, May 6, at Montclair, Colo., injuring engineer Leslie O. Parker. The outfit belonged to the Davidson Flying Machine Co., and the machine itself, of which a demonstration was soon to be given, was badly damaged.

(170.)—A tube ruptured, May 6, in a water-tube boiler at the Bloomfield and Fourteenth street station of the Public Service Corporation of New Jersey, Hoboken, N. J.

(171.)—A boiler used in drilling an artesian well exploded, May 7, on the Rocco Archero ranch, two miles east of Arvada, Colo. John Archero (a son of the owner of the ranch) was killed, and George Clepit, Thomas McCowan, and Charles Censtrom were seriously injured.

(172.)—A boiler exploded, May 9, on the steamer *Brockville*, of the Richelieu & Ontario Navigation Line, while she was at her dock at Toronto, Ont. Octave Cote and Adolphe Savegeau were killed instantly, and Bruneau Pintal, A. Gouin, and E. Charbonneau were badly injured.

(173.)—Two boilers exploded, May 9, in the sawmill of the W. C. Wood Lumber Co., at Collins, Miss. Morris Whitten and Monroe Hatton were instantly killed. The mill was also destroyed, and the property loss was estimated at $40,000.

(174.)—A slight boiler accident occurred, May 12, in the Shreveport Cottonwood Co's plant, Shreveport, La.

(175.)—On May 12 an accident occurred to a water-tube boiler at the Port Edwards Fibre Co.'s pulp mill, Port Edwards, Wis. Extensive repairs were required.

(176.)—A boiler ruptured, May 12, at the Camden Ice & Coal Co.'s plant, Camden, Ark.

(177.)—A boiler exploded, May 16, in William Boyington's sawmill, Pelham, Ga. James Cumbin was killed, and A. H. Davis and Dekle Miles were injured.

(178.)—On May 18 a portable locomotive boiler exploded at the Casparis Stone Co.'s plant, Lexington, S. C.

(179.)—A tube ruptured, May 18, in a water-tube boiler at the plant of the Nichols Copper Co., Laurel Hill, near Long Island City, N. Y. Joseph Crosplan was injured.

(180.)—A cast-iron heating boiler exploded, May 18, in the basement of Armour & Co.'s plant, on Commerce street, Norwich, Conn.

(181.)—The boiler of a traction engine exploded, May 19, near Bryant, Ind. Edward Bricker and James F. Arnold were severely injured, and Oliver Pyle and Sherman Pyle, brothers, were injured less seriously.

(182.)—On May 20 a boiler exploded in the flour and feed mill owned by The Phelps & Sibley Co., at Cuba, N. Y. The property loss was estimated at upwards of $10,000. Frank Boughton, who was passing the mill at the time, was injured by a flying brick.

(183.)—A boiler used for irrigation purposes exploded, May 20, near Elk Creek, Glenn county, Cal. Nathan Green was injured seriously and perhaps fatally, and Samuel Green and Harvey Province received lesser injuries.

(184.)—A boiler used in drilling for oil exploded, May 25, on the Bauer farm, just outside of Savonburg, Kans.

(185.)—A boiler exploded, May 30, on the steam launch *Bessie A.*, on the Delaware river, opposite Frankford, Pa. Frank Cassidy was killed, and Mrs. Nina Moreck was seriously injured. Several other persons also received lesser injuries.

(186.)—A boiler on a pumping boat owned by the Monongahela Consolidated Coal & Coke Co. exploded, May 30, on the Ohio river, two miles above Jeffersonville, Ind. Charles Humphrey and Frank Briggs were seriously and perhaps fatally injured.

JUNE, 1908.

(187.)—A blowoff pipe failed, June 1, in the American Hide & Leather Co.'s plant, Munising, Mich. Engineer Herbert Terwilliger was scalded.

(188.)—On June 3 a boiler exploded in a flouring mill owned by John Birth, Sr., at Knottsville, Ky. John Birth, Jr., was killed, and another man named Logsdon was fatally injured.

(189.)—A boiler used in drilling for oil, and belonging to Contractor Clay, exploded, June 3, in the Follansbee oil field, near Steubenville, Ohio.

(190.)—An 18-inch steam main failed, June 3, in the power plant of the National Cash Register Co., Dayton, Ohio. John Kissling, Elton Arment, and Joseph Miller were killed, and George Schroth, J. Hanson, and M. Gebhart were injured.

(191.)—A tube failed, June 5, in a water-tube boiler on the United States armored cruiser *Tennessee,* while she was steaming at a speed of 19 knots, off Point Hueneme, Cal. George Wood, E. C. Boggs, A. Rheinhold, and George W. Meek were killed, and S. S. Temattis, F. S. Maxfield, and J. A. Carroll were fatally injured. E. J. Burns, Walter S. Burns, R. W. Watson, R. E. Rutledge, C. M. Corns, and A. Hays were injured more or less seriously, but not fatally. The *Tennessee* was launched December 3, 1904.

(192.)—A blowoff pipe failed, June 6, in the saw and planing mill of the Edgewater Mill Co., Seattle, Wash. Fireman Louis Williambert was scalded.

(193.)—On or about June 8 a boiler tube burst on the steamer *Chicago,* of the French line, as she was nearing New York on her maiden trip from Havre, France. Nobody was injured.

(194.)—The boiler of a traction engine exploded, June 8, at Millersville, near Lancaster, Pa. John C. Herr was injured so badly that he died a few hours later. Frank Kilheffer, Abram Charles, and a young man named Eshbach were also injured to a lesser degree.

(195.)—A boiler exploded, June 9, in Wolf Bros' sawmill, in Hebron township, twelve miles from Cheboygan, Mich. Lee Clark, James Cooper, and John Mosser were slightly injured, and the mill was completely wrecked.

(196.)—A tube ruptured, June 9, in a water-tube boiler at the Reliance Works of the American Cement Co., Egypt, Pa.

(197.)—The Superior Malting Co's big grain elevator, known as Chicago Junction Elevator "H," and located at West Hammond, Ill., was destroyed by fire on June 10, and during the course of the fire one or more of the boilers in the elevator exploded.

(198.)—A boiler exploded, June 11, in the Queens Borough Gas & Electric Light Co.'s plant, at Far Rockaway, N. Y.

(199.)—A cast-iron header fractured, June 13, in a boiler in the Blair Milling Co.'s flouring mill and grain elevator, Atchison, Kans.

(200.)—On June 14 a boiler accident occurred in the Acme Ice Co's plant, Richmond, Mo.

(201.)—On June 16 an elevator exploded on a main steam pipe at the Trenton Rubber Manufacturing Co.'s plant, Trenton, N. J. Frank McGurk, a night watchman, was scalded.

(202.)—A boiler exploded, June 17, in G. H. Garrison's sawmill, in Rusk county, ten miles from Garrison, Tex. Fireman Esty Lewis was killed, and William Mayfield, Robert Brown, and one other man whose name we have not learned, were injured.

(203.)—On June 17 a boiler exploded in the Keelor Chemical Works, at Wetmore, near Kane, Pa. John Michaels was killed, and John Passenger was injured seriously and perhaps fatally. The property loss was probably between $10,000 and $15,000.

(204.)—On June 17 a slight accident occurred to a boiler in the South Dakota Insane Asylum, Yankton, S. D.

(205.)—An accident occurred, June 18, to a boiler in the Waccamaw Lumber Co.'s plant, Bolton, N. C.

(206.)—A boiler exploded, June 22, on an oil lease at Raven Rock, near Sistersville, W. Va. Albert P. Heckathorn was killed.

(207.)—The boiler of a Grand Trunk freight locomotive exploded, June 22, two miles east of Imlay City, Mich. Engineer Thomas Gibbs was instantly killed, and fireman William Brown was fatally scalded. Brakeman Douglas Smith was also terribly injured, though he may recover. The locomotive was destroyed.

(208.)—The boiler of a traction engine exploded, June 23, on East Second street, Sedalia, Mo. Walter Eicholz was injured severely, but not fatally.

(209.)—On June 23 a tube ruptured in a water-tube boiler in the electric lighting plant of the Durham Traction Co., Durham, N. C.

(210.)—The boiler of a locomotive exploded, June 23, on the Pennsylvania railroad, at Stelton, a flag station two miles east of New Brunswick, N. J. William Roberts, John Holman, and Robert Donnelly were killed, and the locomotive was completely wrecked.

(211.)—A tube failed, June 24, in a water-tube boiler on the Cook & Brown Lime Co.'s tug boat *Whitford,* at Oshkosh, Wis.

(212.)—A boiler exploded, June 25, on L. L. Wilson's timber tract, near Randolph, N. Y.

(213.)—A boiler owned by the Fuller Canneries Co., and used to operate a peaviner, exploded, June 25, at Cottage, near Forestville, N. Y. Charles Cottrell, William Van Slyke, and Glenn Remington were killed, and De Forest Benton, Myron W. Wilcox, and Rev. Elgin Howard were injured so badly that two of them, at least, will certainly die.

(214.)—The boiler of a donkey engine exploded, June 26, at Palmer, Ore. Engineer A. A. Smith was instantly killed.

Hartford Steam Boiler Inspection and Insurance Company.

ABSTRACT OF STATEMENT, JANUARY 1, 1908.

Capital Stock, . . . $1,000,000.00.

ASSETS.

	Par Value	Market Value.
Cash in office and in Bank, ...		$115,831.34
Premiums in course of collection (since Oct. 1, 1907),		203,819.78
Agents' cash balances, ...		9,846.14
Interest accrued on Mortgage Loans, . . .		26,224.54
Loaned on Bond and Mortgage, ...		1,041,950.00
Real Estate, ...		97,000.00
State of Massachusetts Bonds, ...	$100,000.00	88,000.00
County, City, and Town Bonds, ...	337,000.00	341,830.00
Board of Education and School District Bonds,	34,000.00	35,000.00
Railroad Bonds, ...	1,556,000.00	1,580,760.00
Street Railway Bonds, ...	55,000.00	51,900.00
Miscellaneous Bonds, ...	87,500.00	75,475.00
National Bank Stocks, ...	43,300.00	62,250.00
Railroad Stocks, ...	201,700.00	209,583.00
Miscellaneous Stocks, ...	165,600.00	120,725.00
	$2,580,100.00	
Total Assets, ...		$4,060,194.80

LIABILITIES.

Re-insurance Reserve, ...		$1,933,139.74
Commissions and brokerage, ...		40,763.95
State, County, and Municipal Taxes, due and accrued, ...		8,500.00
Losses unadjusted, ...		70,923.05
Surplus, ...	$1,006,868.06	
Capital Stock, ...	1,000,000.00	
Surplus as regards Policy-holders, .	**$2,006,868.06**	2,006,868.06
Total Liabilities, ...		$4,060,194.80

On December 31, 1907, the Hartford Steam Boiler Inspection and Insurance Company had 98,287 steam boilers under insurance.

L. B. BRAINERD, Pres. and Treas. FRANCIS B. ALLEN, Vice-President.
C. S. BLAKE, Secretary. L. F. MIDDLEBROOK, Asst. Sec.
A. S. Wickham, Superintendent of Agencies.
E. J. Murphy, M. E., Consulting Engineer.
F. M. Fitch, Auditor.

Board of Directors.

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GEORGE BURNHAM, Baldwin Locomotive Works, Philadelphia.
PHILIP CORBIN, Prest. American Hardware Corporation, New Britain, Conn.
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The Locomotive

PUBLISHED BY THE HARTFORD STEAM BOILER INSPECTION AND INSURANCE COMPANY.

Vol. XXVII. HARTFORD, CONN., OCTOBER, 1908. No. 4.

Concerning Solid Deposits in Steam Boilers.

In the operation of steam boilers of every kind, one of the commonest sources of trouble consists in the deposition of solid matter within them; the material so deposited being apt to result in serious damage to the boiler, unless proper care is taken. The deposit may consist, in large measure, of greasy matter which has been introduced with the feed water, mainly by reason of the cylinder oil from the engines getting into the water from open condensers or heaters; or it may take the form of a mud or sludge, composed principally of mineral matter, and merely tending to settle on the plates and

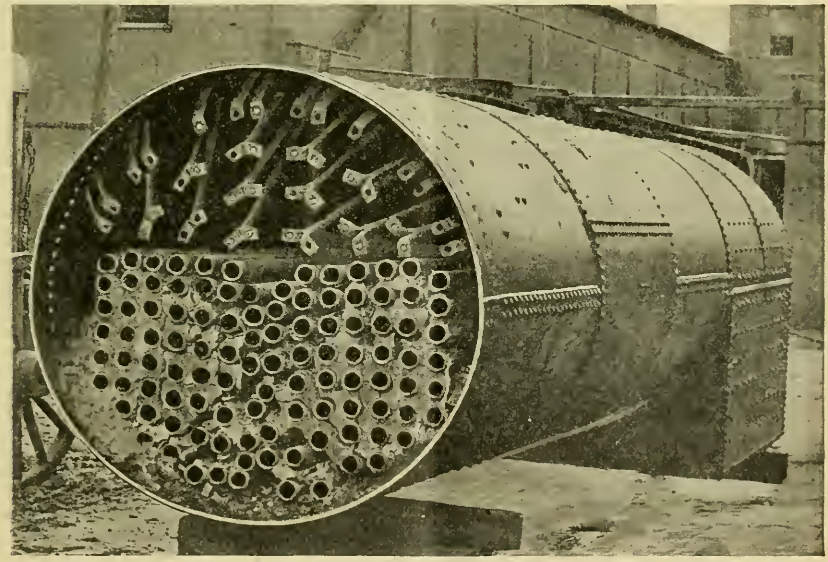

Fig. 1.—A Boiler badly coated with Scale.

tubes, without forming a compact mass, except when exposed to a high heat; or, finally, it may come down in the form of a more or less hard and stone-like mass, consisting chiefly of compounds of lime and magnesia.

Even in the case of mineral scale of a stone-like hardness, a portion of the solid matter consists, of course, of particles of mud, sand and clay, which were originally held in suspension in the feed water as it was introduced into the boiler, and which would then have been visible to the eye if the water had been examined in a clear glass bottle. Particles of this sort can be removed from the water, in large measure, by filtration, or by the use of large settling tanks; and such means are often useful and effective when the sediment held in suspension in the water is troublesome in amount. In most cases, however, the blowoff pipe of the boiler is relied upon, for the removal of sediment of this character.

A very large part of the scale that is formed in boilers, and which goes to make up the stone-like masses that are found in them, is composed, however, of matter that was present in the original water in the dissolved state; and this part could not have been removed by filtration or settling, nor could it have been seen by the eye, nor by the microscope, any more than we can see the salt that is present in the dissolved state, in clear sea-water. It is with the scale that is formed from this invisible, dissolved matter that we shall mainly deal in the present article.

Source of the Scale-Forming Material.

Rain water, falling upon the ground and sinking into it, percolates through the soil, and in doing so it comes in contact with mineral matters of many kinds, the particular kinds that predominate depending upon the locality. Now water can dissolve a great variety of mineral substances, and for this reason it has been called, somewhat inaccurately but most expressively, the "universal solvent." In its passage through the soil the water dissolves, to some extent, the minerals with which it comes in contact and it still retains them in solution when it is introduced into the boiler. In western New York the soil contains a great deal of limestone, and the underground water therefore carries a considerable quantity of lime in solution, and we find correspondingly heavy deposits of that substance in the boilers. On the other hand, there is a belt stretching across parts of Alabama, Georgia, Louisiana, and Texas, in which the underground water is alkaline to such an extent that it may even foam in the boiler. Here we find little or no sulphate of lime, and although there is a certain amount of carbonate of lime present, it gives but little trouble. The water which comes to the surface of the ground in springs, or which is collected in deep wells and brought to the surface by pumping or otherwise, has for the most part penetrated the earth to some depth, and has therefore had an opportunity to dissolve a considerable amount of mineral matter. This corresponds to the fact that the "hardest" water (that is, the water with the greatest amount of lime in solution) is usually met with in such springs or wells, or in brooks which are largely fed by springs.

Surface water, which has not penetrated into the ground, but which has run off into water-courses or into ponds soon after falling from the clouds, has rarely been in contact with the same variety and quantity of mineral matter as have the waters from wells and other subterranean sources, and hence it does not, in general, contain an equally large quantity of such mineral matter in solution. In its course over the ground, however, it takes up more or less organic matter, extracted from swamps, or from leaf-mold in the woods, or from mountain mosses, or simply from dead leaves and other decaying vegetation. Organic matter from such sources is usually corrosive in soft, non-alkaline waters, but it may be actually beneficial under other circumstances; for in our best waters, from pure sources carrying some organic matter, a varnish-like coating, consisting of compounds of low iron oxides with organic matter, soon covers the iron surfaces, and protects them very perfectly, sometimes for years. The water from streams and ponds rarely consists exclusively of surface water, however, but almost invariably contains, in addition, a certain proportion of water derived from springs, and containing, therefore, more or less mineral matter.

The Deposition of Dissolved Solids.

When water containing mineral matter in solution is introduced into a boiler, certain of the substances it contains may be thrown down in the solid form by the action of the heat, before any evaporation has taken place; but others will remain in solution until a good deal of the water has passed away as steam. When water is evaporated, volatile substances that may be present in it, such as air, or carbonic acid gas, or kerosene oil, pass away with the steam; but the non-volatile substances, such as lime and

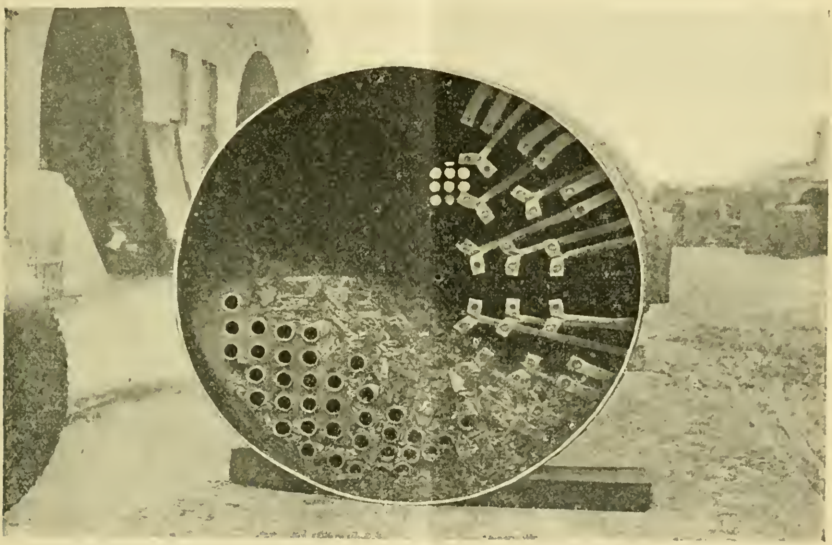

Fig. 2. — The same Boiler, with some of the Tubes Removed.

magnesia, remain behind in the boiler. As the evaporation proceeds, and more dissolved mineral matter is continually brought in with the feed, it is plain that the water in the boiler, unless blown off from time to time, will eventually attain a state in which it contains as much of some particular substance as it is capable of holding in solution. It is then said to be "saturated" with respect to this particular substance. If the evaporation proceeds yet further, then each pound of water that passes away as steam will leave behind it, in a solid and visible form, whatever it contained of the constituent with respect to which it was saturated; the remaining water being now unable to dissolve the matter so deposited, because it is itself carrying all of this particular substance that it can hold. And if the evaporation still continues, with more mineral matter being continuously introduced with the feed and none being removed by way of the blowoff pipe, the water will eventually become saturated with respect to a number of the constituents that it has in solution, and thereafter the deposit will be of a mixed nature, containing every substance with respect to which the water has become saturated, as well as those substances which may be thrown down in the solid form by the heat alone, irrespective of the process of evaporation.

Quantity of Deposit Formed.

A steam boiler evaporates an enormous quantity of water in the course of a year, and the total amount of solid matter deposited may therefore be very great, even if the original feed water contains but a few grains of it to the gallon. An evaporation of 1,500 pounds of water per hour, for example, is a moderate duty for an ordinary horizontal tubular boiler; and in a year of 300 working days, containing 10 hours each, this amounts to 4,500,000 pounds, or about 540,000 gallons. If each gallon of the feed water contains the moderate amount of 30 grains of dissolved mineral matter, the total deposition of solid matter in the course of the year (assuming that the blowoff is not opened, and that the boiler is not cleaned in any way, and also neglecting the relatively small amount of solids still in solution in the boiler at the end of the year) will be 16,200,000 grains, or 2,314 pounds. That is, under the conditions here assumed, the boiler, at the end of the year, would contain more than a ton of deposited solid matter.

Of course a boiler could hardly hold such a quantity of deposit as this, without being practically destroyed by overheating; but we have seen many boilers containing hundreds of pounds of deposit which had accumulated in this manner by neglect, and we fear that there is many a boiler now in use, whose condition approaches the condition here indicated, more nearly than one would believe to be possible. In Figs. 1 and 2, for example, we show a boiler of the locomotive type, which was scaled so badly that the head of the boiler had to be removed in order to get at the deposit and clean it out. (These two illustrations originally appeared in the August, 1908, issue of the *Boiler Maker;* and we are indebted to that journal, and to Mr. H. J. Hartley, for permission to reproduce them.)

Loss of Efficiency from Scale.

There can be no doubt but that the efficiency of a boiler is lowered to some extent by the presence of scale upon the heating surfaces; but it is hard to say just what the loss of efficiency will be, under given conditions, for the subject is much more complicated than it appears to be at the first glance. The loss depends, doubtless, upon the thickness of the scale, but it also depends in very large measure upon the physical and chemical nature of the matter constituting the scale. Moreover, we must not forget that the amount of heat transmitted through one square foot of heating surface depends not only upon the conductivity of the surface (which is undoubtedly reduced by the presence of a layer of mineral deposit), but also upon the difference in temperature between the two sides of the surface. In a boiler coated with scale, the very presence of the scale will cause the plate to become much hotter on the fire side than it would be if it were clean; so that the scale, while lessening one of the factors (namely, the conductivity) upon which the transmission of heat depends, simultaneously increases the other factor. It is by no means easy to say, in any given case, to what extent the effect of diminishing one of these factors will be counteracted by increasing the other one.

We must remember, too, that a boiler is never uniformly coated with scale in all its parts. The absorption of heat might be much impeded, locally, by a deposit of scale, without the efficiency of the boiler as a whole suffering to any great extent. Indeed, a lessening of the absorption of heat in one part of a boiler will tend to increase the absorption in other parts, over which the gases of combustion have yet to pass. For example, if the shell of a horizontal tubular boiler is coated with scale, toward the back end, sufficiently to greatly reduce the absorption of heat at that place, the gases entering the tubes will be hotter than they would have been if the absorption through the shell had been more perfect; and hence the transmission of heat through the walls of the tubes will be greater than it would have been if the boiler had been clean throughout. The compensation thus brought about will be only partial, if the boiler is designed so as not to have any great excess of heating surface when it is clean and free from scale; but, even though only partial, it will nevertheless be real, and it will reduce, in a measure, the loss of efficiency that would otherwise be brought about by the diminished absorption through the scale-coated part of the shell.

In general, we may say that the loss of efficiency from the presence of scale has been overestimated by many writers in the past. Experience indicates that the presence of a layer of scale of ordinary composition, and of a thickness of an eighth of an inch or so, does not require the expenditure of any very great excess of fuel, over and above what the same boiler would require when clean. The most definite figures are sometimes given in the books, however, to prove that the contrary is the case. For example, the author of a certain standard reference book on steam engineering says: "More fuel is required to heat water in an incrusted boiler than in the same boiler if clean. A scale 1/16 in. thick will require the extra expenditure of 15 per cent. more fuel; this ratio increases as the scale thickens. Thus, when it is ¼ in. thick, 60 per cent. more fuel is needed; ½ in. thick, 150 per cent., and so on." These figures, or others closely similar, have been widely quoted in publications relating to steam engineering; but they can hardly be justified by appeal to experience, nor, so far as we are aware, can they be justified by appeal to any experimental results that have been obtained under conditions approximating at all closely to the conditions that prevail in practice.

Mr. Albert A. Cary (*Engineering Magazine*, Vol. 13, June, 1897, page 424) says that the estimates just quoted are supposed to have originated with Professor J. G. Rogers of Madison, Ind. "It is barely possible," says Mr. Cary, "that he may have obtained the first two figures by experiment with a certain kind of boiler scale, but such figures are very seldom obtained in boiler practice. In fact, I have found scale in boilers one inch thick, where no great difference has been noticed in the amount of fuel used. The scale was merely a very light and porous carbonate of lime, through which water and steam had very little difficulty in passing." Mr. Cary cautions his readers, however, against supposing that inch-thick scale would, in general, produce so little difference in economy; and he says he cites the case just mentioned, to show that there is a wide difference in the effects produced by scales of differing compositions.

In the issue of THE LOCOMOTIVE for July, 1892, we gave the results of two tests made by an inspector of this company upon the same boiler, and under conditions almost identical except that in the first case the boiler had been in constant use, day and night, for four weeks, without cleaning or change of water, while in the second case the boiler had been run only one day since being cleaned and washed. In the first trial the boiler evaporated 9.09 pounds of water, from and at 212° Fahr., per pound of combustible, while in the second trial (that is, after the boiler had been thoroughly cleaned) the corresponding evaporative performance was 10.0 pounds. Cleaning, therefore, increased the efficiency by just ten per cent. We have no data at hand as to the condition of the plates and tubes at the first trial. They were not extreme in any respect, however, and the difference of ten per cent. may be taken as indicating, in a rough way, the order of the effect that an ordinary, average condition of scale and soot has upon the evaporative efficiency of a steam boiler.

DAMAGE TO BOILERS FROM SCALE.

Although scale is objectionable on account of the real though uncertain reduction in efficiency that it causes, it is far more objectionable on account of the serious damage to the boiler that an undue accumulation of it is almost certain to bring about. As is well known, the water within a steam boiler cannot be heated to a temperature higher than that corresponding to the pressure of the steam. For example, the temperature of saturated steam having a gage pressure of 200 pounds per square inch is approximately 388° Fahr.; and hence the water in a boiler cannot be heated above this temperature of 388°, without running the pressure up higher than 200 pounds per square inch. Now it is found by experience that when a boiler plate is clean, so that the water comes into good contact with the actual metal, the cooling effect of the water is so pronounced that we cannot heat the plate (unless it is far thicker than an ordinary boiler plate) to a temperature much above the temperature of the water with which it is in contact. Even with a pressure of 200 pounds, therefore, the temperature of the boiler plate, if it is clean and in contact with water, will not materially exceed 388° Fahr. — a temperature which wrought iron and steel can sustain without the slightest impairment.

Now if the boiler is coated with a hard, stony scale, or with a deposit of any kind which prevents the water from touching the plate, or coming very near to it, then it will be evident that the plate, being in large measure deprived of the cooling influence of the water, will be heated by the hot gases to which it is exposed, to a temperature materially higher than the temperature of the water within the boiler. The extent to which this overheating will occur will depend, of course, upon the thickness of the scale, upon its porosity (a porous scale permitting of the passage of more or less water and steam), and upon the conducting power of the scale for heat. A deposit consisting largely of greasy matter does not permit of the passage of water to the plate, and such deposits are, moreover, poor conductors of heat; so that we find, in practice, that greasy deposits are peculiarly apt to bring about serious overheating of the metal, although they are in themselves often quite soft and sludge-like.

The overheating due to scale or other forms of deposit may manifest itself in various ways. Thus the plate may become oxidized, or "burned," so as to lose its strength and crack open; or the heating may result in the actual softening of the material, so that its strength is reduced to such a point that the pressure of the steam in the boiler can blow it out into a bulge, or "bag." Overheating also manifests itself by bringing about the loosening of the joints between the parts of which the boiler is composed. For example, scale accumulating around the rear head of a boiler is apt to lead, through the consequent overheating, to the loosening of the tubes in the head; and the head itself may even become loosened from the shell, by reason of the overheating of the riveted joint by which the two are attached.

A Boiler Explosion Due to Accumulated Scale.

Boiler explosions are not infrequently due, either directly or indirectly, to the presence of scale; but it often happens that the boiler is so torn to pieces that the fact that scale was the cause of the explosion is not immediately evident to the eye. In the issue of The Locomotive for July, 1902, however, we illustrated an explosion that was so manifestly due to the accumulation of scale around the ends of the tubes, that we reproduce one of the engravings herewith. (See Fig. 3.) This boiler was situated in a Texas salt refining plant employing some 160 men, and one man was killed and three others were injured. The shell was uninjured, save for a few indentations, but both heads were bulged to the extent of about 5½ inches. The rear ends of the tubes, which were coated with scale ⅜ in. in thick-

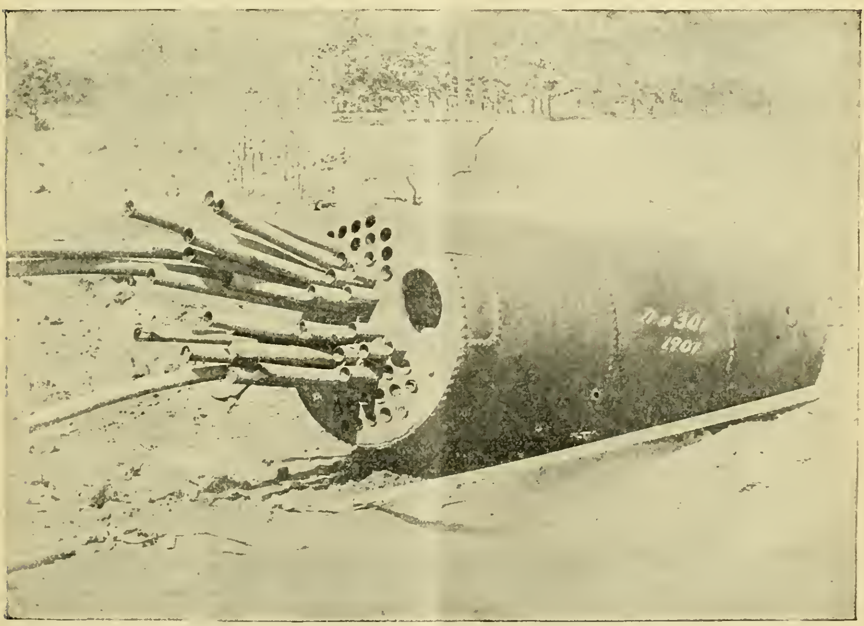

Fig. 3. — A Boiler that Exploded from Accumulated Scale.

ness in some places, pulled out of the head, and the reaction from the rush of water and steam out of the tube holes caused the entire boiler to be projected to a horizontal distance of 173 feet. Condensed water was used for feeding the boiler, but the "make-up" water that was required to supply the place of the waste was taken from a well, and contained considerable mineral matter. Evidently the explosion was brought about as follows: The tube ends became thinned from wear, and the scale that formed around them, and against the rear head, caused overheating so that the holding power of the tubes was destroyed. The stress that was thus thrown upon the braces caused them to rupture, and the head bulged outward, the tubes being thereby drawn from their holes; and the rest of the observed results followed as natural consequences. The safety-valve of the boiler was found to be in good working order, after the explosion. The property loss was upwards of $5,000, and it would have been far greater than this, save for the fact that the boiler, in its flight, took the most fortunate direction possible, eventually landing in a vacant lot.

The Common Constituents of Scale.

The commonest constituents of the mineral scale that we are mainly considering in the present article are (1) carbonate of lime, (2) sulphate of lime, (3) carbonate of magnesia, (4) magnesia *i. e.*, magnesium oxide, (5) chloride of magnesia, (6) salt, (7) oxides of iron, (8) organic matter of one kind or another, (9) silica (either by itself, or in combination with other substances), and (10) alumina, or clayey material. Most of these are present in the water in the dissolved form; but some of the silica and alumina, and a varying proportion of the iron and organic matter, occur in the form of a visible precipitate, or sediment.

Carbonate of lime, as deposited in the boiler, is chemically the same thing as ordinary "limestone." It seldom produces, by itself, a scale which is of a true stone-like hardness. It may collect in large masses, and do serious injury to the boiler; but the deposits that it forms are usually much lighter and more porous than the corresponding deposits of sulphate of lime, and they can be cleaned out of the boiler far more readily, by mechanical means, and often by mere washing with a hose. A considerable part of the carbonate of lime that is deposited in the boiler can also be removed by the frequent and systematic use of the blowoff pipe, as explained in a subsequent paragraph. Clay, organic matter, and iron compounds, when present in considerable amount, will sometimes form with the otherwise loose deposit of lime carbonate a hard and obstinate scale; but this action can be largely prevented by blowing off the lime carbonate frequently, and thereby preventing its accumulation.

The simple lime carbonate, as it exists in limestone, and in the solid deposits in steam boilers, is only slightly soluble in pure water. Natural waters, however, nearly always contain more or less dissolved carbonic acid gas; and a water which contains this gas can dissolve a far larger quantity of limestone, which then goes into solution in the form of a double carbonate, or "bicarbonate." This action explains the observed fact that carbonate of lime is almost insoluble in boiling water, while in a cold, "natural" water it dissolves in amounts that are relatively far greater. If water containing bicarbonate of lime in solution is heated, a portion of the carbonic acid gas that it contains begins to be given off at about 180° Fahr., a corresponding portion of the bicarbonate being simultaneously reduced to the form of limestone (or *mono*carbonate of lime); and this, being far less soluble, is precipitated in the form of small solid particles, floating through the water. As the temperature of the water is increased, this action becomes more and more pronounced, and at 212° Fahr. a large part of the lime carbonate is precipitated in this manner. The precipitation is not complete, however, until a temperature of 290° Fahr. (corresponding to a gage pressure of about 43 pounds) has been attained.

In view of the facts here set forth, it is easy to understand the way in which carbonate of lime is thrown down in a boiler. When the feed water (which we will suppose to be originally cold) is pumped into the boiler, the carbonate of lime that it contains is precipitated in the form of small floating solid particles, as the temperature of the feed (in the feed pipe or in the boiler proper) rises from 180° Fahr. to 290° Fahr. The particles so deposited may adhere to the inner surface of the feed pipe, near the end, or they may collect at the end of the pipe, externally, so as to obstruct the flow of water to some extent; but for the most part they will mingle with the water in the boiler, and be whirled about with it as it circulates. Then, when the boiler has been allowed to stand quiescent for a time, they will settle into a kind of muddy deposit, which will eventually bake upon the sheets, heads, and tubes, in the form of a more or less porous scale, unless it is removed by opening up the boiler and washing it out, or by using the blowoff pipe as elsewhere explained. The character of the scale that is formed will be modified, of course, by the other substances that may be present; some of these substances, as already mentioned, tending to cement the carbonate scale into a hard mass.

Sulphate of lime, as deposited in the boiler, is chemically the same thing as the mineral "gypsum," or (when its water of crystallization has been removed by exposure to a considerable heat) the mineral "anhydrite." The solubility of sulphate of lime in water does not depend at all upon the presence of carbonic acid gas, but it is affected to a considerable extent by the presence of other mineral substances, such as salt. We read in the books that calcium sulphate is most freely soluble in water at 95° Fahr., and that at higher temperatures the solubility diminishes, until, at temperatures above 300° Fahr. (that is, under gage pressures of 52 pounds or more), it is practically insoluble. Experience with steam boilers shows, however, that this is not always the case; and there can be little doubt that the difference between experiment and experience, in this instance, depends upon the fact that the experiments by which the solubility was determined were made with nothing present in the water but pure lime sulphate, while in the actual case we have many other substances present also, some of which tend to make the sulphate notably more soluble.

Sulphate of lime forms a hard, adherent coating upon the boiler, which often resembles natural stone so closely as to be readily confused with it. This deposit is not porous, and it not only effectively prevents the water from coming in contact with the metal of the boiler, but it is also, in itself, a poor conductor of heat. It is apparent, therefore, that a sulphate of lime scale is far more apt to bring about the injury of the boiler than a scale of the same thickness composed of carbonate of lime.

The magnesia minerals form deposits which are mostly light and porous, and they do not injure the boiler like a coating of sulphate of lime. An exception must be noted in the case of chloride of magnesia, however, as this substance sometimes gives rise to corrosion of the plates. Under the influence of heat the magnesia chloride either decomposes with the liberation of free hydrochloric acid, or else (as Ost maintains) it combines directly with iron oxide formed by the action of the water upon the iron of the boiler. The precise way in which the thing occurs is of interest only to the chemist; but the outcome is that the boiler is corroded with the formation of chloride of iron, while the magnesia chloride is simultaneously reduced to the hydrate or oxide. The corrosive action of magnesia chloride appears to be lessened, or altogether prevented, by the presence of carbonate of lime; these substances combining with the formation of calcium chloride, magnesia, and carbonic acid gas. Ost estimates that if the scale contains one-fourth as much lime carbonate as it does of magnesia chloride, the corrosive action of the chloride will be entirely prevented. Sea-water contains much magnesia chloride, but only a trace of carbonate of lime; and hence it is in marine boilers, or boilers used near the sea-shore, that the corrosive effects of the magnesia chloride are mainly observed.

Choice of Boiler Waters.

If a water supply is known to be bad, so far as its use as feed water is concerned, it is best to reject it altogether, and make arrangements to use a supply of a different character, even though this course involves some considerable expense. We often find boiler owners using a poor water because they can obtain it from a well, when a far better supply might be had from the town or city mains by the payment of a water tax. An apparent economy of this sort is often quite illusory.

Let us consider, for example, a hypothetical case, where the choice lies between a pure, soft town water, which costs 18 cents a thousand gallons, and a well water which is free so far as the payment of any rate is concerned, but which contains a good deal of lime, so that the attendant has to blow out about three inches of water every day, and has to clean the boiler out every three weeks. It will be reasonable to assume that the boiler evaporates 2,200 pounds of water per hour; and at this rate 396,000 pounds will be evaporated in three weeks, each containing six working days of ten hours each. In other words, the quantity of water evaporated in the three weeks would be 47,520 gallons; and at 18 cents a thousand gallons, this would cost $8.55.

We may next consider the cost of running with well water of the character assumed above. We may here assume that two pounds of soda ash will have to be used per day (as explained later in this article), in order to prevent damage from the scale, and that 18 pounds are put into the boiler at the beginning of the three weeks' run, upon starting up with fresh water. The total consumption of soda ash will therefore amount to, say, 54 pounds; and at five cents a pound this would cost $2.70. (Five cents a pound would be high, if the soda ash were bought in quantity; but it would not be excessive, in many parts of the country, when the amount purchased at any one time is small.)

At the end of the three weeks the boiler is opened and cleaned, and this involves several items of expense. For example, it will usually be necessary to renew the gaskets; and we may fairly estimate the expense of these to be $1.25. In the absence of any agreement to the contrary, it will probably be necessary to pay the engineer for eight hours of over-time work; and as he will need some help, this item may be safely estimated at $3.00. Then there will be a considerable loss of heat involved in blowing down the boiler, and cooling off the setting. In the issue of The Locomotive for May, 1893, an estimate is made of the quantity of heat lost in this manner, for a boiler such as we are here considering; and it is there shown that the loss, including that due to blowing off three inches of water every day for three weeks, would amount to about $2.10, with coal at $4.50 a ton.

Again, if well water is used, we have to raise it from the well by means of a pump, and then force it into the boiler against the steam pressure. For a case such as we are here discussing, the expense of the pumping required in the case of the well water, over and above that required in the case of town water, may be taken at 22 cents, for a run of three weeks. (See The Locomotive for July, 1893, page 103.) Finally, the efficiency of the boiler would be reduced to some extent by the presence of the scale formed from the well water; and while this loss would vary widely according to the exact facts of the case, it will suffice for our present illustrative purposes to base our estimate of it upon the result obtained by one of our inspectors (and quoted in an earlier paragraph of this article) in comparing the efficiency of a certain boiler, when foul, with that observed in the same boiler when clean. In a four weeks' run, the efficiency of that boiler fell off ten per cent.; and if the diminution of efficiency is assumed to be proportional to the time the boiler had been in service, this would mean that the *average* loss of efficiency, over the whole period, could be taken as five per cent. Lest we may appear to have an undue prejudice against well water, we shall assume that only two-fifths of this loss was due to the scale in the boiler, assigning the remaining three-fifths to the presence of soot in the flues. On this basis, therefore, we have to allow a loss, in the present example, of two per cent. of the total fuel bill, as due to the presence of scale from the well water. If the boiler evaporates eight pounds of water per pound of coal, and coal costs $4.50 per ton, the total cost of the fuel for the three weeks would be $111.37; and two per cent. of this sum is $2.22, which is therefore the loss due to the lowering of the efficiency, by the scale.

Summing up the results herein given for well water, and comparing them with the cost of running with town water, the comparison is as follows:

(1.) — Running with the Well Water.

Cost of scale solvent, ...	$2.70
" " gaskets, ...	1.25
" " labor, ...	3.00
" " the heat lost by blowing off and cooling, ...	2.10
" " pumping water (excess over town water expense), .	0.22
" " fuel lost by lessened efficiency, ...	2.22
Total cost of well water, for three weeks, . . .	$11.49

(2.) — Running with Town Water.

Cost of 47,520 gallons of water, ... $8.55

These figures show that it would be cheaper to use town water than well water, under the assumed conditions. Whether this would hold true or not in other cases can only be told after discussing the new conditions in the same manner. Thus town water is not always as soft as is here assumed, and in any case we should have to allow for an occasional cleaning out of the boiler when running with the town water. Town water, in fact, is selected primarily with respect to its fitness for drinking purposes, and this means, as a usual thing, that it is nearly free from organic matter. Hardness is, of course, an important element to consider in its selection, but healthfulness is so much more important that a relatively hard water is sometimes selected for a town supply, rather than one that would be better for boilers, but not so safe for drinking. On the other hand, there are expenses connected with the use of well water which have not been included in the comparative estimate given above. A water depositing considerable scale will necessitate more frequent repairs to the boiler; but as it is almost impossible to estimate this element of cost fairly, it has not been included above. Again, if a suitable well is not available, the expense of sinking one may have to be considered; and it is often necessary to sink several (driven wells, let us say), in order to obtain a sufficient supply. This may cost as much as $700 or $1,000, according to the locality; and the interest on this outlay may amount to from $40 to $50 per annum. Furthermore, if the plant contains only a single boiler, it may be necessary to provide a tank of some kind, to fill the boiler after it has been put out of use; and this may cost $150 or $200. Enough has been said, we feel assured, to show that in selecting a water for use in boilers a town supply should not be rejected merely because a water-tax must be paid for its use.

Treatment of Feed Water Externally to the Boiler.

When it is not feasible to reject a water that is found to be troublesome, it becomes necessary to determine what is the best course to pursue, in order that the trouble may be reduced as much as practicable. The ideal plan would be to purify the water before introducing it into the boiler, so that the scale-forming matter might not be introduced into the boiler at all. This is practicable when treating water on the grand scale, as in handling a town supply; but under other circumstances we have to be content with filters, settling tanks, and feed water heaters. A filter or a settling tank will remove from the water the greater part of the solid matter that may be present in the form of visible particles, but neither of these devices will remove the dissolved matter, unless this matter has been previously precipitated by heat or otherwise.

Various forms of heaters may be had, for removing a considerable part of the carbonate of lime from the feed water, before the water is passed into the boiler. In the so-called "open heaters," the water is heated in a closed tank by bringing it in direct contact with exhaust steam from the engines, the water being sprayed into the steam, or caused to flow through an atmosphere of steam in the form of thin sheets or jets. In this way the temperature of the water may be raised nearly or quite up to 212° Fahr., if the supply of steam is sufficient, without causing any serious back pressure upon the engines. As we have previously said, the carbonate of lime is thrown down, in large measure, at this temperature, and a considerable part of the carbonate of magnesia is also precipitated at the same time. The particles of solid matter that are thus formed float about in the water at first; but settling chambers, or basins, are provided, in which the water is allowed to stand for a time in a more or less quiescent state, and here the sediment that has been formed by the heat gradually subsides in the form of a muddy deposit, which may be drawn off from time to time, while the clarified water above it is pumped into the boiler.

The "open heater," just described, is effective so far as the removal of a considerable part of the lime carbonate is concerned; but the exhaust steam from the engines brings with it more or less cylinder oil, and this, mingling with the water, is introduced into the boiler, where it sometimes gives rise to trouble more serious than that due to the carbonate scale whose formation it is the province of the heater to prevent; the pasty sludges that are formed in the boiler by mixtures of oil and sediment often giving rise to serious overheating and damage. We do not mean to say that open heaters *always* give trouble in this way, but it cannot be denied that they often do, even when the exhaust steam is passed through an oil separator before being admitted to the heater.

With a view to excluding the oil from the engines, the preliminary heating of the feed water is often carried out in "closed heaters." In these the steam is passed through coils of pipes, which are submerged in the water to be heated, so that the desired temperature is communicated to the water without permitting the water and steam to actually mingle. The same end is also attained, in other forms, by passing the water through coils of pipe, which are themselves surrounded by steam. Closed heaters are harder to keep clean than open heaters are, and their first cost is also greater.

Scale Solvents and Preventives.

We come, now, to the consideration of the substances that may be introduced into the boiler, either to prevent the formation of scale, or to ensure that such scale as may be formed shall be readily removable from the boiler, and shall not be likely to give rise to overheating.

Of first importance among the substances that are used as "solvents" is the material that is commercially known as "soda ash." Chemically, soda ash is crude carbonate of soda (Na_2CO_3). "Washing soda" has this same composition and the two are identical, except that washing soda is often sold in the crystallized form, containing 63 per cent. of water. The name "soda ash" is derived from the fact that the substance was formerly made, largely or altogether, by lixiviating (or leaching) the black mass, or ash, obtained by burning a mixture of coal, carbonate of lime, and sulphate of soda. The soda ash of commerce was quite impure until recently, containing a considerable percentage of other substances, including caustic soda, common salt, and dirt and other inert materials; and the impurities were often sufficient to give the product a decidedly brownish color. Now, however, the processes of manufacture have been improved to such an extent that American soda ash is perfectly white, and contains as much as 98 or 99 per cent. of pure sodium carbonate. The soda ash that is imported chiefly from England is less pure than the American product, and contains, as a rule, something like ten per cent. of caustic soda, which adds to its value as a scale preventive. The English soda ash cannot be conveniently obtained in this country, however, except in the northeastern part; and hence, when the greater activity that is due to the presence of the caustic soda is desired, we often recommend buying the American soda ash and adding to it about one-tenth of its weight of crude caustic soda. We shall refer to this point further, below.

Caustic soda would be an effective substance to use for the treatment of boiler waters, except that it would be expensive if used to do the entire work, and in addition it is bad stuff to handle, and when used in any considerable quantity it is liable to attack gaskets and pump packings, and to cause leakage at fittings.

Sumac extract, bark extract, catechu, and other substances containing considerable quantities of tannin, are often used in the treatment of boiler waters. The tannin precipitates the lime compounds in a form in which they may be more easily removed from the boiler, and it also throws down soluble iron compounds in the form of an inky mass, which has little power of cementing the scale together. Some authorities hold that tannin tends to corrode the iron of a boiler to an objectionable degree, while others hold either that this fear is groundless or that the effect is greatly exaggerated. (On this point, see THE LOCOMOTIVE for February, 1891, page 28.) In our own practice we sometimes recommend tannin-bearing substances; but as a rule we prefer the use of soda ash.

Sal ammoniac (chloride of ammonia) has often been enthusiastically recommended as a scale preventive, and in theory its action is ideal. With the troublesome and highly insoluble sulphate of lime, for example, sal ammoniac forms chloride of calcium and sulphate of ammonia, both of which are exceedingly soluble, so that they would pass away through the blowoff pipe, without forming any solid deposit at all. The trouble with sal ammoniac is, that it exerts a corrosive action on the iron of the boiler — a fact which is well illustrated in the use of a mixture of sal ammoniac and iron filings for making "rust joints," through the readiness with which the iron is oxidized and caused to set into a hard, cement-like mass.

Alum is sometimes used in treating the water supplies of cities or towns, but it is out of the question for use in boilers, for reasons similar to those given above, in connection with sal ammoniac.

Tri-sodium phosphate works very nicely with most boiler waters, and it is entirely unobjectionable except as regards expense. The cost of effectively treating a troublesome boiler water with this substance is materially greater than that involved in the use of soda ash.

ACTION OF SODA ASH IN THE BOILER.

Soda ash, being alkaline, at once neutralizes all free acid substances in the boiler. This property alone renders it valuable in many cases where, without it, the presence of free acid would cause serious corrosion. It is of great value, too, in preventing the formation of the troublesome lime sulphate scale; for carbonate of soda (soda ash) and sulphate of lime act upon each other so as to produce sulphate of soda and carbonate of lime. The sulphate of soda thus produced (and known in commerce as Glauber's salt) is very soluble in water, and passes away through the blowoff pipe; while the carbonate of lime which is formed at the same time can be removed by the blowoff in large measure, and even when it lodges on the boiler in the form of scale, it is far less detrimental to the boiler than the sulphate scale, as has been explained already. With chloride of magnesia, too, soda ash combines to form common salt and carbonate of magnesia; the carbonate of magnesia being relatively unobjectionable, while the common salt (in the quantity in which it is formed by this reaction) is not only non-injurious, but is even advantageous to a certain extent, as it renders the sulphate of lime more soluble, and thereby diminishes the formation of sulphate scale.

The use of soda ash in a boiler water is often recommended even when the scale-forming matter that is present consists mainly of lime carbonate; for while, in this case, there is probably no chemical action that can be expressed by an equation, yet it is found that the carbonate deposit that is formed when soda ash is present is less compact, and more easily washed out, than when the soda ash is absent.

Dissolving the Soda Ash.

Soda ash, which is to be used for the treatment of scale, should first be dissolved in water, and then be passed into the boiler by means of a pump or injector. The solution may be conveniently effected in an iron tank, or in a good wooden cask, a quantity of the soda ash sufficient for a week or two being dissolved at one time. The amount of soda ash to be used depends upon the character of the water, and upon the quantity of it that is used, per day, in addition to such as may be returned from condensers and heating devices, in the form of water of condensation. In making up the solution, the soda ash may be placed in the tank first, or the water may be introduced first, and the soda ash thrown in afterwards. A rough rule for dissolving the ash, which will be found good for most cases, consists in adding one pound of soda ash for every gallon of water that the dissolving tank contains. As a still rougher rule, for use when the plant contains only one or two boilers, we may add a pailful of soda ash to a cask of water. To facilitate the dissolving of the ash, the water may be warmed by blowing steam into the cask or tank; solution taking place far more readily in warm water than in cold. In most cases the American soda ash, used alone, will be found quite sufficient to take care of the scale satisfactorily, if it is used regularly, and in sufficient quantity; but when the water is very bad, or when, for any reason, it is found that soda ash alone does not give satisfactory results, a quantity of crude caustic soda, equal in weight to about one-tenth of the quantity of soda ash that has been dissolved, may also be added to the solution.

All attendants must remember, however, that caustic soda is a powerful chemical, entirely different from soda ash. It exercises a solvent action on the skin, and for that reason it is likely to produce bad sores if handled with the bare hands. Especial care must be taken to prevent any of the caustic from getting into the *eyes* of the attendants; and it is well to have a bottle of vinegar handy, for use in a contingency of this sort. In case any of the caustic should happen to be introduced into somebody's eye, the eye shoould be held open while someone dashes water into it copiously, until the caustic has been well washed out. The eye should then be washed out thoroughly with a solution of one part of vinegar to three of water, to neutralize the caustic that remains; and after this a solution of borax in water will be found to be a soothing wash. If any of the caustic is swallowed, several mouthfuls of the weakened vinegar should be swallowed after it.

Caustic soda will absorb moisture from the air very rapidly, being thereby converted into a wet, slushy mass, or even entirely dissolved. For this reason it should be kept tightly covered, except for the few brief moments when the containing vessel must be opened to remove some of it. The caustic is not rendered less effective by the absorption of moisture, but it becomes far less convenient to handle.

Introducing the Solvent into the Boiler.

The soda ash having been dissolved in the tank or cask, we shall next consider the means that may be most conveniently employed for introducing the solution into the boiler, as it is wanted. In some plants the soda ash is introduced only upon starting up again, after the boiler has been shut down for cleaning; a large quantity of the solvent being then introduced, in the expectation that it will take care of the boiler until the next periodical cleaning is due. This method of using a solvent is unwise, for the original charge will be entirely blown out of the boiler long before the time for introducing the next one comes.

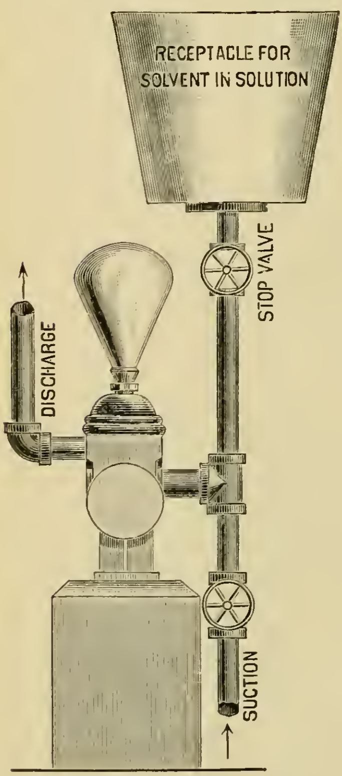

Fig. 4.—Simple Arrangement for introducing Solvents.

Some years ago The Locomotive illustrated the methods of introducing solvents that are suggested in Figs. 4, 5, and 6; and these have been widely employed, mostly with satisfaction. Explanation of these engravings is hardly necessary, as they are sufficiently plain in themselves. In Fig. 4 a tee is inserted in the suction pipe of the pump, and from this a vertical pipe rises to any convenient height. This pipe is provided with a stop valve, and carries at its upper end a receptacle for the solution that is to be passed into the boiler. If the pump is drawing its supply from a lower level than the solvent receptacle, the only thing necessary to do, when it is desired to introduce some solvent, is to open the valve in the pipe connecting the receptacle to the pump, and the solvent will be passed into the boiler in a very few strokes. If, on the contrary, the pump is drawing its supply from some source which exerts more or less pressure, the stop valve in the main suction pipe must be closed while the connection to the solvent receptacle is open, as otherwise the solution will be driven out of the receptacle into the room, instead of being forced into the boiler.

Although the foregoing arrangement is both simple and effective, it may sometimes be inconvenient to make the attachment, owing to the location of the pump. Fig. 5 shows a modification which is useful under such circumstances. In this arrangement a tee is to be placed in the suction pipe, near its connection with the pump, and two stop valves are to be provided, as shown, one being on the suction pipe a little below the tee, and the other in the extension of the tee itself. On the end of the tee connection a hose is attached, which runs to a pail or tub containing the solution. The way

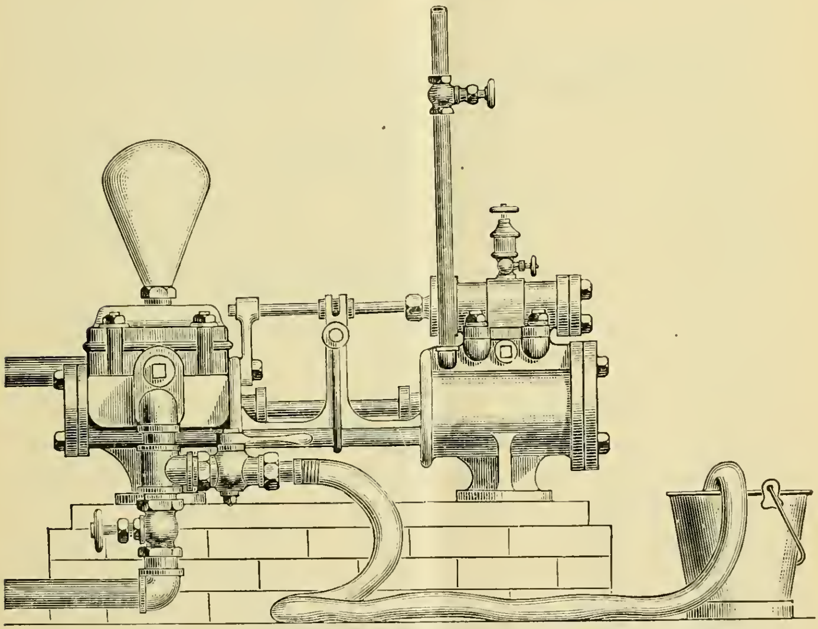

Fig. 5.—Another Simple Arrangement for Introducing Solvents.

in which the apparatus is to be used is evident. Fig. 6 shows a similar arrangement, for use in connection with an injector.

The methods shown above ordinarily work well in practice, and they have the merit of simplicity. We have had occasional complaints, however, to the effect that the soda ash, when passed through the pump, eats out the packing thereof. This would hardly be likely to occur with a new packing, but with an old one, which had become impregnated with oil or grease, the soda ash might easily have such an effect, particularly when used in connection with caustic soda. To assist those who may have had trouble of this sort, we show, in Fig. 7, another plan for introducing the dissolved solvent, by which it is forced into the boiler without passing through the pump at all. This arrangement, which was first shown in

The Locomotive for September, 1901, calls for more piping than the others, and its only advantage is that it saves the pump.

Referring to the illustration, *A* is a section of big pipe — say 6 inches in diameter and 30 inches long — which is to serve as a reservoir. This connects with the feed pipe running from the pump to the boiler, by means of the pipes *B, C,* and *F,* which are so arranged that they connect with the feed pipe on opposite sides of the stop valve *D.* Over the reservoir is a funnel, *K,* by means of which the reservoir, *A,* can be filled through the valve *H.* The reservoir, *A,* is provided with pet-cocks, *a* and *b,* at the top

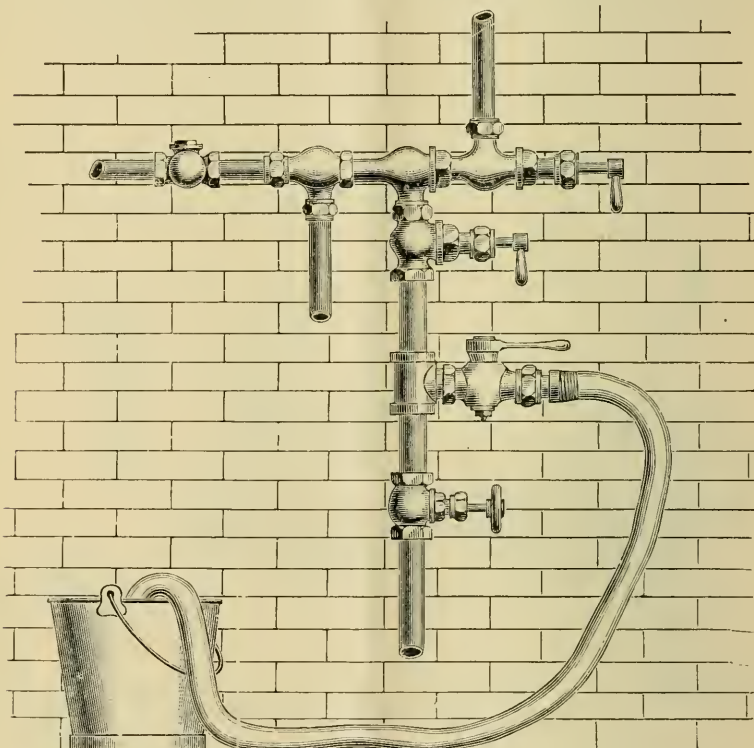

Fig 6.—Arrangement for Introducing Solvents with an Injector.

and bottom, so that it may be readily filled and emptied. A union is provided at *C,* to facilitate the assembling of the piping. (A right-and-left elbow, of course, may be used instead, if it is preferred.)

The device is used as follows: The reservoir *A* being empty, valves *E* and *F,* and pet-cock *b,* are first closed, and valve *H* and pet-cock *a* are opened. The soda ash solution is then poured into *K,* until the reservoir *A* is filled. The valve *H* and the pet-cock *a* are next closed, as well as the valve *D,* in the main pipe. Valves *E* and *F* are then opened, and the pump is started. The device is now in the condition shown in the engraving, and the water from the pump passes around through *B, C,* and *A,* as shown by the arrows, sweeping the contents of *A* out into the boiler.

When the pump has been run long enough to thoroughly remove all soda ash from *A*, valve *D* may be opened, and valves *E* and *F* closed. The reservoir *A* is then emptied by opening the pet-cock *b* and either pet-cock *a* or valve *H*, and the device is again ready for operation.

Quantity of Soda Ash Required.

On this point it is manifestly impossible to give any general directions that will be found satisfactory in all places. Every plant must determine for itself the proper quantity to use to keep the boilers in satisfactory condition, and this can best be done by trial. For the benefit of those who have had little or no experience in the use of scale preventives, however, we shall make a few suggestions, with the explicit understanding that these suggestions are intended only for the guidance of an attendant who would otherwise be at a loss to know how much soda ash to begin with, and that the quantities here mentioned are to be modified according to the experience that follows upon their tentative use.

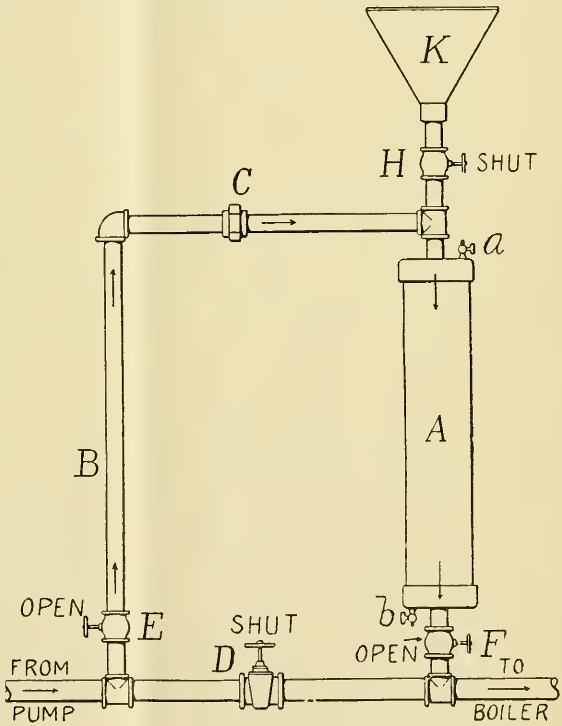

Fig. 7. — Arrangement for Introducing Solvents without Passing them through the Pump.

A horizontal tubular boiler, 72 inches in diameter and with tubes 18 feet long, will contain, under ordinary conditions, about 18,000 pounds of water; and when worked at full capacity, such a boiler, if well designed and well set, will evaporate over 30,000 pounds of water, per day of ten hours. When filling such a boiler up with fresh water, after cleaning it out, it is a good plan to introduce about ten pounds of the soda ash at the start, and thereafter to introduce two or three pounds a day, by means of one of the forms of apparatus shown and described above. If the soda ash is dissolved in the proportion of one pound of the ash to each gallon of solution, this will correspond to the introduction of ten gallons of the solution, when the boiler is first filled up, and two or three gallons a day thereafter. If the water is bad, and deposits an unusual amount of scale, the quantity of solvent may be increased from this provisional estimate; and if, on the contrary, it is unusually soft and pure, a corresponding reduction of the quantity herein indicated would be called for, at the very outset.

Manipulation of the Blowoff Pipe.

A considerable fraction of the solid matter deposited by the feed water may be removed from the boiler by frequent and judicious use of the blowoff; for much of it remains in suspension in the water for a considerable time after it has been precipitated in the solid form, being whirled about with the circulation currents in the boiler, before settling upon the plates and becoming baked on in the form of scale. In fact, if the circulation in the boiler is good (as it always ought to be in a well-designed boiler), the precipitated particles do not usually settle until the draft of steam is stopped for some reason — as, for instance, in shutting down at night, or in banking the fires for the noon hour. After the boiler has stood quietly for an hour or so, the sediment that has formed as the result of the evaporation, and in consequence of the rise in temperature of the freshly-introduced feed water, will have settled to a large extent, mainly towards the back end of the boiler, where the circulation is least active. The best time to open the blow for the purpose of removing sediment is therefore just before starting up the fires at 1 o'clock, or after the boiler has stood idle for an hour or so at night, or before beginning work in the morning. In any one of these cases, however, the blow should be opened before the fire has been touched in any way; for the circulation of the water in the boiler will be immediately established to some extent as soon as the fires are brightened in the least degree; and this means that more or less of the sediment that has already settled will be picked up again and whirled about, so that the opening of the blowoff pipe will not remove as much of it as would be removed if everything was perfectly quiescent. Some of the sediment will have settled in the blowoff pipe itself, and hence a proper care of the blowoff requires that it be opened occasionally, even apart from the desirability of removing deposits from the shell of the boiler.

In blowing down for the purpose of removing deposit from the boiler, the blow should be opened wide for a few moments, until the level of the water in the boiler has been reduced by an inch or more. This establishes a current in the water along the bottom of the boiler, and especially near the back end of the shell, where the deposit has mainly settled; and the result is that a considerable quantity of the sediment will be swept out of the boiler, the blowoff pipe being itself thoroughly cleaned out at the same time.

The importance of opening the blowoff valve periodically in this way is hard to impress upon the mind of the average boiler attendant, who is too apt to regard the blowoff as nothing but a sort of drain pipe, which he is to use only when he wants to run the water all off and empty the boiler completely. The frequency with which the blow should be opened depends upon the nature of the water that is used, and upon the amount of evaporative duty that is required of the boiler. All blowoff pipes should be opened at least once in every twenty-four hours, however, in order to ensure that they are themselves free and clean; and they should be opened twice or three times a day when the water is bad and the boiler is working up to its full capacity.

In opening a blowoff valve, or closing it, it is extremely important not to do either too suddenly. This word of caution appears to be necessary, because it is not at all uncommon to see a fireman open the cock with a yank, and close it again with another yank. This practice is exceedingly dangerous. No valve about a steam system should be opened or closed suddenly, except in time of great emergency; because stresses that are thrown suddenly upon the boiler or its attachments are much more destructive than those that come on gradually. It is particularly dangerous to *close* the blowoff valve suddenly, because the stresses that are produced in this way are far greater than a person who had not given thought to the matter would suppose. The importance of closing a blowoff valve slowly will be appreciated by those who are familiar with the hydraulic ram, which is an apparatus in which the extra pressure resulting from the sudden stoppage of a current of water is put to practical use and made to raise a part of the volume of the water to a height perhaps twenty times as great as the supply head. We have given a calculation, in the issue of The Locomotive for April, 1901, by which it appears that the sudden closing of a blowoff pipe when it is discharging a full stream under boiler pressure may give rise to stresses in the blowoff pipe which are comparable with the strength of the metal of which the pipe is made; and in the same issue we illustrated an accident in which the threads of a blowoff pipe were stripped by a too sudden closing of the cock, with the result that the fireman was scalded to death. Such accidents are by no means uncommon; and if they are to be avoided with certainty, it is necessary to open and close the blowoff cock slowly, so that each of these operations consumes several seconds, at least.

Opening and Cleaning the Boiler.

Every boiler should be opened and cleaned out periodically, although no general rule can be given as to the frequency with which this should be done. When the water is bad, and deposits a considerable quantity of scale, the cleaning will evidently have to be performed far oftener than would suffice if the water were soft and pure. In some parts of the country, where the water is exceedingly soft, it is unnecessary to open the boilers and clean them oftener than once every four months or so, except in the springtime when (in our northern latitudes) the surface water consists largely of melted snow, or when the feed water has temporarily become unusually soft for any other reason, as from the prevalence of heavy rains or freshets. (The reasons for opening up the boiler oftener under such circumstances are given in a subsequent section of this article, under the heading "Natural Variations in Feed Water.") When using water that normally contains a large amount of scale-forming matter, it may be necessary to open the boiler and clean it out every week. Between these limits, the attendant will have to learn for himself how often the cleaning will be necessary; but it should always be remembered that it is safer to clean too often than to err on the other side, and not clean often enough.

In removing the water from a boiler preparatory to cleaning, care should be taken to let the boiler and the setting cool down well, before blowing off. A pressure of four or five pounds is quite sufficient for emptying the boiler. If the water is blown off under a considerable pressure, and before the setting has cooled down materially, the heat that is radiated from the brickwork to the boiler after the water has all run off is likely to cause the deposit to bake into a hard mass, which can be removed only by honest work; whereas if the setting and the boiler are both well cooled off before blowing, it will often be possible to wash out a considerable part of the deposit by means of a hose. In washing out boilers that have manholes under the tubes, we find that the attendants often introduce the hose merely from the under side of the tubes. This does not clean the boiler as effectively as washing from the top, since deposits of mud and fragments of scale often lodge upon the upper sides of the tubes, where they cannot be reached from below.

Even when the scale that forms in a boiler does not produce damaging results as it lies against the boiler in its original position, it may easily do so when it has been loosened up by mechanical means, or by the action of solvents or of kerosene oil (the use of which is presently to be mentioned), or by the temporary use of a water that is softer than usual; for then the scale is liable to flake off and settle upon the bottom of the shell, there forming piles which prevent the water from coming into contact with the sheets, almost as effectively as though the scale were originally deposited on the fire sheets in great thickness.

After emptying a boiler and opening it up, any piles of scale that may be present should be removed, and the mud and unattached sediment should be washed out by the use of the hose. The attendant should then go over the boiler, in every part, and clean out all of the adherent scale. Rapping the shell and tubes with a light hammer will often detach large quantities of it, but it is often necessary to go at it with a chisel also. A light iron bar, several feet long, and provided with a chisel-like end, is useful for removing the scale from places not readily accessible. After the scale has been cleaned out as thoroughly as possible, a final washing may be given to the shell, tubes, and heads.

Removal of Scale from Badly Scaled Boilers by "Boiling Out."

When the accumulation of scale in a boiler is very bad, as in the case illustrated in Figs. 1 and 2, it is often useless to try to remove it without taking out the tubes of the boiler or one of the heads. When, however, there is merely a bad deposit, but not enough to apparently call for such radical measures, it is often useful to "boil out" the boiler with soda ash. To do this it is well, in the first place, to empty the boiler and take out as much of the scale as can be removed without great labor. After this, the boiler may be filled up with fresh water to a level two or three inches above the usual water level. A considerable quantity of soda ash, running up to fifty pounds, or even more in the worst cases, is then to be added to the water. A slow fire should next be started under the boiler, and maintained for three or four days. The boiler had better be left "open" while this is done; but if the manhole has been replaced, care must be taken to maintain just enough fire to keep the water in the boiler boiling.

This treatment will often result in detaching large quantities of the scale, so that when the "boiling out" is completed, and the boiler is emptied, loose piles of the scale will be found upon the bottom sheets. Much more can also be readily flaked off from the tubes and plates. We wish to insist strongly upon the exercise of care in applying this "boiling out" method, to see that the heat is always a *very gentle* one; for otherwise the boiler will be almost certainly burned, on account of the accumulation of the detached scale on the fire sheets.

After a boiler has been treated in this way, and then well cleaned and put in service again, it is well to open it up before the usual time for so doing comes around once more; for some of the scale still remaining in the boiler will in all probability be more or less affected by the "boiling out," so that, even though it did not detach itself at the time the boiler was emptied and cleaned, it may come down in unusual amount after the boiler has been in service for a short time.

Use of Oil in Scale Treatment.

Crude petroleum and the products obtained from it have been successfully employed for removing scale from steam boilers. Unlike most other substances used for this purpose, the oil does not act chemically. It does not dissolve nor destroy the scale, but it modifies the form in which new scale matter is deposited, and causes old scale to flake off copiously, and fall to the bottom of the shell. Hence the cleaning of the boiler should be attended to with especial care when oil is used.

Crude petroleum is sometimes called "rock oil," and sometimes "well oil." It varies considerably in composition, and the lighter oils are best adapted for use in boilers, since the heavier kinds, when used in the crude state, contain asphalt and other objectionable substances in considerable amounts. When crude petroleum is used for the prevention or removal of scale, it is of the highest importance that it should be pure "well oil"; for oil sometimes passes under the name of crude oil when it really consists of well oil mixed with tallow or some other similar grease, to give it a heavy "body," for lubricating purposes. The introduction of tallow, or similar grease, would be likely to ruin the boiler; for, as we have already explained in a previous section, a grease of this character forms a sludge with sediment and fragments of loose scale, and brings about serious overheating. The lighter oils, having a density of from 38° to 46° Baumé are the best adapted, of the crude oils, for use as scale preventives. So-called "crude oil" often consists, too, either wholly or in part, of oil that has been partially distilled; and in such cases the sulphuric acid that is used in the treatment is not always neutralized, and may give rise to corrosion in the boiler. For these reasons we strongly recommend the use of kerosene instead of crude oil; for kerosene is nearly or quite as effective, and it does not form a sludge on the heating surfaces, nor is it corrosive.

In using crude petroleum or kerosene as a scale preventive, it is usual to introduce the oil into the boiler by means of an automatic sight-feed device, similar to those that are used for lubricating engine cylinders, since this method of introduction enables the attendant to gage the amount supplied, very nicely. Numerous devices for this purpose are advertised in the trade papers. A good form of feeder was shown in the *American Machinist* some years ago, and a modified form of it is illustrated in Fig. 8. *A* is a piece of 4-inch pipe, which is capped at the top and bottom. *C* is a gage glass, which shows the quantity of kerosene in the reservoir. *B* is a funnel by means of which the reservoir, *A,* is filled. *D* is a sight-feed for regulating the flow of oil; the oil rising, drop by drop, into the feed pipe, which passes along just above. The "condensing chamber" consists of a length of (say) two-inch pipe, which is connected with the steam space of the boiler. Steam condenses in the "condensing chamber," and the water of condensation gives a static head of water, the pressure of which causes the oil in *A* to pass out through the sight feed, *D*; the flow of the condensed water into *A* being regulated by means of the small valve *E*. As the apparatus is practically balanced, so far as the direct boiler pressure is concerned, it is necessary for the "condensing chamber" to stand *above* the level of the water in the boiler, in order to get the static head required for the delivery of the oil. The upper nipple on the left, which is marked "solid," is filled with a lead plug, since its only purpose is to unite *D* rigidly to the reservoir *A*.

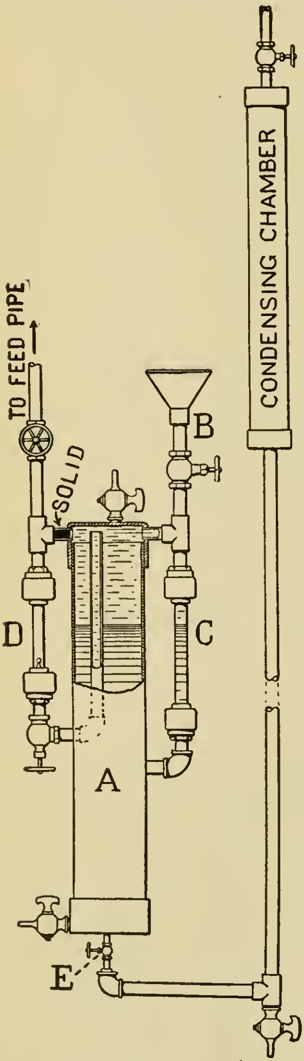

FIG. 8.—SIGHT-FEED APPARATUS FOR INTRODUCING KEROSENE.

To fill the reservoir *A* with kerosene, we close the valve *E*, and also the one in the pipe leading to the feed pipe. Then we open the two pet cocks at the top and bottom of *A*. When the water in *A* has run off, we close the lower pet cock, and then fill the reservoir with kerosene by means of the funnel *B*. The reservoir *A* being full, and all the air being expelled from it, we close the upper pet cock, and also the valve just below *B*; and the apparatus is ready for work again.

Some difficulty will be found in packing the glass gages tightly enough to prevent the escape of oil. The plan recommended by Mr. Dutcher in the *American Machinist* is a very good one. He proposes a solid rubber washer, about an inch long, and made to fit the glass on the inside, and the reducer on the outside.

The action of kerosene in preventing or checking the formation of scale, when it is used in the way here described, appears to consist in the formation, around each particle of the solid matter, as it is precipitated in the boiler, of a thin skin or pellicle of oil; the presence of these oily films tending to prevent the particles of sediment from cohering into a solid mass.

When oil is to be used for the removal of scale that has already formed in the boiler, the procedure should be as follows: The boiler is first thoroughly dried out, so as to remove all moisture from the scale. This is accomplished by opening the manhole and handholes, as soon as the boiler is blown down. When the boiler has cooled sufficiently for examination and cleaning, the scale will have become dry. (The drying out is important, because oil will not penetrate wet scale.) All sediment and loose scale should then be brushed out, and kerosene oil sprayed over the plates and tubes, so as to saturate the scale thoroughly. The oil which accumulates in the bottom of the boiler will rise on the surface of the water when the boiler is filled, and be brought in contact with such parts of the tubes as may not be reached by the direct spray.

Oil so applied will penetrate the scale and work its way in between the scale and the iron, and the old scale will soon begin to flake off. It is highly important, therefore, to open up the boiler in a week or so, and clean it out thoroughly; for otherwise the loose deposit that falls upon the fire sheets will cause them to burn, as we have several times explained.

Open lights must not be used around a boiler when it is being treated with kerosene; and when kerosene or any other inflammable substance has been used in a boiler in any quantity, care should always be taken, in opening the boiler up next time, to ventilate it thoroughly before bringing an open light near the manhole. We have before us, as we write, accounts of two accidents that were due to the neglect of this precaution, one man being fatally burned in each case. In both instances kerosene had been used for cleaning the boiler, and the vapors subsequently exploded through contact with an open light. An incandescent electric lamp is the best thing to use in such work.

Kerosene is useful, not only for removing old scale, but also for removing lubricating oils that may have found their way into the boiler from the engines or pumps. Mineral lubricating oils cannot be entirely removed by washing, nor will they saponify so as to leave the plates clean, even when the boiler is "boiled out" with soda ash. But if the engineer, in such cases, will clean the fire sheets by wiping them with a mop dipped in kerosene, he will find that the lubricating oils will readily dissolve. Water-tube boilers may be freed from oil in a similar manner, by mopping out their tubes with kerosene; and the oil may be removed from parts that are inaccessible to the mop by saturating them with kerosene and repeating the operation several times.

Natural Variations in Feed Water.

The character of a given feed water will often vary to an important degree with the season and with the amount of the rainfall; and a failure to bear this fact in mind often results in serious trouble from scale, and even in the burning of the boilers. This year, for example, the rainfall has been unusually light in many parts of the country, and our inspectors report that there has been an uncommon amount of scale in the regions so affected. The reason for this is not hard to find. The actual supply of water that is used in a boiler consists, almost invariably, of a mixture of surface water and of ground water. That is, some portions of it have probably been down to a considerable depth and have been in contact with lime rocks and magnesia rocks for a considerable time; while other parts have not percolated through the ground very far, or, perhaps, have not been below its surface at all. The degree of "hardness" of a given water (and hence the amount of scale that it will form) will therefore depend to a large extent upon the *proportion* in which the water from the deeper regions of the ground, and that from the surface or from the superficial layers of the soil, are mingled. Now it is evident that this proportion will vary a great deal with the amount of the rainfall; for in a wet season the surface water is especially abundant, and hence the boiler supply is softer than usual; while in a dry season like the present one the superficial layers of the ground are dried out so thoroughly that the supply consists almost entirely of water which has come from the deeper regions, bringing with it a quantity of dissolved mineral matter which tends to make the feed "harder" than usual.

The lessons to be learned from these very simple considerations are two in number. In the first place, we see that in a dry time the formation of scale is likely to go on more rapidly than usual, so that it is important to open the boilers and clean them (or at least examine them) with a correspondingly greater frequency. It is hard to say just *how much* oftener they should be opened, but it is safe to say that they should be opened at least *twice* as often as usual; a boiler that is ordinarily cleaned once a month being opened up, in a dry time, every fortnight.

Such is the first lesson, and the second is like unto it. It is almost impossible to keep a boiler *perfectly* free from scale, when using a hard water; and hence it must be expected that a considerable quantity of scale will remain lodged in the boiler, so long as the water remains hard, despite the most conscientious efforts of the attendants to keep it out. When a heavy fall of rain comes, however, so that there is once more an abundance of surface water, the feed water will suddenly become far softer. It will then tend to redissolve the scale; and this tendency will manifest itself by loosening up the scale that has accumulated in the boiler and causing it to flake off and fall down upon the fire sheets, causing the sheets to bulge or burn in a short time. It is surprising how quickly a soft feed water will sometimes loosen up old scale in this way. "Snow broth," or the water from melting snow, is peculiarly active in this respect, since it has hardly been in contact with any minerals at all, and is therefore the softest kind of water that is commonly obtainable in any considerable quantity. In the spring, in our northern latitudes, the melting of the snows should therefore be watched carefully; for a boiler carrying any considerable amount of scale should not be allowed, at that time, to go more than a week or two without opening and cleaning; and boilers that are run even with the purest waters should not be left unopened for longer than a month.

Leakage from Pure Water and from Solvents.

It is common, after an old scale has been peeled off by solvents, or by oil, or after it has flaked off by the use of a water much purer than that from which the scale was originally formed, to be told that the oil, or the solvent, or the purer water, has made the boiler leak. It is true that leakage often does occur under these conditions; but such leakage is not due to any detrimental action of the solvent or other remedial agent. The real damage was done to the boiler by the scale, through overheating and consequent starting of the joints. While the scale was still lodged upon the tubes and sheets the leaky places had not betrayed themselves, because they were stopped up by the scale; and when the scale is removed, the damage that had been previously done merely manifests itself.

The Locomotive.

A. D. Risteen, Ph.D., Editor.

HARTFORD, OCTOBER 25, 1908.

The Locomotive *can be obtained free by calling at any of the company's agencies.*
Subscription price 50 cents per year when mailed from this office.
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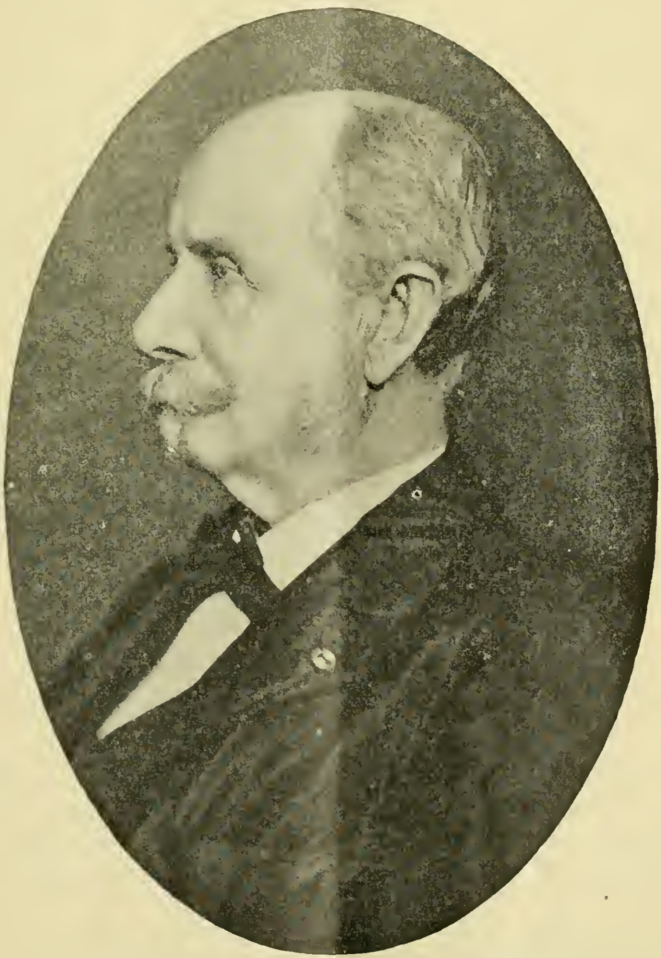

Colonel Curtiss Crane Gardiner.

Obituary.

Curtiss Crane Gardiner.

It is with deep regret that we announce the death of Colonel Curtiss Crane Gardiner, who was for many years manager of our St. Louis department.

Colonel Gardiner was born at Eaton, Madison county, New York, on December 1, 1822. In 1861 he enlisted in the Union army upon President Lincoln's first call for volunteers, being then a resident of Angelica, New York. He took part in many engagements during 1861 and 1862, until he was severely wounded by a shell in the battle of Gaines Mills, June 27, 1862. He remained with his regiment during several subsequent engagements, but was soon forced to apply for leave of absence; and on July 24, 1862, he resigned his commission, and was honorably discharged from the service for disability arising from wounds received in action. On May 22, 1865, he was brevetted Lieutenant Colonel and Colonel U. S. Volunteers, for "gallant and meritorious services during the war."

Colonel Gardiner became connected with the Hartford Steam Boiler Inspection and Insurance Company early in 1873, and continued as General Agent of its Southwestern Department, with headquarters at St. Louis, until November 1, 1900, when, owing to his advancing years, he resigned the active management of the office, and was succeeded by his son, Mr. Curtiss Crane Gardiner, Jr., who is now the manager of the New York department of this company. His death occurred, at the age of 86, on September 4, 1908, at his temporary home at Santa Barbara, California.

Colonel Gardiner was married in 1862 to Mary P. Thurston, daughter of the late Judge Ariel Standish Thurston, of Elmira, New York; and his wife and three children survive him.

It is impossible to give adequate recognition to the services that Colonel Gardiner rendered to the Hartford Steam Boiler Inspection and Insurance Company, for they covered a period of twenty-seven years, the early part of which was filled with difficulties that younger employees can hardly comprehend. He was a pioneer in an untried field; but he overcame every obstacle, and few men have done as much as he to establish the business of steam boiler insurance upon a sound foundation.

Boiler Explosions.

July, 1908.

(215.) — A boiler exploded, July 3, in John M. Miller's big orchard, near Gerrardstown, W. Va. Harry Mason was killed, and Calvin Crimm was injured.

(216.) — On July 4 a boiler exploded in the Stomps-Burkhardt Co.'s factory, at Dayton, Ohio. Engineer Ambrose Baker was severely injured.

(217.) — A boiler exploded, July 6, at the colliery of Beddow & McCreary, at Primrose, near Pottsville, Pa. George Beddow, one of the owners, was scalded so badly that he died a few hours later. Joseph Smith was also injured, and the boiler house was wrecked.

(218.) — A boiler flue burst, July 7, on the U. S. monitor *Nevada*, while she was on the practice grounds, near New London, Conn. Three of her firemen were scalded — one, Thomas J. Caulley, so badly that he may die.

(219.) — On July 7 a boiler exploded at the plant of the Monongahela City Water Co.'s plant, Monongahela, Pa. Engineer William McGrew was killed, and Mrs. Anna Solosky, W. Sloan, and one other person were injured. The property loss was approximately $6,000.

(220.) — A boiler exploded, July 10, in the machine shop of J. A. Cross, at Fultonville, Montgomery county, N. Y. Engineer Charles Settemeyer was injured so badly that he died a few days later.

(221.) — The boiler of a Hocking Valley freight locomotive exploded, July 12, at Powell station, sixteen miles north of Columbus, Ohio. Engineer William Wetterman and fireman M. H. Baus were killed, and the boiler was thrown to a distance of sixty feet.

(222.) — On July 13 a boiler exploded in the Jones shingle factory, two miles north of Hillsdale, Ind. William Widner was terribly injured, and Edward Jones was seriously bruised and burned. George Jones, the owner of the mill, was slightly bruised. The plant was demolished.

(223.) — A boiler exploded, July 14, during a fire in the Golden Grain Biscuit Co.'s plant, Grand Forks, N. D.

(224.) — A boiler exploded, July 14, in the Platts Box Co.'s plant, Troy, N. H. Edward Morin, M. Dooley, H. Albee, and H. Buckwold were slightly injured, and the property loss amounted to about $4,200.

(225.) — A boiler exploded, July 14, during the course of a fire in the paint department of the Greenpoint Metallic Bed Co., Brooklyn, N. Y. The explosion injured fireman William Carroll badly.

(226.) — A slight explosion occurred, July 14, in the boiler room of the steam tug *Mentor*, at Chicago. The tug took fire and burned to the water's edge.

(227.) — A boiler exploded, July 14, in Jones & Green's big flooring plant, Dighton, Mich. Night watchman George Steiner was instantly killed, and Herbert Johns was injured. The property loss was estimated at $30,000.

(228.) — A tube ruptured, July 15, in a water-tube boiler in the Real Estate Trust Co.'s building, Broad and Chestnut streets, Philadelphia, Pa.

(229.) — A boiler flue burst, July 16, in the Home Laundry, on Bicking Street, Indianapolis, Ind. A panic resulted among the girls, but nobody was injured.

(230.) — On July 17 a slight boiler explosion occurred in Frank Goetz' cracker bakery, New Haven, Conn.

(231.) — A tube ruptured, July 17, on Edward F. Whitney's steam yacht *Arrow*, in the Buttermilk channel, opposite New York City. Fireman Andrew Anderson was fatally injured, and engineer Thomas Calford was injured severely.

(232.) — A boiler exploded, on or about July 17, on the steamboat *Piriot*, near Okoboji, Iowa.

(233.) — The boiler of a threshing machine outfit belonging to Burton C. Hoop exploded, July 17, on W. G. Craig's farm, near Lexington, Ky. The property loss was about $1,000.

(234.) — On July 18 a boiler exploded in Charles E. Flock's Dixie Creek sawmill, six miles north of Prairie City, Ore. Hiram Ray was injured so badly that he died within a day or two, and Charles E. Flock and James L. McKay were injured. The mill was demolished.

(235.) — On July 18 a steam main connected with the forward starboard boiler exploded on the U. S. battleship *Kearsarge,* at Honolulu, H. I. Water tender Wilson and first class fireman Ferguson were badly injured, and coal passers Pomplun and Miner received lesser injuries.

(236.) — A boiler belonging to the United States Oil Co., and used in drilling for oil, exploded, July 19, at Conant Creek, Wyo., near Riverton.

(237.) — A small boiler used for roasting peanuts exploded, July 20, at Fifth Avenue and Walnut Street, McKeesport, Pa. Ralph Wheatman was burned so badly that he died three days later.

(238.) — On July 24 a boiler exploded in M. W. McDaniels' sawmill, three miles southeast of Moscow, Kemper county, Miss. Fireman Robert Davis was instantly killed. Phelan McDaniels and his little brother Frank, and M. W. McDaniels and his son George, were seriously injured; and at last accounts the first two were not expected to recover. The mill was completely demolished.

(239.) — A tube ruptured, July 25, in a water-tube boiler in the power station of the Philadelphia Rapid Transit Co., at Beach and Laurel streets, Philadelphia, Pa.

(240.) — On July 25 a tube ruptured in a water-tube boiler in the Third Avenue and Second Street power house of the Brooklyn Rapid Transit Co., Brooklyn, N. Y., badly scalding fireman Frank Holyea. Later in the day another tube burst in the same boiler, terribly and perhaps fatally scalding John Mauson, James Olsen, and Thomas Bayer, and scalding John Bush less seriously.

(241.) — The boiler of a mogul freight locomotive exploded, July 27, on the Erie railroad, at Hornell, N. Y., as the result of a derailment. Engineer E. M. Clawson and fireman T. C. Billings were injured so badly that they lived but a short time.

(242.) — A locomotive left its track, July 28, at the steel plant of the Colorado Fuel & Iron Co., Pueblo, Colo., and fell from a trestle. As a result of the fall, the boiler exploded. Engineer W. T. Thomas and fireman James Roach, who were pinned down by the wreckage, were scalded to death before they could be rescued.

(243.) — On July 29 a nipple connection ruptured in a water-tube boiler in the Narragansett Hotel, Providence, R. I.

(244.) — A boiler exploded, July 29, on the Mayes oil lease, near Sapulpa, Okla. Newton Campbell was injured.

(245.) — On July 30 a blowoff pipe burst at the Geneva Lumber Co.'s plant, Eleanor, Fla. Fireman William Lee was killed.

Hartford Steam Boiler Inspection and Insurance Company.

ABSTRACT OF STATEMENT, JANUARY 1, 1908.

Capital Stock, . . . $1,000,000.00.

ASSETS.

	Par Value.	Market Value.
Cash in office and in Bank, ...		$115,831.34
Premiums in course of collection (since Oct. 1, 1907),		203,819.78
Agents' cash balances, ...		9,846.14
Interest accrued on Mortgage Loans, . . .		26,224.54
Loaned on Bond and Mortgage, ...		1,041,950.00
Real Estate, ...		97,000.00
State of Massachusetts Bonds, ...	$100,000.00	88,000.00
County, City, and Town Bonds, ...	337,000.00	341,830.00
Board of Education and School District Bonds,	34,000.00	35,000.00
Railroad Bonds, ...	1,556,000.00	1,580,760.00
Street Railway Bonds, ...	55,000.00	51,900.00
Miscellaneous Bonds, ...	87,500.00	75,475.00
National Bank Stocks, ...	43,300.00	62,250.00
Railroad Stocks, ...	201,700.00	209,583.00
Miscellaneous Stocks, ...	165,600.00	120,725.00
	$2,580,100.00	
Total Assets, ...		$4,060,194.80

LIABILITIES.

Re-insurance Reserve, ...		$1,933,139.74
Commissions and brokerage, ...		40,763.95
State, County, and Municipal Taxes, due and accrued, ...		8,500.00
Losses unadjusted, ...		70,923.05
Surplus, ...	$1,006,868.06	
Capital Stock, ...	1,000,000.00	
Surplus as regards Policy-holders, .	**$2,006,868.06**	2,006,868.06
Total Liabilities, ...		$4,060,194.80

On December 31, 1907, the Hartford Steam Boiler Inspection and Insurance Company had 98,287 steam boilers under insurance.

L. B. BRAINERD, Pres. and Treas. FRANCIS B. ALLEN, Vice-President.
C. S. BLAKE, Secretary. L. F. MIDDLEBROOK, Asst. Sec.
A. S. Wickham, Superintendent of Agencies.
E. J. Murphy, M. E., Consulting Engineer.
F. M. Fitch, Auditor.

Incorporated 1866. Charter Perpetual.

The Hartford Steam Boiler Inspection and Insurance Company

ISSUES POLICIES OF INSURANCE COVERING

ALL LOSS OF PROPERTY

AS WELL AS DAMAGE RESULTING FROM

LOSS OF LIFE AND PERSONAL INJURIES DUE TO STEAM BOILER EXPLOSIONS.

Full information concerning the Company's Operations can be obtained at any of its Agencies.

Department.	Representatives.	Offices.
NEW YORK, . .	C. C. GARDINER, JR., Manager, R. K. McMURRAY, Chief Inspector,	New York City, N. Y., 100 William St.
BOSTON, . . .	C. E. ROBERTS, Manager, F. S. ALLEN, Chief Inspector,	Boston, Mass., 101 Milk St. Providence, R. I., 29 Weybosset St.
PHILADELPHIA, .	CORBIN & GOODRICH, Gen. Agents, WM. J. FARRAN, Chief Inspector,	Philadelphia, Pa., 432 Walnut St.
BALTIMORE, . .	LAWFORD & McKIM, Gen. Agents, R. E. MUNRO, Chief Inspector,	Baltimore, Md., 13-14-15 Abell Bldg. Washington, D. C., 511 Eleventh St., N.W.
CHARLESTON, .	W. S. HASTIE & SON, Gen. Agts., W. M. FRANCIS, Chief Inspector,	Charleston, S. C., 44 Broad St.
BIRMINGHAM, .	LOUIS V. CLARK & CO., Gen. Agents, H. E. STRINGFELLOW, Chief Inspector,	Birmingham, Ala., 214-216 N. 20th St.
NEW ORLEANS, .	PETER F. PESCUD, General Agent, R. T. BURWELL, Chief Inspector,	New Orleans, La., 833-835 Gravier St.
HARTFORD, . .	E. H. WARNER, General Agent, H. C. LONG, Special Agent, F. H. WILLIAMS, JR., Special Agent, F. S. ALLEN, Chief Inspector,	Hartford, Conn., 56 Prospect St.
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PITTSBURG, . .	JAMES W. ARROTT, LTD., Gen. Agt., BENJAMIN FORD, Chief Inspector,	Pittsburg, Pa., 401 Wood Street.
CLEVELAND, . .	H. A. BAUMHART, Manager, H. A. BAUMHART, Chief Inspector,	Cleveland, Ohio, Century Building.
CHICAGO, . . .	H. M. LEMON, Manager, JAMES L. FOORD, Chief Inspector,	Chicago, Ill., 169 Jackson St.
ST. LOUIS, . .	V. HUGO, Manager, V. HUGO, Chief Inspector,	St. Louis, Mo., 319 North Fourth St.
DENVER, . . .	THOS. E. SHEARS, General Agent, THOS. E. SHEARS, Chief Inspector,	Denver, Col., Room 2, Jacobson Bldg.
SAN FRANCISCO, .	H. R. MANN & CO., General Agents, J. B. WARNER, Chief Inspector,	San Francisco, Cal., Merchants' Ex. Bldg.
PORTLAND, . .	McCARGAR, BATES & LIVELY, G. Agts., C. B. PADDOCK, Chief Inspector,	Portland, Ore., Failing Building.

The Locomotive

Vol. XXVII. HARTFORD, CONN., JANUARY, 1909. No. 5.

The Boiler Explosion on the "Sultana."

The most awful boiler explosion known to history was undoubtedly the one which destroyed the Mississippi river steamboat *Sultana,* in 1865, the number of persons killed in that one accident being no less than 1,238.

The *Sultana* and the *Luminary* left New Orleans together, on April 21, 1865, and raced up the river for Vicksburg, where many Union soldiers, just released from southern prisons, were awaiting transportation to the north. The *Luminary*

The "Sultana," Before the Explosion.

reached Vicksburg first, but she did not get the contract to carry the soldiers, and she shortly proceeded northward on her trip.

About ten hours before reaching Vicksburg, a leak developed along a joint at the front end of one of the *Sultana's* boilers, forcing her to lay over at that place, 33 hours, for repairs. The repairing was done, apparently, by a competent boiler maker, and it consisted in putting on a "soft patch," of quarter-inch iron plate.

Previous to the arrival of the *Sultana*, the *Henry Ames* had carried 1,300 of the soldiers north, and the *Olive Branch* had taken 700 more. It was at first reported that no men would be sent by the *Sultana,* as the rolls had been made out for only 300 of those that remained. Before the *Sultana* was ready to depart, however, it was decided to send *all* of the remaining men by her, counting and checking them as they went aboard, and preparing the rolls afterwards. She therefore took on 1,866 soldiers, including 33 paroled officers; and she carried, also, 70 cabin passengers, and a crew of 85.

No inspection was made of the boat at the time, to determine her carrying capacity or condition. The cooking facilities were grossly inadequate, and the men, who did not even have room to lie down, felt that they were treated with unnecessary harshness, in being thus crowded together in great discomfort, when at least two other northward-bound boats had been at the landing during the day, and one very good one (the *Pauline Carroll*) was actually lying alongside at the time of embarkation.

Proceeding up the river the *Sultana* passed Helena, Ark., on April 26, at 10 o'clock a. m. It was there that the photograph was taken, from which the accompanying engraving was prepared, and for which we are indebted to Mr. Paris C. Brown, of Cincinnati, Ohio. At about 3 o'clock a. m., on April 27, 1865, and only seventeen hours after this photograph was taken, the repaired boiler exploded with tremendous violence, a few miles above Memphis, Tenn. Many persons were killed outright, and many more were thrown into the river and drowned; and the wrecked vessel took fire, and was entirely destroyed. Of the soldiers, 1,101 (including 19 officers) were killed, and of the passengers and crew 137 were killed; the total number of lives lost being 1,238, as we have already stated.

So far as we aware, the cause of the explosion was never definitely ascertained. The boiler was a return tubular,—a type which had not been previously tried in the river service. We are told that the shell was 48 inches in diameter and 0.354 inch thick. A new iron shell of this character, with a double-riveted joint having an efficiency of 70 per cent., could carry a pressure of about 90 lbs., with a factor of safety of five. It is likely that the actual pressure carried was 150 lbs. or even more; but in justice to the officers of the *Sultana* it should be remembered that it was customary, at that time, to operate the boilers on river steamboats under a factor of safety which would not now meet with the approval of any engineer.

We do not know whether the initial line of rupture in the boiler ran through the original sheet, or through the patch, which was only 0.25 in. thick; nor do we know the diameter or pitch of the rivets in the shell, nor of the bolts that were used in putting on the patch. It is quite possible that a knowledge of these points would shed light upon the cause of the explosion.

The boilers of the *Sultana* had been examined by a government inspector, at St. Louis, about a fortnight before the explosion, and were then pronounced to be safe and in good condition. The chief engineer, and the second engineer (who was fatally scalded), testified that the boilers were carefully watched after the repairs at Vicksburg, that they contained plenty of water at all times, and that they were apparently all right, up to the very moment of the explosion.

The *Sultana* was undeniably overloaded, and many ugly charges and counter-charges of bribery were current among the Union officers who had to do with the transportation of the soldiers, in view of the fact that there were other serviceable boats at hand, anxious to get a share of the business.

[There was a well-known river steamer bearing the name *Sultana,* plying upon the Mississippi river some years prior to the Civil war; but the vessel to which this article relates was built either at Cincinnati, Ohio, or at Wheeling, W. Va., in 1862-3, being completed, if we are correctly informed, in January, 1863.]

Ten Thousand Boiler Explosions.

As readers of The Locomotive are well aware, we have made a practice, for many years, of recording, in this journal, the boiler explosions that occur in the United States and in adjacent parts of Canada and Mexico; and each year we also publish a summary of the explosions of the year preceding, giving the number of such explosions, and the number of persons killed and injured by them. We began keeping these statistics on October 1, 1867, so that they now cover a period of over forty-one years; and it is both instructive and impressive to look back over the record.

As will be seen by Table 1, the total number of boiler explosions recorded and briefly described in these pages, up to and including the present issue, is no less than 10,051. These have resulted in the death, either immediately or within a few days, of 10,884 persons, and in the more or less serious injury of 15,634 others; so that the total number of persons killed and injured by the explosions that have been recorded in The Locomotive is 26,518. These figures are worth more than passing attention, and we commend them particularly to those persons (for there still are such) who believe that boilers do not explode, or that they explode only rarely.*

In preparing Table 1 we have revised all of the lists of explosions that have been published during the period that it covers; and we have made out new summaries for the years previous to 1879, not only for the purpose of detecting any errors that previous summaries may have contained, but also with the additional object of securing uniformity in the method of summarizing. In the early days, for example, explosions occurring in England, Germany, France, and other distant parts of the world, were recorded and included in the annual summaries, if they were of a serious character; but in later years we have omitted such explosions from our regular lists, mention of them, when mention has been given, being confined to separate paragraphs or articles. In preparing the tables given in the present article, foreign explosions have been omitted altogether, except (as noted above) those occurring near our borders, in Canada or in Mexico.

In looking over accounts of boiler explosions, we often find it said that "several" persons were injured; and for the purpose of summarizing the explosions during a given period it is necessary to estimate the probable number that the word "several" signifies, when so employed. Some years ago we undertook to settle this point as definitely and fairly as possible, by studying those cases in which some of our accounts of a given explosion said "several" persons were injured, while other accounts of the same explosion gave the exact number; and we found that the average number of persons injured, when the account says "several," appears to be almost exactly three. In recent years we have therefore assumed that "several" means "three," when used in this way; and this interpretation has been given to it, in the earlier years as well as in the later ones, in making out the present revised summary of the explosions since 1867.

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* The dreadful explosion on the *Sultana*, of which some account is given in this issue, took place more than two years prior to the beginning of the period covered by Table 1, and hence the loss of life which occurred in that instance is not included in the statistics given in the present article. If we were to take the *Sultana* explosion into account, the total number of persons killed by the boiler explosions that have been recorded in The Locomotive would be 12,122, and the average number of persons killed, per explosion, would be 1.206.

TABLE 1.—SUMMARY OF BOILER EXPLOSIONS FROM OCTOBER 1, 1867, TO JANUARY 1, 1909.

YEAR.	Number of Boiler Explosions.	Number of Persons Killed.	Number of Persons Injured.	Total of Killed and Injured.
1867*	31	48	52	100
1868	101	226	185	411
1869	96	147	268	415
1870	109	213	272	485
1871	89	383	225	608
1872	98	232	235	467
1873	92	130	215	345
1874	96	175	160	335
1875	102	134	195	329
1876	75	147	145	292
1877	83	157	201	358
1878	97	178	216	394
1879	132	208	213	421
1880	170	259	555	814
1881	159	251	313	564
1882	172	271	359	630
1883	184	263	412	675
1884	152	254	251	505
1885	155	220	278	498
1886	185	254	314	568
1887	198	264	388	652
1888	246	331	505	836
1889	180	304	433	737
1890	226	244	351	595
1891	257	263	371	634
1892	269	298	442	740
1893	316	327	385	712
1894	362	331	472	803
1895	355	374	519	893
1896	346	382	529	911
1897	369	398	528	926
1898	383	324	577	901
1899	383	298	456	754
1900	373	268	520	788
1901	423	312	646	958
1902	391	304	529	833
1903	383	293	522	815
1904	391	220	394	614
1905	450	383	585	968
1906	431	235	467	702
1907	471	300	420	720
1908	470	281	531	812
Totals,	10,051	10,884	15,634	26,518

*Last three months of year.

From the data given, it appears that for the whole period of over forty-one years, the average number of persons killed per explosion was 1.083, while the average number of persons injured (but not killed) per explosion was 1.555; the average number of persons that were *either* killed or injured, per explosion, being therefore 2.638.

It is interesting to note the way in which the number of persons killed or injured, per explosion, has varied with the progress of time. This variation is shown very clearly in Table 2, in which the data given in the larger table have been summarized for four successive ten-year periods,— the average number of persons killed and injured, per explosion, being given separately for each period. If we take the average number of persons killed, or the average number injured, as an indication of the seriousness of an explosion, Table 2 indicates that the boiler explosions of the country have been growing less and less serious, — the change in this respect being marked and continuous. No doubt the tendency here indicated is in part real, owing to the improvement that has taken place in the design, construction, and operation of steam boilers. We are of the opinion, however, that the progressive diminution in seriousness that is indicated so plainly by the last three columns of

Table 2.—Comparison by Ten-Year Periods.

Ten-Year Period.	Total Number of Explosions.	Total Number of Persons Killed.	Total Number of Persons Injured.	Persons Killed per Explosion.	Persons Injured per Explosion.	Persons Injured per Person Killed.
1868 to 1877* .	941	1,944	2,101	2.07	2.23	1.08
1878 to 1887* .	1,604	2,422	3,299	1.51	2.06	1.36
1888 to 1897* .	2,926	3,252	4,535	1.11	1.55	1.39
1898 to 1907* .	4,079	2,937	5,116	0.72	1.25	1.74

*Inclusive, in each case.

Table 2 is in considerable measure illusory, being due mainly to the vast improvement that the forty years have brought, in our facilities for obtaining information concerning explosions, The collection of these statistics began, for example, only twenty-three years after Morse's first experimental telegraphic line had been erected; and the early part of the table is therefore concerned with a period in which the telegraphic news service of the country was exceedingly imperfect, and in many sections almost non-existent. Moreover, the Hartford Steam Boiler Inspection and Insurance Company was a very small concern, forty years ago; whereas it is now a vast organization, having, almost everywhere, representatives who are all the time looking for information concerning boiler explosions. Bearing these two facts in mind, it is natural to conclude that in the early part of the forty-year period the smaller explosions escaped our attention in large measure, while the constantly increasing efficiency of the telegraphic news service, and the continued growth of this company, would cause explosions of relatively smaller "news value" to be noted and reported to our home office in the later years, so that the average seriousness of an explosion would *appear* to diminish with the progress of time, even if there were no such diminution in reality.

We do not consider that the falling off in apparent seriousness has been due in any appreciable measure to the increasing use of sectional boilers, for our experience has indicated that the bursting or rupture of such boilers is all too frequently attended with serious consequences in the way of killing or injuring the attendants. Moreover, the falling off in seriousness dates from a time when the number of such boilers in service was altogether too small to have any considerable effect upon the statistics of the country as a whole; and, finally, even if there were a real tendency towards decrease in seriousness, due to the gradual adoption of sectional boilers, we believe that this would be more than counterbalanced by the simultaneous tendency that there has been towards higher steam pressures, and the use of larger boilers.

We are often asked whether boiler explosions occur with equal frequency at all times of the year, or whether there is any evidence that they happen oftener in some months than in others. The data required for answering this question are given in Table 3, where the explosions are classified according to months, for each period of ten years. During the ten-year period beginning with January 1, 1888, and ending with December 31, 1897, for example, there

TABLE 3.—CLASSIFICATION OF BOILER EXPLOSIONS BY MONTHS, SINCE 1868.

MONTH.	Ten-Year Period.				Forty Years. 1868 to 1907*	Percentage of Explosions per Month During Forty-year Period.
	1868 to 1877*	1878 to 1887*	1888 to 1897*	1898 to 1907*		
January, . . .	98	181	288	425	992	10.39
February, . .	87	141	269	347	844	8.84
March, . . .	68	129	224	327	748	7.83
April, ...	83	102	180	294	659	6 90
May, ...	67	117	205	260	649	6.79
June, ...	65	126	177	263	631	6.61
July, ...	56	124	211	305	696	7.29
August, . . .	73	138	276	339	826	8.65
September, . .	86	131	246	359	822	8.61
October, . . .	87	129	301	377	894	9.36
November, . .	81	143	275	389	888	9.30
December, . .	90	143	274	394	901	9.43
Totals, . .	941	1,604	2,926	4,079	9,550	100.00

*Inclusive, in each case.

were 288 boiler explosions in the month of January, 269 in the month of February, 224 in the month of March, and so on. In the sixth column a similar classification by months is given for the whole period of forty years extending from January 1, 1868, to December 31, 1907; and in the final column we give the number of explosions in each respective month, expressed as a percentage of the whole number of explosions that occurred during the forty years.

As might be expected, there is no very pronounced variation in the number of explosions from one month to another, but yet the frequency does depend to a certain extent upon the time of the year.

It is evident that there is a sensible falling off in the number of explosions in April, May, and June, and that there is a corresponding increase in the number in October, November, December, and January. This change is partially due, no doubt, to the explosion of heating boilers in our northern latitudes during the colder months. It cannot be entirely due to this cause, however, for there is a decided falling off between January and February, notwithstanding the fact that February is perhaps as cold as January, so that between these months there would be no material reduction in the number of heating boilers in service, nor in the duty required of those in use. Also, it is plain that the increase in the number of explosions begins in the hot weather, the number of explosions in August being already greater than the average number, per month, for the whole year.

Boiler Explosions.

August, 1908.

(246.) — A mud drum attached to some boilers in the plant of the Standard Guano & Chemical Manufacturing Co., ruptured, August 1, at New Orleans, La.

(247.) — A boiler exploded, August 2, in a cement factory near Fenton, Mich. Glenn Hatt and two other men were scalded to death.

(248.) — On August 4 the elbow of a blowoff pipe ruptured at the plant of the Wolverine Mfg. Co., South Memphis, Tenn. Charles Anderson was injured.

(249.) — On August 5 a feed pipe pulled out of the head of a boiler in E. M. Statler's hotel, Buffalo, N. Y. Herman Strehlow, assistant engineer, was slightly scalded.

(250.) — A boiler belonging to W. W. Twinam exploded, August 7, at Crawfordsville, Iowa. Harold Twinam and Samuel Truax were scalded so badly that they died within a few hours.

(251.) — A boiler exploded, August 7, in the Parrsboro Lumber Co.'s sawmill, at Windsor Forks, twenty miles from Windsor, Ont. Engineer Edward Keith was killed, and two men named Swimmer and Leary were seriously and perhaps fatally injured.

(252.) — A boiler exploded, August 8, in the Decatur Ice Co.'s plant, Decatur, Ala.

(253.) — On August 8 a boiler exploded in the plant of the Edgerton Lumber Co., Victoria, Va. Two men were scalded to death.

(254.) — On August 8 a cast-iron header failed in a water-tube boiler, in the Philadelphia Rapid Transit Co.'s power station, 13th and Mt. Vernon streets, Philadelphia, Pa.

(255.) — A boiler exploded, August 10, in the Bailey Slaughter House, Danville, Ill. One person was injured.

(256.) — On August 10 the boiler of a steam automobile exploded at the foot of Stickney Hill, about a mile and a half from Painesville, Ohio. In the machine at the time were Frederick Beckwith, his wife and daughter, and his wife's mother, Mrs. Mary Rawdon. Mrs. Beckwith and Mrs. Rawdon were killed, and Mr. Beckwith was seriously injured, but has since recovered. Miss Bessie Beckwith, the daughter, was also painfully bruised. The explosion occurred at the foot of the long hill, after coasting down it with the power shut off.

(257.) — A boiler exploded, August 10, in the York Rolling Mill, a branch of the Susquehanna Iron Co., at York, Pa. John Schlossman, Harry Sechrist, Harry Fager, Benjamin F. Brenner, Max Puttkeimer, Edward Fitler, Thomas Gallagher, Paula Tuzci, Alexander F. Scott, and one other man were killed, and twenty other persons were injured. The mill was wrecked, and the property loss was estimated at $20,000.

(258.) — A boiler exploded, August 11, in Ingram's sawmill, on White River, near Rogers, Ark., killing Hart Clinton, an employee, and seriously injuring Charles Ingram, a son of the owner of the mill.

(259.) — On August 11 a boiler exploded at the plant of the Breakwater Construction & Engineering Co., near Guilford, Conn. Giovanni Angelini was killed, and Massimo Bettio was badly injured. Two other men also received lesser injuries.

(260.) — A boiler exploded, August 11, in the stamp mill at the Harte gold mine, near Kershaw, S. C. E. A. Thies, general manager of the mill, was fatally injured, and died on the following day. M. B. Truesdell and two other men were also badly hurt. The big brick stamp mill was totally wrecked.

(261.) — On August 12 a tube ruptured in a water-tube boiler at the Spring street plant of the Columbus Railway & Light Co., Columbus, Ohio.

(262.) — On August 13 a boiler exploded in J. C. Mulfinger's mill, at Pleasant Gap, near Bellefonte, Pa. Gottlieb Mulfinger, a son of the owner, was terribly scalded, and the building was badly wrecked.

(263.) — The boiler of a threshing machine outfit exploded, August 13, near Prosper, Minn. Gabnal Munson was killed, George Johnson was fatally injured, and a young son of Mr. Munson was injured seriously, but not fatally.

(264.) — On August 14 a boiler tube ruptured in the Sefton Manufacturing Co.'s paper box factory, Chicago, Ill.

(265.) — A boiler exploded, August 17, in William Reid's sawmill, near Draco, Caldwell county, N. C. Henry Gilbert and Frederick Jackson were killed, and William Reid and his son, Hugh Reid, were fatally injured. The plant was wrecked.

(266.) — The boiler of the steamer *Leelanau* exploded, August 17, on Carp Lake, near Leland, Mich. Mrs. Isabel La Bonte was killed, John Hartung was fatally injured, and eight other persons were more or less seriously scalded.

(267.) — A boiler exploded, August 17, in a sawmill at Bozeman, Mont. Engineer William Thompson was killed.

(268.) — On August 19 two tubes ruptured in a water-tube boiler at the plant of the Hamilton-Brown Shoe Co., St. Louis, Mo.

(269.) — A boiler exploded, August 19, in the laundry of the Imperial Hotel, Red Bluff, Cal., as the result of a fire in the building.

(270.) — A tube ruptured, August 19, in a water tube boiler at the Memphis Street Railway Co.'s power plant, Memphis, Tenn. Charles Smith and William Roberts were injured in trying to escape from the building.

(271.) — A boiler exploded, August 19, in Erschick, Deffenbaugh & Risser's grain elevator, Columbus Grove, Ohio. Engineer Curtis Lytle was instantly killed, and John Erschick, one of the owners of the elevator, was badly injured. The property loss was estimated at $20,000. Several other neighboring buildings were slightly damaged.

(272.) — A slight boiler explosion occurred, August 20, in the Hattiesburg Traction Co.'s power plant, Hattiesburg, Miss.

(273.) —A boiler used to operate a sawmill exploded, August 20, on E. F. Woestman's ranch, at Husted, ten miles north of Colorado Springs, Colo. Mrs. Caroline Kirchoff was instantly killed, and Henry Hanning was fatally injured.

(274.) — On August 20, a boiler exploded in the sawmill of W. A. & A. L. Behnke, at Park Falls, Wis. Engineer William Plunkett was killed, and several other persons were injured. The property loss was estimated at $3,000. A report has been current to the effect that this same firm owned the boiler that exploded, January 22, 1906, near Holcombe, Chippewa county, Wis., killing seven persons; but Messrs. Behnke Bros. deny this, stating that the mill in question was owned by another man, who was cutting logs for them under contract. (Compare explosion No. 32, on page 50 of the issue of The Locomotive for April, 1906.)

(275.) — A boiler exploded, August 21, in J. & H. A. Matson's sawmill, situated on Indian Creek, some fifteen miles east of Manti, Utah, and near Ferron. The mill was completely wrecked.

(276.) — The crown sheet of a locomotive on the Salt Lake railroad gave way, on August 22, at Ontario, Cal. The engineer and fireman were each slightly injured.

(277.) — The boiler of a Delaware & Hudson locomotive exploded, August 22, at Cooperstown Junction, N. Y. One man was severely injured.

(278.) — The boiler of a threshing machine outfit exploded, August 26, on Del Cross's farm, near Litchville, N. D. Mr. Cross was severely injured, and it was believed that he could not recover.

(279.) — A small boiler, carrying a pressure of fifty pounds per square inch, and used for roasting peanuts and popping corn, exploded, August 26, on Garrison Avenue, Fort Smith, Ark. Monroe Blocker was painfully but not seriously injured.

(280.) — The boiler of a switching locomotive exploded, August 29, at Ann Arbor, Mich. One man was seriously injured.

September, 1908.

(281.) — The boiler of a Denver & Rio Grande passenger locomotive exploded, September 2, near Thompson Springs, Utah, 75 miles west of Grand Junction, Colo. Engineer George A. Lund was fatally injured, and fireman Harry Ridell was injured very badly, though it was thought he had a small chance of recovery.

(282.) — On September 4 the boiler of W. B. Whitman's threshing outfit exploded at New Rockford, N. D., instantly killing engineer Charles Olmstall, and injuring W. B. Whitman (the owner), John Whitman (his son), Arthur Michaelson, and Siebert Olson.

(283.) — The boiler of a Seaboard Air Line locomotive exploded, September 5, in the yards at Raleigh, N. C. Fireman Hugh Murchison was fatally injured.

(284.) — A boiler used in constructing a reservoir at Warwick, N. Y., exploded on September 5.

(285.) — The boiler of a San Antonio & Aransas Pass locomotive exploded, September 7, about 15 miles from Yoakum, Tex. Fireman Augustus Ryan and head brakeman Joseph May were fatally injured, and died later in the day. Engineer Z. W. Welch was also injured, but not fatally so.

(286.) — A slight boiler accident occurred, September 8, at a coal mine near Toluca, Ill.

(287.) — On September 8 a boiler accident occurred in the I. B. Worth Co.'s plant, Petersburg, Va.

(288.) — On September 9 a boiler belonging to Moudy & George exploded at Floyd, Tex. Two men were seriously injured, and the property loss was estimated at $3,500.

(289.) — Milton C. Hogeboom, of St. Paul, Minn., was fatally injured, September 10, by a slight boiler explosion at the Tonka Bay Hotel, near St. Paul.

(290.) — The boiler of a threshing outfit exploded, September 11, at Middleburg, near Hagerstown, Md. Edward Bovey, the owner, was severely scalded.

(291.) — On September 11 a boiler exploded in the Boylan Creamery, at Jenison, Mich. The property loss was about $500.

(292.) — A boiler exploded, September 11, in Head's sawmill, on Copper Creek, 14 miles north of Mt. Vernon, Ky. Fireman Thomas Sword was killed, and two other employees were injured.

(293.) — A tube ruptured, September 12, in a boiler at the Winnfield Ice Co.'s plant, Winnfield, La.

(294.) — On September 12 a tube ruptured in a water-tube boiler at the Southwestern Mechanical Co.'s ice factory, North Fort Worth, Tex.

(295.) — A boiler exploded, September 14, in Huber's cider mill, near Linwood, twelve miles northwest of Berlin, Ont. Thomas Huber and William Attig were instantly killed, and the mill was demolished.

(296.) — On September 15 a boiler belonging to David Pross exploded at Fessenden, N. Dak. One man was killed, and two were seriously injured.

(297.) — A boiler ruptured, September 15, in the Edgewater Hygeia Ice Co.'s plant, Edgewater, N. J. The boiler was practically destroyed.

(298.) — A portable boiler, used for furnishing power for a threshing outfit, exploded, September 17, on Mrs. Halstead R. Pritchard's farm, on the Bell Hill road, Deerfield, N. Y. Engineer Herman Jenkins was painfully injured.

(299.) — On September 17 three sections of a cast-iron heating boiler fractured, in the High School building, Watertown, Mass.

(300.) — A boiler exploded, September 17, on the Shafer farm, Titusville Pa.

(301.) — A boiler exploded, September 19, in the Continental Mexican Rubber Co.'s plant, at Torreon, Mex. Three men were fatally injured, several others were injured less seriously, and a large part of the plant was wrecked.

(302.) — A slight explosion occurred, September 19, on one of the New York, New Haven & Hartford railroad's freight locomotives, at Meriden, Conn. Engineer F. W. Kenyon and fireman Robert Green were thrown from the cab, and severely burned and bruised. So far as we can judge from the data at hand, the explosion consisted in the failure of one of the tubes.

(303.) — A boiler exploded, September 20, in the water and lighting plant at Etna, near Allegheny, Pa. One side of the building was blown out.

(304.) — A tube burst, September 21, in a boiler in the Wabash Water & Gas Light plant, Wabash, Ind. Frank Harris was seriously burned.

(305.) — Engineer Joseph Pulz was instantly killed, September 21, by the explosion of the boiler of a locomotive on the Monon railroad, at Roselawn, near Lafayette, Ind. Fireman Roy Houston was slightly injured.

(306.) — A boiler belonging to R. J. McFadden, of Moundsville, W. Va., and used for crushing stone, exploded, September 21, on the Waynesburg road, three miles east of Moundsville. Engineer John Hagerman was instantly killed.

(307.) — A boiler exploded, September 22, at the Doyle quarry, at Dark Hollow, near Bedford, Ind. The power house and engine room were demolished.

(308.) — A small boiler used for sawing wood exploded, September 23, at Middleboro, Mass. George W. Williams was severely burned.

(309.) — A still, operated by steam, exploded, September 24, in Ferdinando Bessolo's distillery, on Ord street, Los Angeles, Cal. John Cavallera was fatally injured, and James Ferrero, John Bessolo, and G. Pacci were injured more or less seriously, but not fatally. The flimsy structure in which the accident occurred was destroyed.

(310.) — The boiler of Charles Johnson's traction engine exploded, September 24, at East Oak Hill, N. Y. Two persons were severely injured.

(311.) — A boiler owned by the Dempsey Contracting Co. and used for hoisting stone and running a steam drill, exploded, September 25, on Washington Avenue, Long Island City, N. Y. James Isolei was severely burned.

(312.) — A boiler exploded, September 26, at Brock Wheatley's sawmill, on Eckler mountain, ten miles from Dayton, Wash.

(313.) — On September 27 a tube ruptured in a water-tube boiler at the Alpha Portland Cement Co.'s No. 4 plant, Martin's Creek, Pa. Fireman William Downs was burned so badly that he died a few days later.

(314.) — The boiler of a freight locomotive exploded, September 27, on the Chicago, Milwaukee & St. Paul railroad, near Portage, Wis. Engineer Frederick J. Good was killed, and fireman Christopher Hanson and brakeman B. N. Taylor were seriously scalded.

(315.) — On September 28 a blowoff pipe failed at the Elk Tanning Co.'s plant, Newport, Pa. Night watchman A. F. Smith was slightly injured.

(316.) — A boiler exploded, September 28, in the Cahaba Coal Co.'s plant, at Coalmont, four miles from Helena, Ala. Frederick Orr and January Goodiron were killed, and three other men were injured. R. C. Middleton, president of the company owning the boiler, was one of the injured persons.

(317.) — A cast-iron unit of a power boiler exploded, September 29, in the Phosphor Bronze Smelting Co.'s plant, 21st street and Washington Avenue, Philadelphia, Pa. Engineer Timothy McCartney was slightly scalded.

(318.) — A boiler exploded, September 29, in the Novelty Factory, Jasper, Ind. Joseph Kress was badly scalded.

(319.) — A large steam drying cylinder exploded, September 30, in the new mill of the California Paper & Board Mills, Antioch, Cal. Edgar B. Pierce, head electrician, was instantly killed.

OCTOBER, 1908.

(320.) — The boiler of a freight locomotive exploded, October 1, on the Trenton Cut-off railroad, at Fort Hill, near Flourtown, Pa. Engineer A. K. Miller was injured so badly that he died soon afterwards. Fireman D. E. Parks and brakeman W. T. Rowland were also injured seriously, but it was believed that both would recover. The property loss was estimated at $10,000.

(321.) — A boiler exploded, October 2, in the basement of "Crest Hall," a summer hotel at Winthrop Beach, near Boston, Mass. Fire followed the explosion, and a number of neighboring buildings were destroyed, with a total property loss estimated at $200,000. One woman is known to have perished in the fire.

(322.) — On October 3 a boiler exploded in a wood yard on Main street, Buena Vista, Colo. F. E. Bagley was seriously injured, and the building in which the boiler stood was destroyed.

(323.) — On October 3 a blowoff pipe ruptured in the West End Paper Co.'s plant, Carthage, N. Y. Norman Ingraham was scalded.

(324.) — A boiler exploded, October 4, in the power house of the "C" mine, at Superior, a coal camp near Rock Springs, Wyo. The building and machinery were wrecked.

(325.) — A tube ruptured, October 5, in a water-tube boiler in the New York & Pennsylvania Co.'s pulp and paper mill, at Johnsonburg, Pa.

(326.) — On October 5 a boiler exploded in a dry cleaning establishment, at Pawhuska, Okla. Lynn S. Smith was badly burned.

(327.) — A boiler exploded, October 5, in C. C. Putnam & Son's mill, at Putnamville, Vt. The engineer had just left the boiler room for the purpose of signing an application for accident insurance.

(328.) — A boiler exploded, October 5, on the Knickerbocker Towage Co.'s tug *Delta,* at Bangor, Me. Fireman Warren Stover was killed, and engineer George Arri was badly scalded.

(329.) — A cast-iron header ruptured, October 6, in a boiler in the Hollenden Hotel, Cleveland, Ohio.

(330.) — A slight boiler accident occurred, October 6, at the Missouri Athletic Club, St. Louis, Mo. Firemen Jacob Schmidt and Samuel Weaver were severely scalded.

(331.) — On October 7 a boiler exploded on Section 2 of the Santa Fé holdings, in the Kern river oil field, Kern county, Cal. The plant was wrecked, and the boiler was thrown 300 feet.

(332.) — A steam boiler and ten boxes of giant powder exploded, October 7, at the Apache Maid mine, Webb City, Mo. Robert C. Feland, Jasper Lee, and George Smith were killed, Frank Holderby and Edward Johnson were injured, and the mine buildings were destroyed. The explosion of the boiler is said to have been the initial cause of the accident.

(333.) — On October 8 a tube ruptured in a water-tube boiler in the Pittsburg-Butler Street Railway Co.'s power house, Renfrew, Pa. (See also No. 335, below.)

(334.) — On October 8 a cap blew off at the rear end of a water-tube boiler in the Bergner & Engle Brewing Co.'s plant, Philadelphia, Pa. Fireman John Fleitz was scalded to death.

(335.) — A tube ruptured, October 12, in a water-tube boiler in the Pittsburg-Butler Street Railway Co.'s power house, Renfrew, Pa. (See also No. 333, above.)

(336.) — On October 12 a tube ruptured in a water-tube boiler in the B. F. Goodrich Rubber Co.'s plant, Akron, Ohio. Fireman James Roby was scalded.

(337.) — A slight boiler accident occurred, October 12, in the electric lighting plant and water works, at Downers Grove, Ill.

(338.) — On October 12 a boiler exploded in the Thos. Ross Soap Co.'s plant, Columbus, Ohio. One person was injured. The property loss was about $1,000.

(339.) — The boiler of a Southern railway freight locomotive exploded, October 13, at Mayo, on the Atlantic & Danville division, some 40 miles from Danville, Va. Engineer James Pharr was killed, and firemen Frederick Smith and Charles E. Massie were slightly injured.

(340.) — A boiler used in the construction of a sewer system exploded, October 13, on the Ridge road, West Seneca, Buffalo, N. Y. Carmelia Marcelli was killed, and Frank Kirkmeyer was scalded seriously and perhaps fatally.

(341.) — A boiler exploded, on or about October 14, at Bristol, near Clarksburg, W. Va. Harry Barnes was instantly killed, and Herman Rankin was fatally injured.

(342.) — A boiler used for heating water exploded, October 16, in the I. O. O. F. Home, at Thermalito, near Oroville, Butte county, Cal. One side of the room in which it stood was blown out, and the property loss was estimated at $500.

(343.) — A boiler used for sawing lumber exploded, October 17, on the J. L. Mott ranch, at Carrollton, Ill. Elihu Shaw and Marshall Voiles were killed, and Benjamin Shaw was seriously injured.

(344.) — The boiler of a Denver & Rio Grande locomotive exploded, October 18, near Carlton, eight miles north of Colorado Springs, Colo., as the result of a derailment. Leonard F. Banker, who was serving as fireman at the time, was killed.

(345.) — On October 20 a boiler ruptured in the McCarty Gin Co.'s cotton gin, Cedar Hill, Tex.

(346.) — A cast-iron header fractured, October 20, in a water-tube boiler in the Milwaukee Coke & Gas Co.'s plant, Milwaukee, Wis.

(347.) — A blowoff failed, October 20, in the Angola Railway & Power Co.'s plant, Angola, Ind.

(348.) — On October 20 a cast-iron header fractured in a water-tube boiler in the Eastern Wisconsin Railway & Light Co.'s plant, Fond du Lac, Wis.

(349.) — The boiler of a traction engine exploded, October 21, on the Stevens Creek road, between Campbell and Santa Clara, near San Jose, Cal. A. B. Bell was injured so badly that he died a few hours later, and Carl Lorenzo was severely burned.

(350.) — Several cast-iron headers ruptured, October 21, in a water-tube boiler in the United Gas Improvement Co.'s electric lighting plant, at Wayne, Pa.

(351.) — A heating boiler exploded, October 21, in the parish house connected with St. Anselm's Roman Catholic church, Clinton Avenue and 152d street, New York. Henry Kohn, the janitor, was injured so badly that he died shortly afterwards.

(352.) — The boiler of a Colorado Southern freight locomotive exploded, October 22, near Kinder, La. The engineer and fireman, and one of the brakemen, were more or less severely injured, and it was believed that the fireman could not recover.

(353.) — A boiler exploded, October 22, in a cotton gin on the Murdoch plantation, at Barnes, five miles from Tallulah, La.

(354.) — A tube ruptured, October 23, in a water-tube boiler in the Hamilton-Brown Shoe Co.'s plant, St. Louis, Mo.

(355.) — A boiler exploded, October 23, in Hatton's sawmill, four miles northwest of Miami, Okla. James Branson was badly injured.

(356.) — On October 24 a boiler exploded in James Searle's cotton gin, six miles south of Mt. Pleasant, Tex. James Searle (the owner), Joseph Taylor, and Henry Cooper were killed, and four other men were injured. The property loss was estimated at $5,000.

(357.) — On October 26 an accident occurred to a boiler in the Cartersville Ginning Co.'s cotton gin, Cartersville, S. C.

(358.) — A boiler exploded October 26, in Moffit's sawmill, near Edgewood, Siskiyou county, Cal. Night watchman Louis Neeley was instantly killed, and Louis W. Stark, a boilermaker, was fatally injured.

(359.) — A mud drum, connected to a battery of boilers, ruptured, October 27, in J. N. Pharr & Sons' sugar house, Olivier, La.

(360.) — A tube ruptured, October 28, in a water-tube boiler in the Pacolet Manufacturing Co.'s cotton mill, New Holland, Ga.

(361.) — The boiler of locomotive No. 1966, drawing a milk train on the New York Central railroad, exploded, October 28, near White Plains, N. Y. Fireman George Sommerville and brakeman C. H. Traver were fatally injured, and engineer C. J. Ranus was scalded, but will recover.

(362.) — On October 28 a boiler exploded in the Hope Hosiery mill, operated by Stork & Co., at Adamstown, Pa. A score of persons were injured.

(363.) — The boiler of a Lake Shore freight locomotive exploded, October 28, near Elyria, Ohio. Engineer George P. Owen and fireman J. C. Owen (his son), were fatally injured, and one of the brakemen was injured slightly. The locomotive was totally wrecked.

(364.) — On October 28 a boiler exploded in the Chapman Lumber Co.'s plant, Scappoose, Ore. One person was seriously injured.

(365.) — A boiler exploded, October 28, in Scarritt Moreno's sawmill, at Boggy, Walton county, Fla. Engineer Bostock was fatally injured, and the mill was completely destroyed.

(366.) — A tube ruptured, October 29, in a water-tube boiler at the Hanging Rock Iron Co.'s blast furnace, Hanging Rock, Ohio; and later in the day a second accident of the same nature befell another boiler in the same plant.

(367.) — An accident, reported as the explosion of a low pressure boiler, occurred, October 29, in the Poughkeepsie Light, Heat & Power Co.'s power plant, Poughkeepsie, N. Y.

(368.) — A boiler belonging to J. T. Collins exploded, October 29, at Bayou Macon, La. One person was killed.

(369.) — On October 30 a tube ruptured in a water-tube boiler in the Alkali Rubber Co.'s plant, Akron, Ohio. John Bahm and Henry Jackson, firemen, were injured.

(370.) — A blowoff pipe failed, October 30, in the J. T. Lewis & Bro. plant of the National Lead Co., Philadelphia, Pa.; and later in the day a second accident of the same nature occurred at the same plant.

(371.) — On October 31 a cast-iron sectional boiler ruptured in two of its manifolds, in the apartment house owned by Samuel M. Samuels and Isaac Weinstein, at 77-79 Second Avenue, New York.

(372.) — A cast-iron header fractured, October 31, in a water-tube boiler at the plant of the American Agricultural Chemical Co., Delray, Mich.

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(373.) — A section ruptured, November 1, in a cast-iron sectional heating boiler in St. Mary's Roman Catholic church, Branford, Conn.

(374.) — On November 1 a mud drum, connected to a battery of boilers, fractured on the Evan Hall plantation, of the McCall Bros. Planting & Manufacturing Co., McCall, La.

(375.) — A slight boiler accident occurred, November 2, at the J. P. Raurson Co.'s flouring mill, Howard, S. Dak. Engineer William Homer was injured.

(376.) — On November 3 the shell of a boiler ruptured in the Paul F. Beich Co.'s plant, Bloomington, Ill.

(377.) — The boiler of a small launch exploded, November 4, off the Robbins Reef lighthouse, near Staten Island, N. Y. Three men, residents of Keyport, N. J., were thrown into the sea and drowned.

(378.) — The water leg of a New York Central locomotive ruptured, November 5, near Ardsley, N. Y. Fireman Henry Wenn was seriously scalded.

(379.) — A boiler ruptured, November 5, in G. W. Van Dusen & Co.'s grain elevator, at Plainview, Minn.

(380.) — On November 5 a tube ruptured in a water-tube boiler in the Binghamton Light, Heat & Power Co.'s plant, Binghamton, N. Y. Fireman Thomas Glendenens was slightly burned.

(381.) — A boiler exploded, November 5, in a grist mill at Walkerville, Mich.

(382.) — On November 6 a boiler exploded in the Fort Madison Canning Works, Fort Madison, Iowa.

(383.) — A slight accident occurred November 6, to a boiler in the Farmers' Gin & Grain Co.'s plant, Watonga, Okla.

(384.) — A boiler used in drilling a well exploded, November 7, at the new round house of the Wisconsin Central railroad, Superior, Wis. Simon Miller, Charles Hagstrom, Magnus Anderson, Thomas Burke, and Edward Carlson were killed, and Charles A. Roberts, Frank Clark, Saali Harsau, Thomas Purcell, Harry Thomas, and Walter Fakala were injured.

(385.) — The boiler of a Lake Shore & Michigan Central passenger locomotive exploded, November 9, at Chicago, Ill. Fireman Thomas Daly, Jr., was scalded so badly that he died later in the day.

(386.) — When the steamer *Temiskaming*, of the Temiskaming Navigation Co., was approaching Temiskaming Landing, Quebec, on November 10, her boiler exploded. A hunter named McBride, and two firemen named Menard and Bergounhan, were killed. Two men were also fatally burned, and six others were injured badly, but not fatally.

(387.) — On November 10 a blowoff pipe ruptured at the Forester Coal & Coke Co.'s plant, Duquoin, Ill. One man was slightly injured.

(388.) — A boiler exploded, on or about November 12, in a sawmill at Kampsville, Ill. Two men were killed, and two were seriously injured.

(389.) — The boiler of locomotive No. 833, on the Delaware & Hudson railroad, exploded, November 13, at East Windsor, N. Y., on the Nineveh branch. Brakeman John Carter and fireman E. T. Bradshaw were killed, and engineer Calvin E. Kimball and conductor George Breese were injured.

(390.) — On November 13 a tube ruptured in a water-tube boiler at the Clinton Woolen Mfg. Co.'s plant, Clinton, Mich.

(391.) — A boiler exploded, November 13, in the Miller Lumber Co.'s plant, at Pound, near Wise, Va. John Hubbard, Rollo Fleming, William Tacket, and a man named Mullins were killed, and Elbert Miller, manager of the plant, was fatally injured. Three other men were also injured seriously but not fatally. The property loss was several thousand dollars.

(392.) — On November 13 a tube pulled out of a drum in a water-tube boiler at the plant of the American Furniture Co., Batesville, Ind.

(393.) — A boiler exploded, November 14, in the American Milling Co.'s stock food factory, at Linden, ten miles from Crawfordsville, Ind. George Smith, Roy Mangus, and Warner Keefe were injured so badly that their recovery was considered to be doubtful, and two other men were injured to a lesser degree. Fire followed the explosion, and the total property loss was estimated to be $20,000.

(394.) — On November 14 a blowoff pipe ruptured in the flouring mill and elevator of the Farmers' & Merchants' Mill Co., Ripley, Tenn.

(395.) — A boiler exploded, November 14, at the Huselton & Co. well, on the Ewing farm, in the O'Brien oil field, near Butler, Pa. William Aggas and Addison Hamilton were injured.

(396.) — A tube ruptured, November 14, in a water-tube boiler at the American Gas & Electric Co.'s electric power station, Canton, Ohio.

(397.) — A slight boiler explosion occurred, November 16, in the Davies Laundry, South Bend, Ind. Warren T. Davies, manager, was painfully burned.

(398.) — The boiler of a freight locomotive exploded, November 16, on the St. Louis & San Francisco railroad, near Hayti, Mo. Brakeman Frederick Bossler was instantly killed, fireman H. C. Brock was injured so badly that he died a few hours later, and conductor J. H. Hathaway was fatally injured. Engineer Samuel Frissell was badly hurt, but at last accounts it was thought that he would recover. Sixteen loaded box cars were demolished.

(399.) — A boiler exploded, November 17, in Calvin H. Mack's sawmill, five miles east of Tallulah, La. Mill foreman Solley received injuries that were probably fatal, and Samuel Douglas was injured badly but not fatally.

(400.) — A boiler exploded, November 18, near the Armour plant in the stockyards at Chicago, Ill., killing William Somers, and injuring Arthur Babcock, John Burns, Charles Keefe, and two other men named Rundle and Thompson. It is said that the explosion occurred while the boiler was being tested with compressed air, to determine the amount of pressure it would stand. We presume it was found to be dangerous at the pressure at which it exploded. (This may be a stupid remark, but it isn't half so stupid as the destructive testing of a boiler by means of compressed air.)

(401.) — A heating boiler exploded, November 18, in the basement of the Big Horn County bank building, Basin, Wyo. The building was severely damaged.

(402.) — On November 19 a blowoff pipe ruptured on a boiler in the plant of the Cordele Lumber Co., Cordele, Ga.

(403.) — On November 19 a boiler exploded in David Hames' sawmill, in Billings township, near Melbourne, Ark. Elisha Billings and Richard Vickerey were seriously injured, and the mill was completely destroyed.

(404.) — Two tubes ruptured, November 20, in a water-tube boiler in the Huron Milling Co.'s plant, Harbor Beach, Mich.

(405.) — The boiler of a freight locomotive exploded November 21, at Ripley, N. Y. Fireman Tucker was killed, and engineer William Mayer and brakeman Wagner were scalded.

(406.) — A boiler explosion occurred, November 21, on the Mississippi river steamer *H. M. Carter,* eight miles below Plaquemine, La. George Le Blanc, Casimar Le Blanc, and five other men whose names we have not learned, were killed. Twelve persons were also injured, some of them fatally so. One account of the explosion says: "The *Carter* was an ill-fated boat, and was known as the 'hoodoo' of the river. She had been sunk four times, and each time raised. This time there is nothing left to raise. The explosion destroyed all of the machinery, and what was left of the wreckage of the boat was burned." The *Carter's* valuable cargo was also a total loss.

(407.) — A tube ruptured, November 24, in a water-tube boiler in the plant of the Consolidated Gas, Electric Light & Power Co., Westport, Md. Richard O'Neal, John O'Hara, and Leon Poliades were slightly burned.

(408.) — A slight boiler accident (apparently consisting in the rupture of a tube) occurred, November 25, in the electric lighting plant at Bluffton, Ind.

(409.) —The boiler of a Missouri, Kansas & Texas freight locomotive exploded, November 27, near Idenbro, six miles south of Parsons, Kans. Engineer F. E. Melville and fireman F. F. Wolff were killed, and brakeman C. E. Roe was fatally hurt.

(410.) — During the course of a fire, on November 28, a boiler exploded in the wharf-building plant of Henhoeffer & Vaughan, Camden, N. J.

(411.) — On November 28 a slight boiler accident occurred at the cereal mill of Conrad Geise & Son, Council Bluffs, Iowa.

(412.) — A cast-iron header fractured, November 28, in a water-tube boiler in the plant of the Torrington Co. and Excelsior Needle Co., Torrington, Conn.

(413.) — A boiler used for operating a corn-shredder exploded, November 28, on the premises of Jacob Bueg, two miles from Webster, N. Y., on the Shoecraft road. Mr. Bueg was fatally injured, and Paul Knopp was injured badly but not fatally.

(414.) — Several cast-iron headers fractured, November 29, in a water-tube boiler in the Samaritan Hospital, Philadelphia, Pa.

(415.) — A boiler exploded, November 29, at the Davidson coal mine, Uniontown, Ky. Fire followed the explosion, and the property loss was estimated at $10,000.

(416.) — On November 30 an accident occurred to a boiler in the plant of the Old '76 Distilling Co., Finchtown, Ky. The boiler was considerably damaged.

(417.) A six-inch flue collapsed November —, in a boiler used for grinding cane, on the Golden Gate plantation, Sunshine, Iberville parish, La.

December, 1908.

(418.) — A heating boiler ruptured, December 1, in the Dixon Hospital, Dixon, Ill.

(419.) — The boiler of a Chicago & Northwestern passenger locomotive exploded, December 1, at Evanston, Ill. Fireman J. H. Wall was scalded, and the locomotive was wrecked.

(420.) — A blowoff pipe failed, December 3, in L. R. Gleason & Son's tannery, Driftwood, Pa.

(421.) — A cast-iron header fractured, December 3, in a water-tube boiler at the Philadelphia Rapid Transit Co.'s power house, 33rd and Market streets, Philadelphia, Pa.

(422.) — A hot-water heating boiler exploded, December 3, in a three-story brick apartment house on Aldrich avenue, north, at Minneapolis, Minn.

(423.) — On December 3 a steam main exploded, between the boiler and the stop valve, in Spang, Chalfant & Co.'s rolling mill, Etna, Pa. Peter Gilroy, Michael Winskie, Michael Flanagan, Emil Zimmerman, and Joseph Rohrer were injured.

(424.) — On December 4 a boiler exploded in Samuel Drewry's sawmill, near Brooks, Ga.

(425.) — The boiler of an Ontario & Western freight locomotive exploded, December 4, at Fair Oaks, three miles from Middletown, N. Y. Fireman William P. Kelly was injured seriously and perhaps fatally, and engineer John Dougherty and conductor George L. Knox were injured slightly. The locomotive whose boiler exploded was almost completely demolished, and another locomotive, which was coupled to it, was thrown over an embankment and badly damaged.

(426.) — A tube burst, December 5, in a water-tube boiler in the Ohio Hospital for Epileptics, Gallipolis, Ohio. Fireman Frank Harmon was instantly killed.

(427.) — A tank used for storing hot water under pressure exploded, December 7, in the Wendell Towel Supply Co.'s laundry, on East 131st St., New York. Frank Joachim was slightly injured, and the laundry machinery was wrecked.

(428.) — A cast-iron header ruptured, December 7, in a water-tube boiler at the Louis Bergdoll Brewing Co.'s plant, Philadelphia, Pa.

(429.) — On December 7 a section fractured in a cast-iron heating boiler in a public school building at Cripple Creek, Colo.

(430.) — The boiler of a Chicago, Milwaukee & St. Paul locomotive exploded, December 8, at Elwood, Iowa. Three men were seriously injured.

(431.) — The crown sheet of a locomotive collapsed, December 8, at the Caswell Creek colliery of the Pocahontas Consolidated Collieries Co., Simmons, W. Va. Engineer William Vincent, machinist John Russell, and brakeman Robert Muse, who were on the locomotive at the time, were injured.

(432.) — A steam heating boiler exploded, December 9, in the residence of Louis Sterling, Bay City, Mich. Mr. Sterling's six-year-old son was badly scalded, and the building was considerably damaged.

(433.) — A boiler exploded, December 9, in G. W. Thompson's sawmill, at Drakesboro, Ky. The owner's two sons, Samuel and Benjamin Thompson, were killed.

(434.) — A slight boiler accident occurred, December 9, at the De Hodiamont power station of the United Railways Co. of St. Louis, St. Louis, Mo. George Ernest, Walter Bryan, and George Jackson were badly scalded.

(435.) — On December 9 a boiler exploded in Edward Goodman's cotton gin, near Concord, N. C. Lloyd Haynes was killed.

(436.) — A heating boiler exploded, December 9, in the Seaford High School, Seaford, Del. The building contained 800 children at the time, but panic was prevented by the coolness of the teachers, and the pupils marched out in an orderly manner, singing as they went.

(437.) — A tube ruptured December 11, in a water-tube boiler at the International Salt Co.'s plant, Ludington, Mich. Martin Kovak was scalded.

(438.) — On or about December 11 a boiler exploded in Ernest E. Webb's steam laundry, Sanford, Fla. The owner was terribly bruised, and may not recover.

(439.) — The boiler of a Southern Pacific freight locomotive exploded, December 12, at Beaumont, Riverside county, Cal. Engineer David McDonald, fireman Roy Reynolds, and conductor Guy Brockman were instantly killed, and head brakeman E. A. Williams was seriously injured.

(440.) — Three sections of a cast-iron sectional heating boiler fractured, December 13, in the office building at 2 and 4 Park Square, Boston, Mass.

(441.) — On December 13 a boiler exploded at the J. W. Roberson Coal Co.'s mine, Weir City, Kans.

(442.) — A boiler exploded, December 14, in George Smith's sawmill, in King George county, Va. Thomas Page was killed.

(443.) — On December 14 a boiler exploded in Andrew Foley's sawmill, near Russell Springs, Russell county, Ky. John Boyle was instantly killed, and three other men were severely scalded.

(444.) — A boiler used for heating water exploded, December 14, in A. E. Nelson's artificial stone works, Minneapolis, Minn. John Reich was killed. The building was considerably damaged, and one fragment of the boiler was thrown 200 feet into the air.

(445.) — The boiler of a freight locomotive exploded, December 16, on the Chicago & Eastern Illinois railroad, at Goreville, Ill. The engineer was killed, and the fireman and a flagman were fatally injured.

(446.) — A boiler exploded, December 16, at the Buffalo mine, Cobalt, Can. One man was seriously injured.

(447.) — A boiler belonging to the Chester Drilling Co., and used in drilling for oil, exploded, December 17, on the Hugh Leeper farm, near Hookstown, Beaver county, Pa.

(448.) — A tube ruptured, December 19, in a water-tube boiler at the power house of the Pennsylvania & Ohio Railway Co., Ashtabula, Ohio.

(449.) — A boiler exploded, December 19, in Dr. C. W. Lawrence's cotton gin, Longview, Tex. Fireman William Poe was killed, and two children named Bush were seriously injured. The explosion wrought considerable damage.

(450.) — A slight boiler explosion occurred, December 19, in William Vogel & Bros.' tin factory, South Ninth St., Brooklyn, N. Y.

(451.) — On December 20 the cast-iron mud-drum of a water-tube boiler exploded at the General Electric Co.'s plant, Schenectady, N. Y. Fireman Adam Conga was injured.

(452.) — On December 21 five sections of a cast-iron sectional heating boiler fractured in the Lowell School, Watertown, Mass.

(453.) — A boiler exploded, December 22, in a saw-mill operated by William Hayes and Patrick Brewer, at Wind Cave, Jackson county, Ky. William Andrews was instantly killed, and Patrick Brewer was fatally injured. James Brewer and Gentry Spivy were also injured, but not fatally so.

(454.) — A blowoff pipe failed, December 22, in the electric light plant, Atlantic, Iowa.

(455.) — A blowoff pipe failed, December 23, in the Iowa Condensed Milk Co.'s plant, West Liberty, Iowa.

(456.) — A slight boiler accident occurred, December 24, in the New York Hat Co.'s store, conducted by Spitzer Bros., Elmira, N. Y.

(457.) — The head of a blowoff tank blew off, December 24, in the Todd building, Louisville, Ky. The engineer was instantly killed.

(458.) — On December 24 a blowoff pipe failed in F. Eckenroth & Son's planing mill, New York City.

(459.) — A blowoff tank exploded, December 25, in the basement of the "Chronicle" building, San Francisco, Cal. Engineer Thomas Wafer was burned so badly that he died two days later, and another man was injured less seriously.

(460.) — On December 28 three cast-iron headers fractured in a water-tube boiler at the Pressed Steel Car Co.'s plant, McKees Rocks, Pa.

(461.) — The boiler of a traction engine belonging to John M. Grimmer exploded, December 30, on Emil Watschinger's farm, some five miles east of Mascoutah, St. Clair county, Ill.

(462.) — A heating boiler exploded, December 30, in the basement of an apartment building at 101 Quincy street, Brooklyn, N. Y. Janitor Frederick Munthe and his two little daughters, Mabel and Isabella, were badly injured. Mabel died shortly afterwards, and it is doubtful if her father and sister can recover.

(463.) — A slight explosion occurred December 31, on a Rio Grande locomotive at Isabel, Tex. Fireman Juan Leica was terribly burned, and the engineer, whose name we have not learned, was also badly scalded.

Boiler Explosions During 1908.

We present, herewith, our usual annual summary of boiler explosions, giving a tabulated statement of the number of explosions that have occurred within the territory of the United States (and in adjacent parts of Canada and Mexico) during the year 1908, together with the number of persons killed and injured by them. As we have repeatedly explained, it is difficult to make out accurate lists of boiler explosions, because the accounts that we receive are not always satisfactory; but, as usual, we have taken great pains to make the present summary as nearly correct as possible. It is based upon the monthly lists of explosions that are published in THE LOCOMOTIVE; and in making out these lists it is our custom to obtain several different accounts of each explosion, whenever this is practicable, and then to compare these accounts diligently, in order that the general facts may be stated with a considerable degree of accuracy. We have striven to include all the explosions that have occurred during 1908, but it is quite unlikely that we have been entirely successful in this respect, for many accidents have doubtless occurred that have not been noticed in the public press, and many have doubtless escaped the attention of our numerous representatives who furnish the accounts. We are confident, however, that most of the boiler explosions that have attracted any considerable amount of notice are here represented.

The total number of boiler explosions in 1908, according to the best information we have been able to obtain, was 470, which is almost exactly the same as the number in 1907. There were 471 in 1907, 431 in 1906, 450 in 1905, and 391 in 1904. When two or more boilers have exploded simultaneously, we have followed our usual practice and counted each boiler separately in making out the summary, believing that by so doing we should represent the actual damage more accurately than we should if we simply recorded the number of separate occasions on which boilers have exploded. In some few cases two accidents have happened in the same boiler room, on the same day. These have been counted separately, in preparing the summary. (See, for example, No. 366, in the list for October, printed in the present issue.)

Summary of Boiler Explosions for 1908.

Month.	Number of Explosions.	Persons Killed.	Persons Injured.	Persons Killed and Injured.
January, ...	48	13	39	52
February, ...	51	25	111	136
March, ...	37	20	33	53
April, ...	31	15	35	50
May, ...	23	9	30	39
June, ...	28	28	24	52
July, ...	32	19	32	51
August, ...	35	37	55	92
September, ...	39	21	36	57
October, ...	55	27	49	76
November, ...	45	45	53	98
December, ...	46	22	34	56
Totals, ...	470	281	531	812

The number of persons killed by boiler explosions in 1908 was 281, against 300 in 1907, 235 in 1906, 383 in 1905, and 220 in 1904; and the number of persons injured (but not killed) in 1908 was 531, against 420 in 1907, 467 in 1906, 585 in 1905, and 394 in 1904.

The average number of persons killed, per explosion, during 1908, was 0.598, and the average number of persons injured but not killed, was 1,130.

A summary of the boiler explosions that we have recorded as occurring in the United States, Canada, and Mexico, during the past forty-one years, will be found in the present issue, under the heading "Ten Thousand Boiler Explosions."

On January 1 Mr. Francis T. Maxwell, president of the Hockanum Mills Company, of Rockville, Conn., was elected a director of the Hartford Steam Boiler Inspection and Insurance Company, in the place of the late Mr. George A. Fairfield.

Inspectors' Reports.

On pages 152, 153, and 154 we give a general summary of the work done by the inspectors of the Hartford Steam Boiler Inspection and Insurance Company, showing the number of defects of various kinds that were discovered each month, from April, 1908, to December, 1908, inclusive. The number of visits of inspection made, and various other data respecting the work during this period, are given in the "Summary by Months," on page 158.

Inspectors' Reports for April, May and June, 1908.

Nature of Defects.	April.		May.		June.	
	Total defects.	Dangerous.	Total defects.	Dangerous.	Total defects.	Dangerous.
Cases of deposit of sediment,	1,731	112	1,724	110	1,814	97
Cases of incrustation and scale,	3,599	124	3,243	102	3,720	108
Cases of internal grooving,	228	18	274	25	280	27
Cases of internal corrosion,	1,025	41	1,077	43	1,463	65
Cases of external corrosion,	845	62	857	64	943	84
Defective braces and stays,	173	48	190	42	134	46
Settings defective,	535	82	458	74	555	47
Furnaces out of shape,	688	35	625	43	671	37
Fractured plates,	294	36	264	39	290	43
Burned plates,	427	40	428	32	420	43
Laminated plates,	61	5	70	7	94	3
Cases of defective riveting,	276	38	242	43	210	47
Defective heads,	157	17	159	36	158	30
Leakage around tubes,	934	165	1,035	174	1,053	399
Cases of defective tubes,	611	160	725	212	723	157
Tubes too light,	191	40	123	34	252	76
Leakage at joints,	465	33	407	24	422	44
Water-gages defective,	222	67	226	58	203	64
Blow-offs defective,	336	121	331	100	380	115
Cases of deficiency of water,	47	19	28	11	43	21
Safety-valves overloaded,	113	42	119	32	78	31
Safety-valves defective,	144	52	97	35	98	25
Pressure gages defective,	663	64	642	59	636	50
Without pressure gages,	14	14	14	14	26	26
Unclassified defects,	2	0	1	1	0	0
Totals,	13,781	1,435	13,359	1,414	14.666	1,685

Inspectors' Reports for July, August and September, 1908.

Nature of Defects.	July.		August.		September.	
	Total defects.	Dangerous.	Total defects.	Dangerous.	Total defects.	Dangerous.
Cases of deposit of sediment,	1,858	105	1,468	89	1,471	109
Cases of incrustation and scale,	3,525	98	3,055	65	3,047	94
Cases of internal grooving,	270	22	205	8	248	27
Cases of internal corrosion,	1,606	67	1,272	36	1,104	52
Cases of external corrosion,	950	65	846	62	738	53
Defective braces and stays,	139	39	152	27	158	43
Settings defective,	517	50	357	42	413	42
Furnaces out of shape,	687	44	543	15	523	10
Fractured plates,	266	28	225	46	231	27
Burned plates,	365	32	348	15	364	26
Laminated plates,	73	3	49	2	46	2
Cases of defective riveting,	348	62	253	41	332	106
Defective heads,	123	15	112	11	172	18
Leakage around tubes,	938	160	695	60	856	99
Cases of defective tubes,	674	235	419	109	1,028	111
Tubes too light,	154	30	127	25	119	42
Leakage at joints,	414	38	340	32	314	24
Water-gages defective,	179	35	156	28	198	54
Blow-offs defective,	341	99	253	87	261	67
Cases of deficiency of water,	24	9	19	5	27	6
Safety-valves overloaded,	93	33	70	22	106	42
Safety-valves defective,	74	25	63	14	69	31
Pressure gages defective,	576	28	523	32	577	45
Without pressure gages,	34	34	29	29	17	17
Unclassified defects,	0	0	0	0	0	0
Totals,	14,228	1,356	11,579	902	12,419	1,147

Inspectors' Reports for October, November, and December, 1908.

Nature of Defects.	October.		November.		December.	
	Total defects.	Dangerous.	Total defects	Dangerous	Total defects	Dangerous.
Cases of deposit of sediment,	1,571	88	1,374	97	1,478	98
Cases of incrustation and scale,	3,061	78	2,760	107	2,888	109
Cases of internal grooving,	206	15	219	11	222	38
Cases of internal corrosion,	901	18	861	42	957	66
Cases of external corrosion,	757	38	756	77	659	59
Defective braces and stays,	178	47	172	48	183	65
Settings defective,	425	46	453	56	425	31
Furnaces out of shape,	616	46	561	27	498	32
Fractured plates,	257	33	295	43	276	58
Burned plates,	348	36	369	36	382	38
Laminated plates,	39	1	42	1	38	1
Cases of defective riveting,	265	43	232	86	326	65
Defective heads,	135	13	116	9	102	12
Leakage around tubes,	804	198	923	218	1,039	209
Cases of defective tubes,	576	181	540	149	875	186
Tubes too light,	82	18	86	24	103	15
Leakage at joints,	368	23	413	29	411	42
Water-gages defective,	210	50	227	31	189	47
Blow-offs defective,	290	73	340	96	304	82
Cases of deficiency of water,	32	19	21	8	27	11
Safety-valves overloaded,	120	30	90	23	95	36
Safety-valves defective,	74	22	94	32	108	45
Pressure-gages defective,	576	34	593	46	586	51
Without pressure-gages,	16	16	20	20	24	24
Unclassified defects,	0	0	0	0	0	0
Totals,	11,907	1,166	11,557	1,316	12,195	1,420

The Locomotive.

A. D. Risteen, Ph.D., Editor.

HARTFORD, JANUARY 25, 1909.

The Locomotive *can be obtained free by calling at any of the company's agencies.*
Subscription price 50 cents per year when mailed from this office.
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Agency Changes.

For a number of years past, our Southeastern department has been conducted through a divided agency, its executive management being at Charleston, S. C., while the inspection work has been directed from Atlanta, Ga. The business of the department has now grown to such proportions that it is no longer practicable to conduct it in this manner, and a consolidation of the two offices has become necessary. In effecting this consolidation, it is highly desirable to locate the central office at Atlanta, not only because that city is much nearer to the geographical center of the territory that the department covers, but also because much of the business of the department is tributary to Atlanta, or is located upon transportation lines readily accessible therefrom. Messrs. W. S. Hastie & Son, of Charleston, who have long and ably represented this company as its general agents, have been unable to consider any proposition to continue with us in this capacity, in the city of Atlanta, as their other large interests would not permit them to leave Charleston. They have therefore tendered their resignation, and Mr. W. M. Francis has been appointed manager of the department, with offices at Nos. 611, 612 and 613 Empire Building, Atlanta, Ga. We are pleased to state, however, that Messrs. W. S. Hastie & Son are not severing their connection with us entirely, as they will continue to represent us in Charleston and vicinity. Mr. W. M. Francis, the new manager, is well and favorably known to our friends and patrons throughout the department, as he has been chief inspector there for many years.

An important administrative change has also been made in the Ohio region, by the establishment of a general agency at Cincinnati. Heretofore the business of that section has been conducted through the Chicago department, to which the Cincinnati office has been tributary; but our interests have grown to such a magnitude that the rendering of prompt and efficient service to our assured requires the placing of the Cincinnati department upon an independent basis, so that it can be brought into more direct relation with the home office. Mr. W. E. Gleason, who has been associated with the Cincinnati branch office for many years, will be manager of the new Cincinnati department, and Mr. B. F. Cooper, who has had charge of the local inspection force for an even longer period, will be chief inspector. The offices will be at 67, 68, and 69 Mitchell Building, Cincinnati, Ohio. The territory covered by the new department will embrace the southern part of Ohio, the eastern part of Kentucky, and a portion of Indiana.

Obituary.

George Albert Fairfield.

With deep regret we record the death, on November 9, 1908, of Mr. George A. Fairfield, who was a director of this company, and one of the best known business men in the city of Hartford.

Mr. Fairfield was born at Lansingburg, New York, March 20, 1834; but his family moved to western Massachusetts when he was four years old, and here his youth was spent, working upon a farm and attending school, until he was seventeen. He then went, as an apprentice, into the machine shop of Lucius and Ira Dimmock, at Northampton, Massachusetts, and two years later he entered the Holyoke Machine Shop as a day workman. After a varied experience in mechanical lines, during which he lived in Ohio, Virginia, and again in Massachusetts, Mr. Fairfield came to Hartford in 1857, entering the employ of the Colt's Patent Fire Arms Manufacturing Company, where he worked, at first, upon a contract for the Russian government. Later he became a contractor at Colt's, himself, and, subsequently, he was the largest contractor there. In January, 1858, he opened a school of mechanical drawing at Hartford, and in this school some of the most successful mechanics and engineers of the city had their early training. In 1865 he became associated with the Weed Sewing Machine Company, which, largely through his labors, became a great concern. Subsequently he engaged with Colonel A. A. Pope in the manufacture of bicycles, and he was therefore instrumental in the foundation of what has since become one of Hartford's largest industries. About 1876 he became interested with Mr. C. M. Spencer in the manufacture of machine screws, and from the small foundation thus laid he developed the Hartford Machine Screw Company, of which he was the executive head for many years.

Mr. Fairfield's business acumen, together with his charming personality and his tireless activity, brought him into close relations with many of the leading financial institutions of Hartford. He was a director of the Hartford National Bank, the Mechanics Savings Bank, the Hartford County Fire Insurance Company, the Hartford Steam Boiler Inspection and Insurance Company, and the Western Automatic Screw Company, and at the time of his death he was secretary of the Hartford Board of Trade. His wife survives him, and he also leaves a son, George E. Fairfield, and a daughter, Mrs. W. S. Andrews, both of this city.

The directors of the Hartford Steam Boiler Inspection and Insurance Company, in taking formal notice of Mr. Fairfield's death, adopted the following minute, which was entered upon its records:

"The members of this Board desire to record their sorrowful appreciation of the loss they have sustained, in the death of their friend and associate, George A. Fairfield.

"Mr. Fairfield had served as a member of the Board for more than ten years, having been elected to it on February 15, 1898; and during all that period he had attended its meetings regularly and conscientiously, assisting in its deliberations with counsel born of a wide experience. He brought to its service a rare combination of faculties; for while he was noted for his conservatism, and for his advocacy of prudence and of safety, he was nevertheless courageous, forceful, and virile, and ready to bend vast energies to the realization and accomplishment of any end that he had once determined to be right and wise.

"The members of this Board have lost, not only a fellow member whose counsel was earnestly sought and highly prized, but also a friend whose genial presence will be greatly missed. He was a power in the business and financial world, yet he was simple, kindly, charitable, and loving; — a pleasant, thoughtful, considerate companion, yet a man of great strength and high character, who has left an indelible impress upon Hartford institutions."

Summary of Inspectors' Reports for the Year 1908.

During the year 1908 the inspectors of the Hartford Steam Boiler Inspection and Insurance Company made 167,951 visits of inspection, examined 317,537 boilers, inspected 124,990 boilers both internally and externally, subjected 10,449 to hydrostatic pressure, and found 572 unsafe for further use. The whole number of defects reported was 151,359, of which 15 878 were considered dangerous. The usual classification by defects is given below, and a summary by months is given on page 158.

Summary, by Defects, for the Year 1908.

Nature of Defects.	Whole Number.	Dangerous.
Cases of deposit of sediment,	18,879	1,242
Cases of incrustation and scale,	37,924	1,193
Cases of internal grooving,	2,649	249
Cases of internal corrosion,	13,053	555
Cases of external corrosion,	9,400	698
Defective braces and stays,	1,993	503
Settings defective,	5,341	642
Furnaces out of shape,	6,981	380
Fractured plates,	3,119	482
Burned plates,	4,605	440
Laminated plates,	666	44
Cases of defective riveting,	3,395	713
Defective heads,	1,565	223
Leakage around tubes,	10,929	2,103
Cases of defective tubes,	8,026	2,136
Tubes too light,	1,636	432
Leakage at joints,	4,845	392
Water-gages defective,	2,411	585
Blow-offs defective,	3,818	1,125
Cases of deficiency of water,	391	147
Safety-valves overloaded,	1,216	379
Safety valves defective,	1,068	359
Pressure gages defective,	7,120	531
Without pressure gages,	322	322
Unclassified defects,	7	3
Total,	151,359	15,878

SUMMARY BY MONTHS FOR 1908.

MONTH.	Visits of inspection.	Number of boilers examined.	No. inspected internally and externally.	No. tested hydro-statically.	No. con-demned.	No. of defects found.	No. of dangerous defects found.
January, .	15,169	28,722	9,388	523	39	11,515	1,255
February, .	14,003	26,348	8,623	585	40	11,522	1,431
March, . .	15,004	27,790	9,309	742	35	12,631	1,351
April, . .	14,176	26,901	11,085	837	39	13,781	1,435
May, . . .	13,408	25,156	10,798	811	41	13,359	1,414
June, . . .	13,797	25,263	12,380	1,083	75	14,666	1,685
July, . . .	13,074	24,217	12,702	1,361	61	14,228	1,356
August, . .	11,883	22,412	10,740	994	37	11,579	902
September, .	12,869	24,681	10,637	1,004	45	12,419	1,147
October, .	15,104	28,947	10,283	997	52	11,907	1,166
November, .	14,534	27,890	9,469	833	47	11,557	1,316
December, .	14,930	29,210	9,576	679	61	12,195	1,420
Totals, .	167,951	317,537	124,990	10,449	572	151,359	15,878

COMPARISON OF INSPECTORS' WORK DURING THE YEARS 1907 AND 1908.

	1907.	1908.
Visits of inspection made, . . .	163,648	167,951
Whole number of inspections made, . .	308,571	317,537
Complete internal inspections, . .	124,610	124,990
Boilers tested by hydrostatic pressure, .	13,799	10,449
Total number of defects discovered, . .	159,283	151,359
" " of dangerous defects, . .	17,345	15,878
" " of boilers condemned, . .	700	572

The following table is also of interest. It shows that our inspectors have made over two million and three quarters of visits of inspection, and that they have made more than five million inspections, of which over two million were complete internal inspections. The hydrostatic test has been applied in more than a quarter of a million cases. Of defects, nearly three and a half million have been discovered and pointed out to the owners of the boilers; and more than a third of a million of these defects were, in our opinion, dangerous.

GRAND TOTAL OF THE INSPECTORS' WORK SINCE THE COMPANY BEGAN BUSINESS, TO JANUARY 1, 1909.

Visits of inspection made, . . .	2,779,262
Whole number of inspections made, . .	5,371,522
Complete internal inspections, . . .	2,102,444
Boilers tested by hydrostatic pressure, .	261,786
Total number of defects discovered, . .	3,484,709
Number of dangerous defects discovered, .	359,098
Total number of boilers condemned, . .	19,700

Hartford Steam Boiler Inspection and Insurance Company.

ABSTRACT OF STATEMENT, JANUARY 1, 1909.

Capital Stock, . . . $1,000,000.00.

ASSETS.

	Per Value.	Market Value.
Cash in office and in Bank, ...		$143,227.09
Premiums in course of collection (since Oct. 1, 1908),		274,020.83
Agents' cash balances, ...		23,011.96
Interest accrued on Mortgage Loans, . . .		25,965.64
Interest accrued on Bonds, ...		35,154.54
Loaned on Bond and Mortgage, ...		1,024,865.00
Real estate, . . . , ...		95,100.00
State of Massachusetts Bonds, ...	$100,000.00	88,000.00
County, City and Town Bonds, ...	399,000.00	407,360.00
Board of Education and School District Bonds, .	24,000.00	24,500.00
Railroad Bonds, ...	1,478,000.00	1,576,960.00
Street Railway Bonds, ...	173,000.00	171,010.00
Miscellaneous Bonds, ...	87,500.00	83,450.00
National Bank Stocks, ...	29,300.00	43,840.00
Railroad Stocks, , ...	215,900.00	263,901.35
Miscellaneous Stocks, ...	180,100.00	144,060.00
	$2,686,800.00	
Total Assets, ...		$4,424,426.41

LIABILITIES.

Re-insurance Reserve, ...		$1,885,729.16
Commissions and brokerage, ...		54,804.17
Other liabilities (Taxes accrued, etc.), . . .		37,476.54
Losses Unadjusted, ...		28,382.11
Surplus, ...	$1,418,034.43	
Capital Stock, ...	1,000,000.00	
Surplus as regards Policy-holders, .	**$2,418,034.43**	2,418,034.43
Total Liabilities, ...		$4,424,426.41

On December 31, 1908, the Hartford Steam Boiler Inspection and Insurance Company had 102,176 steam boilers under insurance.

L. B. BRAINERD, Pres. and Treas. FRANCIS B. ALLEN, Vice-President.
C. S. BLAKE, Secretary. L. F. MIDDLEBROOK, Asst. Sec.
A. S. Wickham, Superintendent of Agencies.
E. J. Murphy, M. E., Consulting Engineer.
F. M. Fitch, Auditor.

Board of Directors.

FRANK W. CHENEY, Treas. Cheney Brothers Silk Manufacturing Co.
CHARLES M. BEACH, of Beach & Co.
GEORGE BURNHAM, Baldwin Locomotive Works, Philadelphia.
PHILIP CORBIN, Prest. American Hardware Corporation, New Britain, Conn.
ATWOOD COLLINS, Prest. Security Co., Hartford, Conn.
LUCIUS F. ROBINSON, Attorney, Hartford, Conn.
JOHN O. ENDERS, U. S. Bank, Hartford, Conn.
LYMAN B. BRAINERD, Director, Swift & Company.
MORGAN B. BRAINARD, Treasurer Ætna Life Insurance Co.
F. B. ALLEN, Vice-Prest., Hartford Steam Boiler Inspection and Insurance Co.
CHARLES P. COOLEY, Vice-Prest., Fidelity Trust Company, Hartford, Conn.
ARTHUR L. SHIPMAN, Attorney, Hartford, Conn.
GEORGE C. KIMBALL, President Smyth Manufacturing Co., Hartford, Conn.
CHARLES M. JARVIS, 1st Vice-Prest. American Hardware Corporation, New Britain, Conn.
FRANCIS T. MAXWELL, President, Hockanum Mills Co., Rockville, Conn.

Incorporated 1866. Charter Perpetual.

The Hartford Steam Boiler Inspection and Insurance Company

ISSUES POLICIES OF INSURANCE COVERING

ALL LOSS OF PROPERTY

AS WELL AS DAMAGE RESULTING FROM

LOSS OF LIFE AND PERSONAL INJURIES DUE TO STEAM BOILER EXPLOSIONS.

Full information concerning the Company's Operations can be obtained at any of its Agencies.

Department.	Representatives.	Offices.
NEW YORK, . .	C. C. GARDINER, JR., Manager, R. K. MCMURRAY, Chief Inspector,	New York City, N. Y., 100 William St.
BOSTON, . . .	C. E. ROBERTS, Manager, F. S. ALLEN, Chief Inspector,	Boston, Mass., 101 Milk St. Providence, R. I., 17 Custom House St.
PHILADELPHIA, .	CORBIN & GOODRICH, Gen. Agents, WM. J. FARRAN, Chief Inspector,	Philadelphia, Pa., 432 Walnut St.
BALTIMORE, . .	LAWFORD & MCKIM, Gen. Agents, R. E. MUNRO, Chief Inspector,	Baltimore, Md., 13-14-15 Abell Bldg. Washington, D. C., 511 Eleventh St., N.W.
ATLANTA.. . .	W. M. FRANCIS, Manager, W. M. FRANCIS, Chief Inspector,	Atlanta, Ga., 611-613 Empire Bldg.
BIRMINGHAM, .	LOUIS V. CLARK & CO., Gen. Agents, H. E. STRINGFELLOW, Chief Inspector,	Birmingham, Ala., 214-216 N. 20th St.
NEW ORLEANS, .	PETER F. PESCUD, General Agent, R. T. BURWELL, Chief Inspector,	New Orleans, La., 833-835 Gravier St.
HARTFORD, . .	E. H. WARNER, General Agent, H. C. LONG, Special Agent, F. H. WILLIAMS, JR., Special Agent, F. S. ALLEN, Chief Inspector,	Hartford, Conn., 56 Prospect St.
BRIDGEPORT, . .	W. G. LINEBURGH & SON, Gen. Agts., F. S. ALLEN, Chief Inspector,	Bridgeport, Conn., 1 Sanford Building.
PITTSBURG, . .	JAMES W. ARROTT, LTD., Gen. Agt., BENJAMIN FORD, Chief Inspector,	Pittsburg, Pa., 401 Wood Street.
CLEVELAND, . .	H. A. BAUMHART, Manager, H. A. BAUMHART, Chief Inspector,	Cleveland, Ohio, Century Building.
CINCINNATI. . .	W. E. GLEASON, Manager, B. F. COOPER, Chief Inspector,	Cincinnati, Ohio. 67-69 Mitchell Bldg.
CHICAGO, . . .	H. M. LEMON, Manager, JAMES L. FOORD, Chief Inspector,	Chicago, Ill., 169 Jackson St.
ST. LOUIS, . .	V. HUGO, Manager, V. HUGO, Chief Inspector,	St. Louis, Mo., 319 North Fourth St.
DENVER, . . .	THOS. E. SHEARS, General Agent, THOS. E. SHEARS, Chief Inspector,	Denver, Col., Room 2, Jacobson Bldg.
SAN FRANCISCO, .	H. R. MANN & CO., General Agents, J. B. WARNER, Chief Inspector,	San Francisco, Cal., Merchants' Ex. Bldg.
PORTLAND, . .	MCCARGAR, BATES & LIVELY, G. Agts., C. B. PADDOCK, Chief Inspector,	Portland, Ore., Failing Building.

The Locomotive

Vol. XXVII. HARTFORD, CONN., APRIL, 1909. No. 6.

Explosion of a Rendering Tank.

The half-tone engraving that we present herewith will give some idea of the damage that was done by the recent explosion of a tallow rendering tank, in the southwest. Fortunately nobody was killed, and there were no serious personal injuries; but the property loss was $22,500.

The operation of rendering tallow consists in treating the material from which the tallow is prepared with live steam, for some hours, under a gage

View of the Wrecked Plant.

pressure of 40 pounds per square inch, or thereabouts. On the afternoon preceding the accident that we are about to describe, the tank that exploded was put into service at about three o'clock, and orders were left with the night man to shut off the steam pressure at half past four on the following morning. At four o'clock the night man started on his regular round through the buildings, to ring up his night signals, and ten minutes later, when he was on the third floor of the building in which the tank stood, the explosion took place. He described what happened as "a heaving and a crumpling and a roaring"; and this probably gives as good an idea of the occurrence, from the standpoint of an eye-witness, as could be conveyed by a longer and more carefully prepared account.

The building in which the tank stood was a new one, and had a frontage of 200 feet on one street, and 150 feet upon another. It was badly wrecked, as will be seen by the illustration. The watchman had a narrow escape from death, for the building was thrown down all about him, save for a narrow piece of flooring upon which he found himself standing when the flying wreckage cleared away, and from which he could not descend. His position is indicated by the black cross. The night was bitterly cold, and when he was rescued by the firemen, half an hour after the accident, he was nearly frozen. Another employee, who was in the building, leaped from a second story window as the ruins fell, and was painfully bruised and strained.

The tank was not insured by the Hartford Steam Boiler Inspection and Insurance Company at the time, but it had been so insured up to within a few weeks of the explosion, and hence we are enabled to give accurate information respecting its design and construction.

It was built in 1903, and was cylindrical in form, standing upright. It was 54 in. in diameter and 10 ft. high. The shell was of steel, ½ in. thick, and was made of two sheets, each running lengthwise of the tank from head to head, these sheets being united by two longitudinal riveted joints, also running from head to head. The shell joints were lapped and double riveted, the rivets being of steel, one inch in diameter as driven, and pitched 3¾ in. from center to center. The heads were of wrought steel, ½ in. in thickness, and bumped to a depth of six inches at the center. There were two manholes, each 10 in. by 16 in., one being located in the upper head, while the other was situated in the shell, near the bottom of the tank.

An examination of the exploded tank, made some days after the accident, showed that the shell gave way in the following manner. One of the longitudinal joints began to fail at the bottom of the shell, owing to the fact that a crack had developed there, between the rivet holes. The rupture continued upward along the rivet holes for a distance of thirty inches, or approximately nine rivet-pitches, after which it passed out into the solid part of the sheet, where it followed along the outside edge of the lap of the joint, to within about thirty inches of the upper head. At this point the fracture left the joint entirely, and passed around the tank for a distance equal to about two-thirds of the circumference of the shell, extending diagonally upward as it progressed, so that it ended within 18 in. of the upper head. The bottom head became detached from the shell, owing to the failure of the rivets, and many of the rivets that had held the lower head in position remained in the shell. About one-fourth of the flange of the lower head also remained attached to the sheets.

The explosion was manifestly due to corrosion of the metal of the shell, and it affords a striking illustration of the importance of frequent and thorough inspections. Organic acids are developed in the treatment of the tallow under heat, and corrosion is almost certain to follow, sooner or later, from the action of such acids upon the metal of the tank. Moreover, this corrosion is often exceedingly rapid, when once it has made sufficient headway to penetrate the iron, beyond the surface skin. As stated above, the tank under discussion was only six years old, and it had been inspected regularly by us, so that our records show its condition from the time it was installed nearly down to the time of the explosion. No evidence of deterioration was discovered by the inspector until September 2, 1907, at which date he reported that there was a slight amount of deposit or incrustation upon the shell, but even at that date he found no signs of actual corrosion. The next internal inspection was made on June 19, 1908, when the inspector reported as follows: "There is a uniform wasting away of the shell plates along the sides, and the rivet heads in the seams are badly deteriorated. No repairs are needed at present, however."

From the condition of the plates after the explosion it is evident that the progress of the corrosion had been exceedingly rapid, so that the metal had become reduced, along the joint and between the rivet holes at the point of original fracture, to a thickness of 1/8 in., and along the line where the fracture ran through the solid plate the thickness had become reduced in some places to 1/32 in. The upper head was also wasted away to a considerable extent along the flange, the material being there reduced to less than half of its original thickness.

It should be remembered that the inspector, when writing the report dated June 19, expected to make another inspection within six months, and was prevented from doing so only by the tank passing out of our supervision in the meantime. A number of similar tanks had been condemned, in the past, in the same plant, from a like cause; and the history of the tank here described did not differ from that of the others that had been taken out in any essential respect, save in the unforeseen rapidity with which the corrosion progressed.

Boiler Explosions.

January, 1909.

(1.) — On or about January 1 a boiler exploded in Nicholas Petro's grist mill, one mile south of Nashville, Ind. Mr. Petro was instantly killed.

(2.) — On January 1 a pulp digester ruptured in the Burgess Sulphite Fibre Co.'s plant, Berlin, N. H.

(3.) — A boiler belonging to W. E. Price exploded, January 2, at Champaign, Ill.

(4.) — A boiler tube burst, January 3, on W. K. Vanderbilt's yacht *Tarantula,* near Havana, Cuba. Two of the crew were scalded.

(5.) — An accident occurred, January 3, to a boiler in the Anderson-Tully Co.'s sawmill, Vicksburg, Miss.

(6.) — A boiler exploded, January 4, in a sawmill at the Shenango Limestone Co.'s quarries, near Newcastle, Pa. John Reed and Jesse Reynolds were killed.

(7.) — On January 4 a slight boiler accident occurred in the heating and lighting plant at the State House, Springfield, Ill.

(8.) — On January 4 a boiler exploded on Palo Alto plantation, three miles from Donaldsonville, La. William M. Leonard was killed, and two other men were badly hurt.

(9.) — A boiler exploded, January 6, in a sawmill at Myrtle Point, Ore. Two persons were severely injured.

(10.) — A boiler exploded, January 6, in the Brooks building, East Liverpool, Ohio.

(11.) — On January 6 a tube ruptured in a water-tube boiler in the J. G. Brill Co.'s car manufacturing plant, Philadelphia, Pa. Andrew Morlinock was slightly injured.

(12.) — A boiler exploded, January 6, on a "Q" wrecker, at Troy, Iowa. One person was seriously injured.

(13.) — A boiler belonging to the Jones Bros. Constructing Co. exploded, January 6, at Louisville, Ky. The property loss was estimated at $4,000.

(14.) — The boiler of a Pennsylvania railroad locomotive exploded, January 7, two miles west of Williamsport, Pa. Engineer Morris L. Kendrick was badly hurt, and fireman C. H. Bell received lesser injuries.

(15.) — A boiler exploded, January 7, during the course of a fire in A. Herschel's cooper shop, on Linden Avenue, San Francisco, Cal. John Schafer was severely burned.

(16.) — A tube ruptured, January 8, in a water-tube boiler at the power station of the Pueblo & Suburban Traction & Lighting Co., Pueblo, Colo. Joseph McAuliffe was killed.

(17.) — On January 9 a tube ruptured in a water-tube boiler at the Scioto Valley Traction Co.'s power plant, at Reeses, near Columbus, Ohio.

(18.) —A heating boiler exploded, January 10, in the building occupied by the Raymond Company and Leuthold & Hinkley, Nashua, Iowa.

(19.) — On January 11 a tube ruptured in a water-tube boiler at the power plant of the American Railways Co., Dayton, Ohio. Firemen R. Smith and C. English were injured.

(20.) — A heating boiler exploded, January 11, in M. B. Little's residence, Glens Falls, N. Y.

(21.) — A corrugated furnace collapsed, January 11, in Swift & Co.'s plant, Houston, Tex.

(22.) — A number of cast-iron headers fractured, January 11, in a water-tube boiler at Lister's Agricultural Chemical Works, Newark, N. J. The property loss was something over $1,000.

(23.) — On January 12 a Baker heater exploded in a passenger car of the Santa Fé railroad, at San Angelo, Tex.

(24.) — A tube ruptured, January 12, in a water-tube boiler at the Phillemac Rolling Mill Co.'s plant, Woodlawn, Ohio.

(25.) — A tallow rendering tank exploded, January 12, in the St. Louis Hide & Tallow Co.'s plant, St. Louis, Mo. About half of the plant was destroyed, and the property loss was $22,500. George Hamilton was injured in escaping from the falling building, and night watchman George Koenig, who was left standing, by the explosion, upon a high and narrow ledge of the wrecked building, suffered considerably from exposure before he could be rescued by the firemen.

(26.) — A boiler exploded, January 13, in Welford's coal yards, Bowling Green, Ky. One person was fatally injured.

(27.) — A blowoff pipe failed, January 13, at the plant of Kramer Bros. & Co., Elizabeth City, N. C. Fireman Willis Weeks was slightly injured.

(28.) — On January 13 a boiler exploded in T. M. Harard's cotton gin, at Rosetta, Miss. Two men, named Tillery and Guy, were badly scalded.

(29.) — The boiler of Doolittle's portable sawmill exploded, January 13, some ten miles north of Millersburg, Mich., Engineer Peter Peterson was seriously and perhaps fatally burned, and the mill was wrecked.

(30.) — On January 14 a boiler ruptured in the Utah Fuel Co.'s plant, Somerset, Colo.

(31.) — A boiler exploded, January 15, in Kuene Bros.' grist mill, at Centerville, near Manitowoc, Wis. The property loss was about $500.

(32.) — A tube ruptured, January 15, in a water-tube boiler in the Indiana Steel Co.'s plant, Gary, Ind.

(33.) — A tube ruptured, January 15, in a water-tube boiler in the Denver City Tramway Co.'s plant, Denver, Colo.

(34.) — On January 15 a slight rupture occurred in a boiler at Cushing Academy, Ashburnham, Mass.

(35.) — A boiler exploded, January 15, in the Tremont High School, Pekin, Ill.

(36.) —A boiler exploded, January 15, in the Union Rolling Mill, Cleveland, Ohio. One person was killed and one fatally injured, and three others received lesser injuries.

(37.) — On January 15 a boiler exploded in the People's Gas & Electric plant, Mason City, Iowa. One person was seriously injured.

(38.) — On January 15 a small boiler exploded in Barnes' sawmill, on the Sandy Ford road, four miles from Laurens, S. C. John Woody, Washington McCreary, and Moses Shands were killed, and Elbert Shands was seriously injured.

(39.) — A boiler exploded, January 15, on the Halliday farm, Tilbury, Ont.

(40.) — A boiler used in grinding sugar cane exploded, January 16, on Henry Quin's farm, four miles east of Magnolia, La. John Thomas and one other person were badly scalded.

(41.) —A slight explosion occurred, January 16, in a heating boiler in the basement of a residence on Cumberland Avenue, Portland, Me., occupied by W. J. O'Neil and E. W. Motley.

(42.) — On January 16 a boiler exploded in Hanna's stave factory, on Brush Creek, near Linton, Tenn. Charles Green was seriously injured.

(43.) — On January 17 a boiler exploded at the sulphur mines, Sulphur, La. Two persons were injured.

(44.) — A tube ruptured, January 18, in a water-tube boiler in the McNeely Co.'s plant, Randolph Street, Philadelphia, Pa.

(45.) — The boiler of a D., M. & N. locomotive exploded, January 18, at West Duluth, Minn. One man was severely injured.

(46.) — A tube ruptured, January 18, in a water-tube boiler at the Kingston Coal Co.'s Gaylord colliery, Plymouth, Pa.

(47.) — A boiler belonging to Harry Dissler exploded, January 20, at Robinson, Ill. One person was severely injured.

(48.) — On January 20 a tube ruptured in a water-tube boiler at the Pueblo & Suburban Traction & Lighting Co.'s power plant, Pueblo, Colo. Firemen Clyde Roles and Edward Odiorne were injured.

(49.) — A boiler exploded, January 21, in an ice-house at Lonsdale, R. I.

(50.) — A boiler exploded, January 21, on the J. A. Crossman farm, Hammerstown, Pa. One person was killed, and two were severely injured.

(51.) — On January 21 the boiler of Aaron Kauffman's traction engine exploded in Lower Paxton township, near Middletown, Pa. Harry Minnich was instantly killed, and his brother, John Minnich, received injuries which may prove fatal. Two other young men were scalded, but not seriously so.

(52.) — A steam heating boiler, belonging to John M. Clement, exploded, January 22, at Schenectady, N. Y.

(53.) — A tube ruptured, January 24, in a water-tube boiler at the Waukegan plant of the American Steel & Wire Co., Waukegan, Ill.

(54.) — A hot-water tank, connected with the heating plant at the Century Boat Club's quarters, on South Broadway, St. Louis, Mo., exploded on January 24, damaging the building somewhat.

(55.) — A tube ruptured, January 24, in a water-tube boiler at the Berkshire Iron Works, Sheridan, Pa.

(56.) — A tube burst, January 25, in a boiler on the steamer *T. J. Potter*, at Portland, Ore.

(57.) — On or about January 25 a tube burst in a boiler in the traction company's car barns, West Washington Street, Indianapolis, Ind. George Lucid and James Moran were severely burned, and Mr. Lucid died from his injuries about a week later.

(58.) — A boiler exploded, January 27, at an oil well on the Price farm, at Mill Creek, Ohio, about three miles from Sistersville, W. Va. John Stewart, a tool dresser, was severely injured, and the boiler was blown to fragments.

(59.) — A boiler used for heating water exploded, January 28, in Kratchman Bros.' Turkish bath establishment, Monroe Street, Philadelphia, Pa. There were no bathers in the place at the time.

(60.) — On January 30 a boiler exploded in the gas plant at Warsaw, Ind.

(61.) — On January 31 a tube ruptured in a water-tube boiler at the Indiana Steel Co.'s plant, Gary, Ind.

February, 1909.

(62.) — On February 1 a tube ruptured in a water-tube boiler in the office building of the Dayton Arcade Co., Dayton, Ohio. Alfred Jones was scalded to death, and Walter Jones, Joseph Barth, and Ross Collins were scalded seriously, but not fatally.

(63.) — The crown sheet of a C., L. S. & E. R. R. locomotive failed, February 1, at Joliet, Ill. One man was severely injured.

(64.) — A cast-iron sectional heating boiler, belonging to F. A. Killian, ruptured, February 1, in the St. James Court apartment house, Brooklyn, N. Y.

(65.) — A boiler used in drilling for oil exploded, February 1, on the John Ryan farm, seven miles southeast of Bluffton, Ohio. John DeVore was badly scalded.

(66.) — A blowoff pipe failed, February 1, in the Minden Oil & Ice Mfg. Co.'s plant, Minden, La.

(67.) — A tube failed, February 1, in a water-tube boiler at the Inland Steel Co.'s plant, Indiana Harbor, Ind.

(68.) — On February 1 a mud drum, attached to a water-tube boiler, fractured in the Westinghouse Electric & Mfg. Co.'s plant, Allegheny, Pa.

(69.) — A boiler belonging to the G. A. Hosmer Co., of Buffalo, N. Y., exploded on February 2. Two persons were severely injured.

(70.) — On February 2 a boiler exploded in the rear of J. J. Richardson's store, Montreal, Ga. Oscar Talton was instantly killed, and Mr. Richardson was slightly injured.

(71.) — A slight rupture occurred, February 2, in a boiler owned by the Showers Bros. Co., Bloomington, Ind.

(72.) — On February 3 a boiler belonging to Alvin Arnold exploded at Petersburg, Ind. One person was severely injured.

(73.) — A tube ruptured, February 3, in a water-tube boiler at the Philadelphia Rapid Transit Co.'s power house, on Beach and Laurel Streets, Philadelphia, Pa.

(74.) — A boiler belonging to the Hardcastle Oil Co. exploded, February 3, at Sour Lake, Tex. George W. Mervin was instantly killed, and Frederick C. Marks, Augustus Shelander, and Charles Duffie were injured.

(75.) — A cast-iron unit ruptured, February 3, in a sectional power boiler at the Phosphor Bronze Smelting Co.'s plant, Philadelphia, Pa.

(76.) — On February 4 a boiler explosion occurred on the launch *Helen May*, at Vineyard Haven, Mass. One person was severely injured.

(77.) — On February 4 an accident occurred to a boiler in the Yakima Valley Power Co.'s plant, Kennewick, Wash.

(78.) — A cast-iron unit ruptured, February 4, in a sectional power boiler at the Tremont Nail Co.'s plant, West Wareham, Mass. Frank Domoniski was injured.

(79.) — A boiler belonging to the Wickham Coal Co. exploded, February 6, at Asbury Park, N. J. One person was injured.

(80.) — The boiler of a traction engine exploded, February 6, at Rock Rapids, Iowa.

(81.) — A tube ruptured, February 8, in a water-tube boiler at Charles T. Luckow's Globe Laundry, Chicago, Ill.

(82.) — On February 9 a boiler exploded in George Bennett's sawmill, near Mt. Vernon, Ill. Arthur Buller and Joseph Bennett (a son of the owner of the mill) were injured, and the mill was wrecked.

(83.) — On February 10 a heating boiler exploded in the residence of a man named Bramlet, at Denver, Colo.

(84.) — The boiler of a Great Northern passenger locomotive exploded, February 10, about a mile and a half south of Mukilteo, near Everett, Wash. Fireman Carl Bloom was killed outright, and engineer John Lenahan was injured so badly that he died soon afterwards. The train was wrecked, and the baggage and express cars entirely demolished, but no passengers were injured.

(85.) — On February 10 a tube ruptured in a water-tube boiler at the

Illinois Steel Co.'s plant, Joliet, Ill. Anton Sukos and Leslie Srygley were injured.

(86.) — A tube burst, February 10, in a boiler at the Grand Forks Gas & Electric Co.'s plant, Grand Forks, N. D.

(87.) — On February 11 a tube ruptured in a water-tube boiler at the New York & Pennsylvania Co.'s paper mill, Johnsonburg, Pa.

(88.) — A slight boiler explosion occurred, February 11, at the Church Press plant, West Haven, Conn.

(89.) — A boiler belonging to Dr. J. Ireland exploded, February 12, at Logansport, Ind. One person was severely injured.

(90.) — The boiler of a locomotive exploded, February 12, at Belmont, Cal. One man was killed.

(91.) — On February 12 a cast-iron header fractured in a water-tube boiler at the Consolidated Gas, Electric Light & Power Co.'s plant, Westport, Md. Firemen John Byrnes and George Weildman were injured.

(92.) — A slight boiler explosion occurred, February 13, in the plant of the American Brewing Co., Detroit, Mich.

(93.) — On February 13 a boiler fractured in the West Point Brick & Mfg. Co.'s plant, West Point, Miss.

(94.) — A tube ruptured, February 13, in a water-tube boiler in the D. Ghirardelli Co.'s chocolate factory, San Francisco, Cal. Fireman Joseph Marcaletti was scalded.

(95.) — A boiler exploded, February 14, at Greenfield, Wis., wrecking the building in which it stood. Joseph Schlosser, a farmer, had a narrow escape from fatal injury.

(96.) — On February 15 a slight boiler explosion occurred in the water and light company's plant, at Wilmington, Ohio.

(97.) — A boiler exploded, February 15, in the Potter mill, Kansas City, Mo.

(98.) — On February 15 a boiler exploded in the plant of the Procter & Gamble Co., at Ivorydale, near Cincinnati, Ohio. Antonio Bulgan and Joseph Wacher were scalded.

(99.) — A boiler belonging to Dr. W. L. Peters exploded, February 15, at Chickasha, Okla.

(100.) — On February 15 a blowoff pipe ruptured in the Cralle & Gilbourne Co.'s planing mill and wagon factory, Aberdeen, S. Dak.

(101.) — A boiler exploded, February 15, on the Morris farm, Sherrard, W. Va.

(102.) — A slight boiler explosion occurred, February 16, in H. F. Littlefield's greenhouses, Worcester, Mass. The property loss was small, and serious damage to the plants was prevented by the prompt use of oil stoves.

(103.) — A boiler fractured, February 17, in the plant of the Sabina Flour Mill Co., Sabina, Ohio.

(104.) — Several sections of a cast-iron heating boiler fractured, February 17, in the New Orleans Sanitarium, New Orleans, La.

(105.) — An accident occurred, February 17, to a boiler in the brewery of John E. and Frank Walter, Louisville, Ky.

(106.) — A slight boiler explosion occurred, February 18, in the Iroquois Hotel, Plainfield, N. J.

(107.) — A tube ruptured, February 18, in a water-tube boiler at the plant of the American Sheet & Tin Plate Co., Bridgeport, Ohio. E. W. Gilbert was burned.

(108.) — A heating boiler exploded, February 18, in the greenhouse at the State School for the Blind, Batavia, N. Y.

(109.) — A boiler exploded, February 19, in the Liverpool Salt & Coal Co.'s plant, Hartford, W. Va. Engineer Robert Barnett and fireman William Smith were instantly killed, and Adam Weims, Joseph Lavender, Clinton McKnight, E. Hall, and two other men were seriously injured. The plant was also wrecked.

(110.) — On February 20 a tube ruptured in a water-tube boiler at the Home Riverside Coal Co.'s plant, Leavenworth, Kans. Fireman Riley Smith was injured.

(111.) — On February 20 a slight boiler explosion occurred in the West Shore Machine Shops, New Durham, N. J.

(112.) — A slight boiler explosion occurred, February 20, at the Standard Oil Works, Long Island City, N. Y.

(113.) — On Feburuary 21 a boiler ruptured in Thomas A. Grist's electric light plant, Knox, Ind.

(114.) — A tube ruptured, February 21, in a water-tube boiler at the Philadelphia Rapid Transit Co.'s power plant, Thirty-third and Market Streets, Philadelphia, Pa.

(115.) — On February 22 a boiler exploded in the College Park buildings, San José, Cal. One person was seriously injured.

(116.) — A tube ruptured, February 23, in a water-tube boiler at the New York & Pennsylvania Co.'s pulp and paper mill, Johnsonburg, Pa.

(117.) — On February 24 a boiler belonging to A. W. Wehe exploded at Redwood City, Cal.

(118.) — Engineer J. McCullough was instantly killed, and fireman John Simmons was fatally injured, February 26, by the explosion of the boiler of a Baltimore & Ohio freight locomotive, several miles west of Hoytville, Ohio.

(119.) — On February 26 a boiler exploded in Jones' sawmill, on Dry Fork Creek, near Gallatin, Tenn. Jefferson Jones was killed.

(120.) — On February 28 a tube failed in a boiler in the Washburn "C" flouring mill, Minneapolis, Minn. Henry Doger and Adelbert Gibbon were seriously but not fatally burned.

March, 1909.

(121.) — The boiler of locomotive No. 270, of the Cincinnati, Hamilton & Dayton railroad, exploded, March 1, on the Fort Wayne branch, some five miles west of Findlay, Ohio. Engineer William J. George was instantly killed, fireman Harry Richards was badly scalded, and the locomotive and several cars were badly wrecked.

(122.) — On March 1 a blowoff pipe failed on a boiler in the Indiana Veneer & Lumber Co.'s plant, Indianapolis, Ind. Engineer Rufus Menges was injured.

(123.) — A boiler explosion occurred, March 1, on the steamer *Lampasas*, at Key West, Fla. One person was killed.

(124.) — A boiler exploded, March 1, in the Beck sawmill, five miles from Thomasville, N. C. Herbert Beck, son of one of the owners of the mill, was instantly killed, and the owners themselves, Hillary Beck and Andrew Beck, were fatally injured. Three other men were also injured seriously, but not fatally.

(125.) — The boiler of a Great Northern railroad locomotive exploded, March 1, at Fergus Falls, Minn. One man was severely injured.

(126.) — A slight boiler explosion occurred, March 3, at the Hogan Drill Works, Mansfield, Ohio.

(127.) — A boiler tube burst, March 3, on the torpedo boat *Truxton*, at Vallejo, Cal. One man was severely injured.

(128.) — A boiler exploded, March 3, at Crowe mine No. 3, some four miles north of Scammon, Kans.

(129.) — A cast-iron sectional heating boiler ruptured, March 4, at Boston, Mass., in the Hotel Norwood, owned by the Boston Elevated Railway Co.

(130.) — On March 4 a tube ruptured in a boiler belonging to the Reading railroad, at Norristown, Pa. One man was severely injured.

(131.) — A tube ruptured, March 5, in a water-tube boiler at the felt paper works of the Barrett Manufacturing Co., Peoria, Ill.

(132.) — A boiler exploded, March 5, in the Pennsylvania railroad shops, Trenton, N. J. One man was severely injured.

(133.) — The boiler of a Cincinnati, Hamilton & Dayton freight locomotive exploded, March 5, just north of Wapakoneta, Ohio. Fireman Elmer G. Tripp was injured so badly that he died later in the day, and B. F. Berry and J. W. Leffey were injured seriously.

(134.) — A tube ruptured, March 6, in a boiler at the Philadelphia Shoe Co.'s plant, Allentown, Pa.

(135.) — On March 8 a boiler exploded in the Friend mill, West Carrollton, Ohio. One person was fatally injured.

(136.) — On March 8 a heating boiler exploded in an apartment building on Fifty-seventh Street, Chicago, Ill. The explosion was followed by a fire, which caused a property loss estimated at $10,000.

(137.) — The boiler of Canadian-Pacific locomotive No. 1381 exploded, March 9, at Farron station, just west of Nelson, B. C. Donald McQuarrie and Francis Glover were fatally injured.

(138.) — A boiler exploded, on or about March 9, at the Bear Hill mine, near Yellville, Ark.

(139.) — A heating boiler exploded, March 9, in Z. K. Jewett & Co.'s greenhouse, Sparta, Wis. Alvin Clemons was killed. Fire followed the explosion, and the property loss was estimated at $5,000.

(140.) — A boiler exploded, March 10, in the plant of the East Side Mill & Lumber Co., Santa Cruz, Mex. The property loss was estimated at $15,000.

(141.) — On March 11 a blowoff pipe failed in the plant of the Manufacturers' Rubber Co., Metuchen, N. J. Fireman Lou Conover was injured.

(142.) — A boiler exploded, March 11, on the steamer *Weitchpec,* on the Sacramento River, near Sacramento, Cal. Fireman Elmer Dennis was fatally scalded.

(143.) — On March 14 a boiler belonging to the New Bedford Ice Co. exploded at Otter Lake, Greenfield, N. H. Engineer Thomas R. Luce was scalded to death.

(144.) — A boiler exploded, March 15, at the Rich ice-houses of the American Ice Co., Farmingdale, Me. Ralph F. Ridley and H. L. Hutchinson were killed, and Charles E. Murphy was badly injured. The building in which the boiler was located was demolished.

(145.) — On March 15 a tube ruptured in a water-tube boiler at the Hamburger Cotton Mills, Columbus, Ohio.

(146.) — On March 15 a boiler exploded in William C. Everett's sawmill, near Nevins, Ky. Mr. Everett was badly and perhaps fatally injured, and Frank Fields, Hugh Minnick, Charles Sanders, Hugh Wilson, and another man named Wilkes were injured less severely.

(147.) — An accident occurred, March 16, to a boiler in the Grantville Hosiery Mills, Grantville, Ga.

(148.) —A boiler connected with a new hot-water heating system exploded, March 17, in the bank building at Walnut, Ill. The property loss was about $1,000.

(149.) — A tube ruptured, March 19, in a water-tube boiler in the New York, New Haven & Hartford Railroad Co.'s power house and repair shop, Readville, Mass. Fireman Charles A. Bird was injured.

(150.) — On March 21 a cast-iron header fractured in a water-tube boiler at the Kingston Coal Co.'s "Gaylord Colliery," Kingston, Pa.

(151.) — Nine cast-iron headers fractured, March 22, in a water-tube boiler at the Edge Moor Iron Co.'s plant, Edge Moor, Del.

(152.) — On March 22 a tube pulled out of the drum of a water-tube boiler in the power house of the Calumet & South Chicago Railway Co., South Chicago, Ill. Fireman John Wypinski was injured.

(153.) — Two 18-inch flues collapsed, March 22, in a boiler at the Goshen Hill Coal Co.'s plant, near New Philadelphia, Ohio. The boiler was thrown to a distance of 400 feet.

(154.) — The boiler of a Lehigh freight locomotive exploded, March 23, near Corfu, N. Y. Engineer Henry Kabel and fireman John Geist were almost instantly killed, and brakeman Henry C. Meyers was blown from the top of a freight car and seriously injured. The locomotive was wrecked, and four cars were derailed.

(155.) — On March 24 an accident occurred to a boiler at the city electric lighting plant, Madison, Ga.

(156.) — On March 25 a blowoff pipe failed on the boiler of Hiram Johnson's portable sawmill, at Quaker City, near Unity, N. H. Mr. Johnson was seriously and perhaps fatally injured, and Ernest Barry was injured less severely.

(157.) — A tube ruptured, March 31, in a water-tube boiler at the Inland Steel Co.'s plant, Indiana Harbor, Ind.

The Locomotive.

A. D. RISTEEN, PH.D., EDITOR.

HARTFORD, APRIL 25, 1909.

THE LOCOMOTIVE *can be obtained free by calling at any of the company's agencies.*
Subscription price 50 cents per year when mailed from this office.
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Obituary.

THOMAS J. ZOLLARS.

We record, with deep regret, the death of Thomas J. Zollars, who passed away, February 21, at Des Moines, Iowa, where he had resided for several months in the hope of benefiting his health. Mr. Zollars was a citizen of Denver, Colorado, and was a prominent figure in that city, in insurance and financial circles. He was born at New Hagerstown, Ohio, in 1839, and was educated at the Iowa Wesleyan University. He enlisted from Iowa as a private upon the outbreak of the Civil War, and served for three years, leaving the service on account of ill health, in 1864, with the rank of captain. Returning to Iowa at the close of the war, he engaged in the insurance business, and about 1884 he removed to Denver, where he continued in the same line of work. He became general agent of the Hartford Steam Boiler Inspection and Insurance Company, at Denver, on July 1, 1888, retaining his connection with us in that capacity until December 1, 1895, when he retired in order that he might be able to devote his entire time to the Columbia Savings and Loan Association, whose president and manager he became in 1892.

Physically, Mr. Zollars was a man of striking appearance. He was six feet and three inches in height, and bore the weight of his years well. He was also a man of fine character and ability, and his death will be a great loss to the community in which he lived. Mr. Zollars' wife, who has been an invalid for some years, survives him, and he also leaves one son, Lieutenant Charles Zollars, of the United States coast artillery.

WE receive many applications, from engineers and others, for positions as inspectors, and these applications are often sent to the home office of the company, at Hartford, even when the applicants live in the remote south or west. We wish to suggest that persons sending in such applications in the future address them to the nearest general agency of the company, and not to the home office. A list of these general agencies, with the address in every case, is given on the back page of each issue of THE LOCOMOTIVE. Furthermore, it may not be out of place to suggest that such a letter produces a somewhat better impression if there is a stamp enclosed in it for reply. And don't stick the stamp down, — not even by one corner. It will not escape from the envelope, and it will not be overlooked. Of course we cannot give work to every one who asks for it; but the man who applies for a job, and encloses a stamp that isn't stuck to the paper, has our sympathy and good will, anyhow.

At a meeting of the board of directors of the Hartford Steam Boiler Inspection and Insurance Company, held on February 9, the following officers were re-elected for the current year: L. B. Brainerd, president and treasurer; Francis B. Allen, vice-president; C. S. Blake, secretary; L. F. Middlebrook, assistant secretary. Mr. W. R. C. Corson, who has been associated with the home office for some time in the mechanical engineering department, was also elected assistant secretary, and A. S. Wickham, superintendent of agencies, E. J. Murphy, M.E., consulting engineer, and F. M. Fitch, auditor, were re-appointed to the respective positions indicated.

In making up the regular lists of boiler explosions that are published in The Locomotive, it is unfortunately impossible to prevent the occasional occurrence of errors, although we take care to avoid them, as far as possible. In the issue for January, 1909, page 140, we stated that the fire that destroyed "Crest Hall," at Winthrop Beach, Mass., on October 2, 1908, was caused by a boiler explosion; and in so doing we relied upon two seemingly trustworthy reports. We have since learned, however, that the boiler did not explode, but that it was found to be in good condition when it was removed from the ruins. We make the correction with pleasure.

In this connection we desire to record that on December 16 a boiler exploded in the ax handle mill of the Central Manufacturing Co., at Colt, Ark., injuring G. W. Bailey, N. J. Allen, and T. M. Barnett. This explosion was not included in our regular December list, because it was not brought to our notice until February. Taking account of the accident in Arkansas, which happened but was not reported, and of the one at Winthrop Beach, which was reported but did not happen, it appears that our summary of the boiler explosions of the year 1908, as given in our last issue, requires no modification so far as the number of explosions is concerned, but that the number of persons reported as injured during 1908 should be increased by three.

Boiler Explosions in England, Germany, and the United States.

The contrast between experience in the United States on the one hand, and in England and Germany on the other, in the matter of boiler explosions, is almost incredible, and it calls loudly for careful and complete investigation. So far as can be judged by a comparison of the available statistics, we are a long way behind our friends across the sea in the safe use of high-pressure steam, and we ought to send over a competent commission, to find out what the matter is, and suggest an efficient remedy.

The gravity of the situation will be apparent upon examining the tables that we present herewith. Table 1, for example, is taken from an official report of the marine department of the British Board of Trade, and it gives the total number of explosions investigated by that body from 1882 down to 1907. As we understand the situation in England, *all* explosions in Great Britain are subject to investigation in this manner, so that the figures here given are exhaustive, and include all the explosions that have occurred during the period covered. The official year, in making out these statistics, does not correspond with the calendar year, but ends with June 30 in each case. The year designated as "1906-07," for example, began with July 1, 1906, and ended with June 30, 1907.

It will be seen that during the twenty-five years extending from July 1, 1882, to June 30, 1907, there were in Great Britain, 1,705 explosions, resulting in the death of 697 persons, and in injury to 1,460 others; the whole number of persons killed and injured being, therefore, 2,157.

A comparison of these figures with the corresponding ones for the United States is disheartening in the extreme. The statistics for this country, as given in The Locomotive for January, 1909, page 132, are summarized in agreement with the calendar years, and hence are not directly comparable with the English data

Table 1.—Total Number of Explosions in Great Britain.

Year.	Number of Explosions.	Personal Injuries.		
		Number of Persons Killed.	Number of Persons Injured.	Total of Killed and Injured
1882–83	45	35	33	68
1883–84	41	18	62	80
1884–85	43	40	62	102
1885–86	57	33	79	112
1886–87	37	24	44	68
1887–88	61	31	52	83
1888–89	67	33	79	112
1889–90	77	21	76	97
1890–91	72	32	61	93
1891–92	88	23	82	105
1892–93	72	20	37	57
1893–94	104	24	54	78
1894–95	114	43	85	128
1895–96	79	25	48	73
1896–97	80	27	75	102
1897–98	84	37	46	83
1898–99	68	36	67	103
1899–00	59	24	65	89
1900–01	72	33	60	93
1901–02	68	30	55	85
1902–03	69	22	67	89
1903–04	60	19	45	64
1904–05	57	14	40	54
1905–06	54	25	21	46
1906–07	77	28	65	93
Totals,	1,705	697	1,460	2,157
Average of 25 years,	68.2	27.9	58.4	86.3

as given in Table 1. It appears from the data in The Locomotive, however, that between January 1, 1883, and December 31, 1906, there were no less than 7,408 boiler explosions in this country, these resulting in the death of 7,144 persons, and in injuries to 10,874 others. Thus without counting the last half of the year 1882 nor the first half of 1907, we had more than four times as many explosions as occurred in Great Britain during the period covered by the table. The number of killed, during the same interval, was more than ten times as great here as there, and the number of injured more than seven times as great.

This vast difference in the number of explosions and of personal injuries is not to be explained by assuming that the number of boilers in this country is correspondingly greater than the number in Great Britain. We have no accurate data as to the number of boilers in the United States, and no data at all with respect to the number in Great Britain; but it is certain that there is not sufficient disparity between the two to account for the difference in the number of explosions.

The case is even worse than the foregoing figures indicate. It would be easy to assume that only the more serious explosions are recorded in England, and that in the statistics that are collected by the Hartford Steam Boiler Inspection and Insurance Company a larger number of trivial accidents are included, which would suffice to account for the difference. Unfortunately the facts are just the other way. In the first place, the figures themselves, when closely examined, show that such an explanation is untenable. For example, in the British explosions the average number of persons killed, per accident, was 0.41, while the corresponding average, over the same period, in the United States, was 0.96. Judging by the loss of life, therefore, the explosions in this country were much worse, on the whole, than those in Great Britain. But we do not have to depend upon inference, to establish the fact that the average explosion in the American statistics was worse than the average one included in the British list. An examination of the regular lists that are published in The Locomotive, and from which our statistics are prepared, shows at once that we do not include explosions of steam pipes, except when these pipes rupture between the boiler and the first stop-valve. In the British statistics, however, many steam pipe explosions are included, as will be manifest upon looking over the detailed accounts that are published by the Board of Trade, from time to time; and if these were omitted from consideration, so as to place the statistics in this country and in England upon a more uniform basis, the showing against the United States would be materially worse than it appears to be from Table 1.

The difference in the experience of the two countries may be due in some measure to the known differences between the prevailing types of boiler that are in common use. On the other side, for example, the flue boiler is the most favored type, while in this country there are relatively few flue boilers, their places being taken by the horizontal tubular and water-tube types. This explanation does not appear to us to be adequate, however, for while we have no thought of condemning the flue boiler, we doubt very much if the mere substitution of that type for the types now in use in this country would make our steam engineering practice materially safer than it is at present.

It is impossible to give any accurate statement as to the average factor of safety in use in either country, but we have more than a suspicion that this factor is larger in England than it is here. If such is indeed the case, the fact would go a long way toward explaining the painful and humiliating comparison given above. The Hartford Steam Boiler Inspection and Insurance Company has striven for proper factors of safety from the moment of its organization down to the present time, and it will continue to strive for them so long as it continues in business. American practice is certainly better in this respect than it used to be, and while we do not wish to appropriate an unfair share of the credit for this improvement, we are sure that all who know our history will agree that *some* part of the credit justly belongs to us.

The disheartening state of affairs shown by comparing our experience with that of England is further emphasized if we compare our record, in like manner, with that of Germany. To facilitate this comparison we give, in Table 2, a summary of the boiler explosions that occurred in Germany during the thirty-one years beginning with 1877 and ending with 1907. For this same period our own statistics show, for the United States, 8,692 explosions, with a total of 8,768 killed and 13,151 injured. The contrast is truly appalling, and it suggests at once that the figures, as we have given them for Germany, are very incomplete. In reply to this we would say that we have made every effort to have them as complete as possible, and that they include (so far as we are aware) all of the explosions, both great and small, that were reported to the police authorities. Moreover, a very wide margin could be allowed for possible incompleteness in the German data as here presented, without affording us the least comfort; for the record, as it stands, shows approximately seventeen times as many explosions in the United States as there were in Germany, during the period covered by the table. Comparing the fatalities in the two countries, the case is still worse; for the number of persons killed in the United States was twenty-seven times as great as the number killed in Germany.

The indictment against the United States in the matter of its boiler explosions is a terrible one, and there is need for radical action of some sort. A great deal could doubtless be accomplished by the adoption of larger factors of safety, and great good could be accomplished, in the opinion of the editor of The Locomotive, if the various companies doing a boiler insurance business would unite in adopting definite minimum factors for all boiler parts, and definite requirements as to construction and materials, and then insist upon a rigid conformity to these requirements, before the issuance of insurance.

Of equal fundamental importance is the making of frequent and thorough inspections,— not perfunctory inspections, but efficient and searching ones, such as the Hartford Steam Boiler Inspection and Insurance Company has insisted upon, and provided for its patrons, ever since it began business. The Manchester Steam Users' Association of Manchester, England, which had 8,716 boilers under its care at the end of 1907, makes the proud claim that in the entire half-century covered by its operations it has never lost a boiler nor a life from any cause that the Association could have foreseen or forestalled. We go abroad for this illustration of the practical possibilities of good inspections, partly in order that we may not give offense by dwelling too much upon our own excellences, and partly (be it confessed) because we do not believe that any American company, no matter how good its service, can show so clear a history. Nor do we believe that any other foreign company could. We are sure that the Manchester association will forgive us if, while sincerely congratulating it upon its excellent and enviable record, we suggest that the entire spotlessness of this record is to some small extent accidental, since absolute perfection, though we ought to strive for it as hard as we can, can never otherwise be attained, over so long a period of years. Inspection, like a certain well-advertised kind of soap, can be made "99.99 per cent. pure", but the other hundredth of 1 per cent. is hard to realize, since inspectors are human beings, and not gods.

The 99.99 per cent. inspections, although they are expensive to make, are the only ones that are really valuable. In this country one company may offer a real 99.99 per cent. inspection, and another one, for a couple of dollars a year

Table 2.—Total Number of Explosions in Germany.

Year.	Number of Explosions.	Personal Injuries.			
		Instantly Killed.	Seriously Injured.	Slightly Injured.	Total of Killed and Injured.
1877	20	21	14	23	58
1878	18	7	4	9	20
1879	18	36	10	32	78
1880	20	10	5	14	29
1881	11	8	18	21	47
1882	11	19	14	15	48
1883	14	23	8	24	55
1884	14	12	11	22	45
1885	13	11	2	9	22
1886	16	10	5	8	23
1887*	14	..	..	..	..
1888	1	4	3	4	11
1889	16	6	5	17	28
1890	16	9	1	11	21
1891	10	0	3	7	10
1892	18	12	11	18	41
1893	10	6	5	10	21
1894	35	12	9	13	34
1895	23	20	23	31	74
1896	21	10	2	13	25
1897	21	17	3	19	39
1898	18	3	7	21	31
1899	14	13	11	11	35
1900	13	6	1	17	24
1901	17	10	3	14	27
1902	17	7	7	10	24
1903	10	6	0	5	11
1904	15	5	5	8	18
1905	9	4	2	3	9
1906	15	5	0	3	8
1907	16	7	4	5	16
Totals, . .	498	319	196	417	932
Average for 31 years, . . .	16.1	10.3	6.3	13.5	30.1

* We have no full statistics for 1887. The 14 explosions recorded include 37 individual boilers. The terrible explosions at Friedenshütte, illustrated in our issue for June, 1888, and in which 22 boilers blew up simultaneously, occurred in that year. By that explosion three employees were instantly killed, nine were injured so badly that they died within a few days, and thirty others were injured more or less severely, but not fatally.

less, may offer one that looks equally good, but which is possibly only of the 50 per cent. kind. The boiler owner has little to guide him in his choice, because he cannot be supposed to be minutely informed on such a specialized subject. But in England, when there is an explosion there is also a subsequent technical investigation by the Board of Trade; and if that body finds that there was no inspection, or that the inspection, though made, was superficial or inadequate in any way, or if it finds that the owner of the boiler received suggestions from the inspector but failed to carry them out, the fact is well advertised, and a fine is imposed upon the person or company found to be at fault. Thus in the investigations that followed the 77 English explosions reported during the year 1906-7, fines were imposed in twenty-two cases; the smallest of these fines being $25, and the largest $2,000. This system has certainly worked well in England, raising the standard of the inspections, and increasing the care exercised by the boiler owners and attendants; the corrective effect depending not so much upon the magnitude of the fine, as upon the publicity that is involved, and the definite fixation of the responsibility. We are of the impression that there would be a great improvement in our boiler practice, and a corresponding diminution of the number of explosions and the loss of life, if we could have, in the United States, some properly constituted power that would exercise a moral influence similar to that exerted in England by the Board of Trade. The boiler insurance companies that actually do give high class inspections would have nothing to lose, and everything to gain; while companies (if there be any such) which may now be making more money by giving inferior inspection service at a less cost to the assured, would either have to mend their ways, or go out of business. The services rendered by boiler attendants would also improve, on the whole, since it is but human for a man to strive to do the best that is in him, when he knows that his sins will surely find him out.

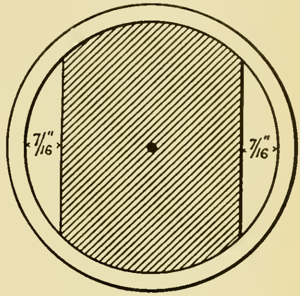
An Engineering Freak.

Some considerable time ago we published one or two articles under the title "Steam Engineering in Darktown", in which we described certain features of engineering practice that had been observed by our inspectors in the South. We give an example, herewith, which shows that we need not have gone so far from our home office to get material of the same general nature.

A certain tannery in New England was fitted out, many years ago, with a small slide-valve engine, which was operated at a pressure of 70 or 80 pounds per square inch, and which proved to be adequate, until quite recently, to the wants of the plant. We do not recall the dimensions of the engine, except that the exhaust pipe was three inches in diameter, internally; nor do we know the exact date when the engine was installed. Inquiry elicited the fact, however, that no repairs had been made upon it within thirty-five years; and hence the state of affairs that we are about to describe had existed for that period, at least.

A short time ago the owners of the plant decided to throw out the old engine, and replace it with one of the Corliss type, capable of furnishing more power. Upon taking the old engine down it was discovered that the exhaust pipe was almost completely closed by means of a piece of cast-iron, of the general appearance indicated by the shaded part of the accompanying sketch. On each side of the cast-iron piece there was a segment-shaped space, 7/16ths of an inch wide at its widest part; and the entire exhaust of the engine had to pass through these two openings for thirty-five years or more.

Mechanics of the older school will see at once how the thing came about; but for the benefit of the youngsters it may be well to explain. In former years it was customary to thread all steam piping except the very smallest, by turning the threads upon it in a lathe. In order to secure the pipe properly in the lathe, it was necessary to provide a center-piece which would fit inside the end of the pipe, and in which a hole could be made, to receive the tail-center of the lathe. The center-piece was of course supposed to be removed, after the completion of the thread; but in the case now before us, this detail of the operation was forgotten, or at all events omitted, and the pipe was put in place, center-piece and all.



End View of Exhaust Pipe.

The editor could use up a lot of space in trying to estimate the waste of coal that this forgotten center-piece has caused, and in comparing this loss with the cost of a good indicator; but he isn't going to. No indicator was ever applied to the engine; and we are not going to show the owners of the plant how big a mistake that omission was.

Locomotive Boiler Explosions in the United States.

Under date of January 22, 1909, the Interstate Commerce Commission furnished to the United States Senate a table showing the number of persons killed and injured by locomotive boiler explosions, in the United States, between August 1, 1903, and November 30, 1908. Through the courtesy of Mr. Edward A. Moseley, Secretary of the Commission, we are enabled to reprint the table, below. The data that it contains are complete and accurate, because the railroads are required by law to report all accidents in which there is loss of life or personal injury. It will be noted that the *number* of explosions is not given. We regret the omission, but we are informed that the Commission is unable to furnish information on this point.

Deaths and Injuries from Locomotive Boiler Explosions.

Period.	Trainmen.		Other Employees.		Passengers.		Total.	
	Killed.	Injured.	Killed.	Injured.	Killed.	Injured.	Killed.	Injured
Year ending July 31, 1904, ...	42	129	1	4	..	..	43	133
" " July 31, 1905, ...	36	109	9	15	..	5	45	129
" " July 31, 1906, ...	38	119	1	7	..	1	39	127
" " July 31, 1907, ...	73	144	5	16	..	5	78	165
" " July 31, 1908, ...	42	101	2	15	..	..	44	116
Aug. 1 to Nov. 30, 1908, ...	15	46	1	..	..	..	16	46
Total, ...	246	6{1}8	19	57	..	11	265	716

The Properties of Steam.

Seventh Paper.— The Experiments of Holborn and Henning, on the Pressure of Saturated Steam.

Since the present series of articles on the properties of steam was begun, a valuable and apparently extremely accurate series of measurements of the pressure of saturated steam, over a wide range of pressure and temperature, has been executed by Messrs. L. Holborn and F. Henning, at the German Physikalisch-Technische Reichsanstalt, Charlottenburg, Germany. A full description of the apparatus and methods used by these experimenters will be found in the *Annalen der Physik,* 4th series, Vol. 26, 1908, page 833, under the title "Ueber das Platinthermometer und den Sättigungsdruck des Wasserdampfes zwischen 50 und 200°" ("On the Platinum Thermometer and the Pressure of Saturation of Water Vapor between 50° and 200° Centigrade"). A much briefer account of the work will also be found in the *Zeitschrift des Vereins deutsche Ingenieure,* 1909, Vol. 53, page 302.

These experiments are of exceeding interest for several reasons. For example, they cover a range of pressure extending from one-eighth of an atmosphere (absolute) up to 225 lbs. per square inch, and they therefore include all the pressures that are used in practical steam engineering, except the very highest and lowest. Moreover, an attempt was made to attain such an order of accuracy as to ensure that the error in temperature should not exceed the fiftieth part of a centigrade degree (or the ninetieth part of a Fahrenheit degree), even at the highest experimental pressure. This error would correspond, at 225 lbs. per square inch, to an uncertainty in the pressure of less than three millimeters (or about one-fifth of an inch) of mercury; or, in other words, to an uncertainty of less than two ounces of pressure, per square inch, in measuring a pressure of 225 lbs. per square inch. No other series of experiments that has been made at these higher pressures can pretend to so great a degree of precision, and for this reason the present series is of great value. It should be remembered, of course, that every experimenter is apt to overestimate the precision of his work, and it is not unlikely that this general principle holds true in the present instance. Nevertheless, we can make a considerable allowance for the presence of unsuspected sources of error, and still feel confident that the experiments of Holborn and Henning, which we are about to describe, are the best that have yet been made, at the higher part of their range. Below 100° C. (212° Fahr.) there is a question as to whether they are as accurate as those made by Wiebe and Gruetzmacher, and described in The Locomotive for October, 1907, page 246.

A distinctive feature of the experimental work of Holborn and Henning is that their temperature measurements were made by means of the platinum resistance thermometer. Platinum resistance thermometry has been used in the laboratory for some years, but heretofore it has not been employed in any extended experimental work upon the relation between the pressure and temperature of saturated steam. For this reason the present series of measurements has for the physicist and the student of thermometry, an added element of interest which it would have lacked if the work had been executed by the aid of thermometers of the usual kind.

We cannot give a detailed explanation of platinum resistance thermometry in the present place, for that would not only be apart from the main subject under discussion, but it would also require a prohibitive amount of space. Following, however, is a brief and superficial explanation of the general principle involved. It is known that the electrical resistance of any given metal varies with the temperature in a perfectly definite manner, provided certain precautions are observed in the manipulation of the metal; and this implies that an accurate knowledge of the electrical resistance of the given metal at any moment will enable us to calculate, with a corresponding degree of precision, what its temperature is,— provided, of course, the particular specimen of metal with which we are working has been previously investigated, so that we know the law in accordance with which its electrical resistance varies with the temperature. As long ago as 1871 Sir William Siemens suggested the use of platinum for the determination of temperatures in this way, and he devised a pyrometer for commercial use, based upon the variation of the electrical resistance of platinum wire with temperature. A committee of the British Association considered the matter, and reported adversely upon the proposed method, so far as concerned its availability for work in which *precision* was essential. Later, however, Professor H. L. Callendar took up the subject again, and in 1887 he succeeded in showing how the uncertainties that beset the earlier forms of the platinum resistance thermometer could be overcome, so as to render the instrument capable of giving quite accurate results. Other experimenters have since carried the investigation further, and in this way an instrument of a high order of accuracy has been evolved. The resistance of platinum is nearly proportional to the temperature; and the temperature, as calculated from the resistance by assuming that this proportionality is exact instead of only approximate, is called the "platinum temperature." If it is desired to reduce a "platinum temperature," as obtained in this way, to the temperature that would be given by a hydrogen thermometer under the same circumstances, we have only to apply a small correction whose value may be calculated by a simple formula that was given by Callendar. Those desirous of further information respecting platinum resistance thermometry may consult the article "Thermometry" in the *Encyclopedia Americana,* and also Preston's *Theory of Heat.*

The experiments of Holborn and Henning were carried out by what is known as the "dynamic method." This was also one of Regnault's methods, and was named by him; and for a fuller account of it the reader is referred to the first of the present series of articles, in the issue of The Locomotive for July, 1906, page 85. In brief, the dynamic method consists in ascertaining the temperature of the steam that is given off when water boils freely under a given constant pressure. The apparatus is composed, essentially, of an "artificial atmosphere," which is merely a tank of some considerable size, containing air at the pressure for which the boiling point is to be determined; a boiler, which is in free communication with the artificial atmosphere so that the pressure that prevails within this artificial atmosphere is also exerted upon the surface of the water in the boiler: a pressure gage which is connected with the artificial atmosphere so as to enable the experimenter to observe the pressure with precision; and, lastly, a thermometer of some form, by which the temperature of the steam in the boiler can be accurately determined. In carrying out the experimental work, the pressure of the artificial atmosphere is adjusted, approximately, to some value determined in advance, and the water in the boiler is then caused to boil freely. The steam that is formed displaces the air in the boiler, and tends to push forward into the chamber containing the artificial atmosphere. This last action is prevented, however, by placing a condenser, cooled by a stream of water, between the boiler and the artificial atmosphere. (In Regnault's apparatus the water of condensation flowed back into the boiler again, and was used over and over; but in the experiments of Holborn and Henning, the apparatus was so disposed that the condensed water was caught in a separate vessel, and was not allowed to return to the boiler.) When the apparatus has reached a steady state, with the water in the boiler in full ebullition, the pressure prevailing in the artificial atmosphere, and the temperature of the steam in the boiler, are accurately measured, the two measurements being made, as nearly as possible, at the same instant. The experiment is then complete, the observed temperature being the temperature that saturated steam has, at the observed pressure.

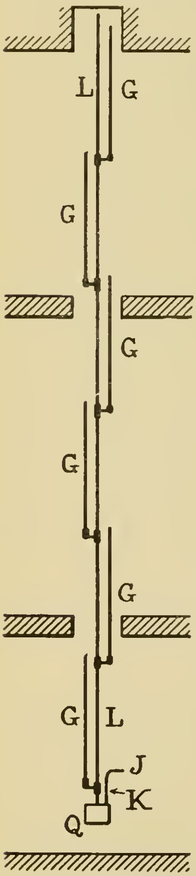


Fig. 1.— Scheme of the High-Pressure Gage.

In describing the apparatus used by Holborn and Henning, we shall dwell mainly upon those points in which their apparatus differed from that employed by Regnault, choosing this course in order to avoid unnecessary repetition; and the reader who desires further enlightenment in regard to the principles involved should re-read the article describing Regnault's work. By doing this, too, he will better appreciate the refinements and improvements that have been made in the experimental apparatus since Regnault's time.

Holborn and Henning, for such of their temperatures as were above the normal boiling point of water (and for the pressures, therefore, that were above the normal atmospheric pressure), measured the pressures by means of a mercury column that had a total length of 12 meters (39 feet); the greatest pressure that they could measure, with the column, being, therefore, about 230 lbs. per square inch above the atmospheric pressure, or 245 lbs. absolute.

Usually, in arranging a mercury column for the accurate measurement of pressure, the column is made of stout glass tubing, and is all in one piece; or, if it is made in several pieces, as a matter of convenience, these are joined together by metal rings or collars, so that the tube is one long straight piece, in effect, even though it may not be so as a matter of literal fact. But in the case of Holborn and Henning the long arm of the pressure gage (*LL* in Fig. 1) was made of steel tubing, arranged in six sections, each two meters (78 in.) long, and mounted vertically over one another. At the joints between the successive sections, side tubes led off, to each of which a vertical glass tube two meters in length was attached. The general arrangement of the mercury gage is shown diagrammatically in Fig. 1, where *GG* are the glass side-tubes; and details of one of the joints between the main steel tube and the branch tubes are shown in Fig. 2.

In using this mercury gage, all the glass side-tubes were shut off from the main column, by means of the cocks *H*, except the one opposite the free end of the mercury in the column at the time the measurement was made; and in order that the experimenter might know the approximate position of the mercury in the steel tube, the apparatus was fitted with an ordinary spring gage (not shown in the illustrations), similar to the gages that are used in steam engineering practice. The pressure being roughly known by means of the spring gage, the cock *H* belonging to the appropriate glass branch tube could be opened, and the accurate measurement of the pressure made by observing the height to which the mercury rose in this branch tube. One of the chief objects in view, in arranging the gage in this way, was to enable the observer to protect the main column from changes of temperature (and consequent variations in the density of the mercury), and to ascertain accurately the temperature that the mercury in the main gage tube actually had, so that the pressure readings could be corrected to the values they would have had if the temperature of the mercury had been 0° C. The main steel tube of the gage was surrounded by a protecting jacket, not here shown, and a nickel wire was run down inside the jacket, this wire being divided into six sections, corresponding to the six sections of the mercury column. The temperature of each section of the column could then be obtained with a high degree of precision, by merely observing the electrical resistance of the nickel wire.

The long arm, *LL*, of the mercury column extended up through three stories of the building in which the experiments were made, openings 12 in.

TABLE I. — EXPERIMENTS OF HOLBORN AND HENNING AT HIGHER TEMPERATURES.

Thermometer No. 7.					Thermometer No. 9.				
Temperature (Centigrade)	Pressure (Millimeters)	No. of Measures	Date (1907)		Temperature (Centigrade)	Pressure (Millimeters)	No. of Measures	Date (1908)	
111.201°	1118.5	9	Dec.	16	110.576°	1095.5	8	Feb.	22
119.716	1475.6	9	"	17	120.245	1500.4	9	"	21
132.021	2150.9	6	"	12	129.821	2014.5	8	"	20
132.648	2190.9	9	"	13	140.861	2776.6	8	"	19
140.470	2745.6	9	"	18	161.537	4817.0	8	"	18
155.072	4081.3	9	"	19	167.413	5574.3	8	"	17
161.166	4773.5	9	"	20	180.217	7550.6	10	"	1
171.590	6168.7	6	"	21	181.127	7710.9	10	"	6
179.784	7475.6	6	"	23	189.656	9333.2	8	"	11
191.333	9683.2	6	"	31	191.340	9683.8	6	Jan.	31
200.238	11703.4	9	Jan.	7*	198.237	11225.6	7	Feb.	5
203.796	12601.5	9	"	8*	201.089	11916.6	5	Jan.	30
....	....	..	....		203.723	12582.2	7	"	29

* 1908

by 27 in. being provided in the floors, to allow of the free passage of the tube and its accessories.

Each of the glass branch tubes of the main arm of the gage was provided with glass scale (*M* in Fig. 2), graduated to millimeters, by which the height of the mercury could be read. The lower end of each of the scales *M* came opposite the upper end of the corresponding scale of the branch tube next below; and the several glass scales, *M*, were adjusted, so far as height is concerned, by the aid of the mercury column itself. For this purpose mercury was allowed to enter two successive branch tubes at the same time,— for example, *G* and *G'*, in Fig. 2. The upper ends of the columns in *G* and *G'* were then on the same level, and the scales *M* and *M'* could be adjusted by means of an arrangement of wedges and screws, indicated at *S*, so that the top mark on *M'* was just even with the mercury in *G'*, at the same moment that the bottom mark on *M* was just opposite the mercury in *G*. To further verify the position of the scales *M M'*, a long steel tape was hung parallel to the main gage tube, *L*, and the graduation marks on this tape were compared with those on the glass scales *M M'*, by means of a cathetometer. The steel tape that was used was carefully tested, under the same tension, at the Normal-Eichungskommission; and it is apparent that with all these precautions, accuracy in the relative positions of the scales *M M'* was well assured. The error due to uncertainty in the temperature and (therefore in the density) of the mercury in the branch tubes *G G'* was eliminated by placing thermometers close to these tubes, and reading them frequently. Owing to the comparative shortness of the tubes *G G'*, an error in the temperature of the mercury in one of these was manifestly of far less importance than an equal error in the temperature of the mercury in the main column.

The shorter arm of the mercury gage consisted of a glass tube, *KK'* in Fig. 2, which communicated with the long arm, *L*, through a canal *F*, which was drilled through a cast-iron cover plate that fitted upon a cistern *Q*, containing surplus mercury. A pump *U* was provided, for passing mercury from the reservoir *Q* into the gage, through the tube *E*, when it was desired to use the gage for a higher pressure; while when a lower pressure was to be measured, some of the mercury in the gage could be allowed to escape through the cock *B*, into the reservoir *Q*. At *A* was a cock for closing communication between the long arm, *L*, of the gage, and the short arm, *K*.

The tube *J* in Fig. 2 communicated with the "artificial atmosphere." This, which is not shown, consisted of a cast-iron cylinder having a capacity of thirty liters, or something over one cubic foot. It was immersed in a water-bath, just as Regnault's was, in order that the temperature (and therefore the pressure) of the air within it might be kept as constant as possible. The pressure in the artificial atmosphere tank could be increased at pleasure, by passing more air into the tank from a reservoir containing compressed air at high pressure.

The boiler used in generating the steam was situated in a different room from the measuring apparatus, so as to avoid errors that might otherwise be caused by the heat radiated from it; and it was connected with the artificial atmosphere by means of a pipe that passed through the wall of the room. Every effort was made, in fact, to have the temperature of the observing rooms uniform and steady, and with this end in view, all artificial heat was shut off from them during the progress of the work.

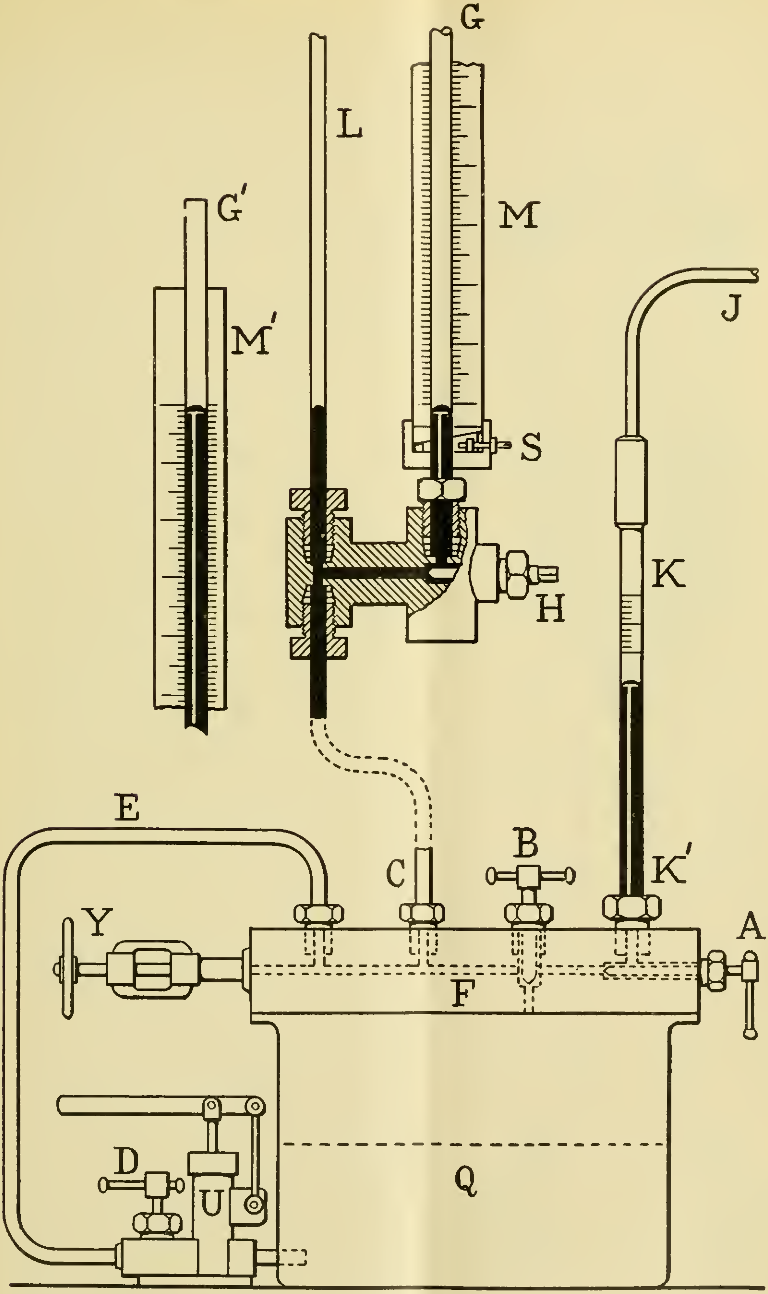


Fig. 2.—Diagram Illustrating the Mercury Column Used for Measuring the Higher Pressures.

The boiler itself is shown in Fig. 3. It consisted of a cylinder, *D*, of cast bronze, approximately 6 in. in diameter, 9½ in. high, and ⅗ in. thick. The cover plate was secured in place by bolts, and was provided with a copper packing ring of square section. The boiler was heated electrically, the temperature being raised nearly to the boiling point corresponding to the given pressure in the artificial atmosphere, by passing an electrical current through some strips of the alloy known as constantan, these (not shown in the illustration) being wrapped around the boiler on the outside, and insulated from it and from one another by sheets of asbestos paper. The temperature of the water being raised to within something like 10° of the boiling point under the pressure for which the artificial atmosphere was regulated, the remainder of the heating was effected by passing an electric current through a similar strip of constantan, *N*, which was enclosed in a steam-tight, hollow brass ring, *R*, and insulated with mica; the copper wires which carried the current in and out passing away through the nickel tube *P*. This method of internal heating was adopted in order to ensure that the steam that was developed should not be in the least degree superheated; superheating being impossible with the arrangement here shown, since the hollow ring *R* was at all times entirely below the level of the water.

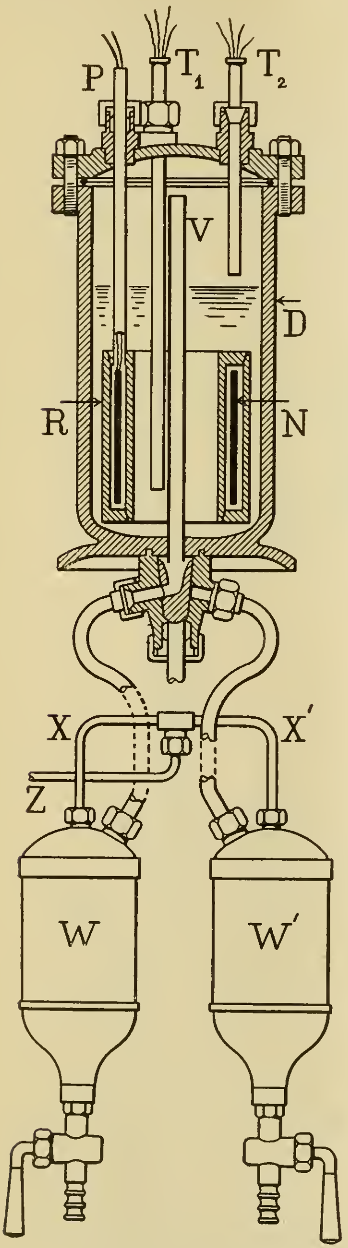


Fig. 3.— Illustrating the Boiler and the Condensers.

The steam that was produced in the boiler passed out through the central tube *V*, and into one or the other of the two condensers *WW'*, these being surrounded with cold water, and provided, at the bottom, with cocks through which the water of condensation could be drawn off. We do not find any statement as to how the boiler was filled with water; and as no device for this purpose is mentioned by Holborn and Henning, nor indicated in their engravings, it appears probable that the cover plate of the boiler was removed when more water was required to replace that which had evaporated. This inconvenient plan, if it was the one actually used, was doubtless adopted by the experimenters for what appeared to them to be excellent and sufficient reasons.

The respective condensers, W and W', were fitted, at the top, with tubes, $X X'$, which communicated with the artificial atmosphere.

T_1 and T_2 were two platinum resistance thermometers, that were used, as outlined above, for the determination of the temperature within the boiler. Of these, T_1, which dipped below the surface of the water, was used only during the preliminary heating, to observe the temperature of the water as the boiling point was approached. T_2, which did not dip below the surface of the water at all, was alone used for the accurate measurement of the temperature of the steam, when the water was boiling under the pressure determined by the artificial atmosphere.

Three different platinum thermometers were used, in all, in the course of the experiments, but only two (designated, respectively, as Nos. 7 and 9) were employed, as shown at T_2, for the definitive measurement of the temperatures of the saturated steam. These were made of the same piece of platinum wire, and had been in use since 1899.

In using the large mercury gage, the routine of the observing was as follows: A determinate pressure was first produced in the artificial atmosphere, and the value of this pressure being approximately known by means of the spring gage to which we have referred, the spring gage was shut off from the apparatus, and, with the cock A closed, the height of the mercury in the long column was brought to correspond, as closely as possible, with the pressure that prevailed in the artificial atmosphere; this regulation being effected by working the mercury pump U, or by opening the cock B. The cock A was then opened, and the pressure allowed to equalize itself throughout the apparatus. If the preliminary adjustment of the height of the mercury in the column L were carefully performed, the mercury in the gage would move only slightly when A was opened. The appropriate cock, H, was next opened, so as to throw one of the glass branch tubes of the gage into communication with the main column. A zero mark was provided towards the upper end of the glass tube $K K'$ and the next step was to bring the mercury meniscus in $K K'$ accurately to the zero mark there, a few graduations being provided above and below the zero mark, to facilitate this operation. To bring about an approximate adjustment, mercury was allowed to escape through the cock B, if the column stood too high in $K K'$, or the pump, U, was operated if the level in $K K'$ was too low. Lastly, an accurate adjustment to the zero mark in KK' was obtained by operating the screw Y, turning this one way to raise the column, and the other way to lower it. In this final adjustment, care was taken to have the meniscuses in KK' and in G come to their ultimate positions from below upwards, on every occasion, so that the shape of these meniscuses might always be the same. When the mercury column in KK' had been brought into exact coincidence with the zero mark there, the observer who was attending to this part of the operation gave a signal, and thereupon another observer read the height of the mercury column in the proper glass branch tube, G, on the long arm of the gage. This completed the observation, so far as the determination of the pressure was concerned. The resistance of the platinum thermometer, T_2, was accurately determined, simultaneously with the reading of the pressure gage, and the temperatures of the various parts of the mercury column were also recorded. The laboratory barometer was then carefully read, in the room at the foot of the mercury column. (The pressure of the atmosphere was taken, because, since the mercury column was open at the top, it was necessary to add that pressure to the reading of the column itself, in order to obtain the absolute pressure of the steam.)

After the reading of the barometer, a new set of readings was taken of the mercury gage and of the platinum resistance thermometer in the boiler, the averages of the temperatures and pressures obtained just before and just after reading the barometer being regarded as constituting a single complete observation. All this time the water in the boiler was in full ebullition, of course, so that the temperature of the steam within it was that which corresponded to the pressure given by the reading of the mercury gage.

In Table 1 we give the general results that were obtained by Holborn and Henning, at pressures greater than the normal atmospheric pressure. Each of the observations recorded in this table is the average result of from five to ten separate experiments, each of which was performed in the manner indicated above; the number of separate experiments upon which the respective tabular entries are based being indicated, in every case, in Columns 3 and 7 of the table. Between the separate observations that were thus averaged together to obtain the results that are given in the table, there was a pause of about twelve minutes; and each single measurement consisted (as explained above) of a pair of readings of the pressure gage and the thermometer, between which came the reading of the barometer. In Holborn and Henning's original memoir, in the *Annalen der Physik,* the individual observations whose numbers are here indicated in Columns 3 and 7 are separately given, and they are all arranged in the order of the dates on which they were made. In preparing the present table, however, we have averaged the temperatures and pressures in each group (the temperatures in any one group never having a range of more than a small fraction of a degree), and we have only given the final results so obtained. We have moreover arranged the measures in the order of increasing temperatures, as this, for most purposes, is far more convenient than having them in the order of the dates.

It will be seen that during the first half of the period, thermometer No. 7 was used in the measurement of the temperature of the steam, while during the second half thermometer No. 9 was used instead.

A few words should be devoted to the explanation of the corrections that were applied. The pressures as obtained by the long mercury column were first reduced to the values they would have had, if the mercury in the column had had the temperature of melting ice. All pressures were also reduced to sea level in latitude 45°, this being now the common practice among physicists who aim at great precision, and at strict comparableness among the results obtained at different places, and under different conditions. Owing to the fact that mercury is slightly compressible, the mercury in the lower part of the long column was slightly more dense than that in the upper part, and a correction was applied for this. Also, the air pressure on the top of the mercury in the long column was slightly less (owing to the decrease of atmospheric pressure with height) than that which prevailed at the somewhat lower level where the barometer was read, and a correction was applied for this. Finally, a correction was required by the fact that the water surface in the boiler was not at precisely the same height as the mercury meniscus in the short arm (*KK'* in Fig. 2) of the mercury manometer; and to allow for this, a pressure equal to that due to the weight of a column of water vapor 40 centimeters (about 16 inches) in height was subtracted from the observed pressures.

The apparatus that we have described above was used in the measurements that were made at pressures exceeding the normal pressure of the atmosphere. In the experiments that were made at pressures lower than that of the atmosphere, the apparatus was somewhat different. Platinum thermometers were employed, as before, and the experiments were likewise performed by the "dynamic method." The arrangement of the apparatus was so similar, however, to that employed by Wiebe and Gruetzmacher (see THE LOCOMOTIVE, October, 1907, page 246), that we shall not describe it further.

In Table 2 we give the data obtained by Holborn and Henning with their second form of apparatus, the arrangement of this table being similar to that adopted above in Table 1. In this part of the work the temperature of the steam was measured by both of the platinum thermometers, in each experiment; and we have given the average reading of the two. The agreement between the readings of the two thermometers, when they were used simultaneously in this manner, was remarkable, the average difference between them being less than 0.002° C.

The memoir of Holborn and Henning concludes with a table of the pressures of saturated steam, the pressure in millimeters of mercury being given for every centigrade degree, from 0° to 205°. Above 50° their table is derived from their own observations, given in the present article; but below that temperature it is based upon the measurements made by Thiesen and Scheel, for which the reader is referred to THE LOCOMOTIVE for October, 1907, page 246. (The figures that are given in Holborn and Henning's table, below 50°, do not agree with those that are given in Scheel's own table, in Landolt and Börnstein's *Physikalisch-Chemische Tabellen*, page 119, because the results given by Holborn and Henning for this range, although based upon Thiesen and Scheel's experiments in the main, are nevertheless influenced by their own work, executed at temperatures above 50°. The further discussion of this point must be deferred to a subsequent article, in which we propose to discuss the formation of steam tables.)

We find nothing in Holborn and Henning's memoir respecting the purity of the water that was employed, nor do we find any statement as to the density of the mercury with which the gage was filled. It would have been exceedingly reassuring if explicit statements respecting these points had been given, and the omission is most unfortunate. As it is, we have to depend upon the known

TABLE 2.—EXPERIMENTS OF HOLBORN AND HENNING, AT LOWER TEMPERATURES.

Temperature* (Centigrade)	Pressure (Millimeters)	No. of Measures	Date (1908)	Temperature* (Centigrade)	Pressure (Millimeters)	No. of Measures	Date (1908)
50.686°	95.52	3	May 4	79.744°	351.25	6	May 8
51.553	99.63	6	" 5	80.053	355.73	6	Apr. 29
59.625	146.68	6	" 6	90.024	526.18	6	May 8
62.023	163.68	7	" 1	90.102	527.61	6	Apr. 28
69.977	233.47	6	" 6	90.186	532.25	7	Apr. 25
70.093	234.53	6	" 7	107.381	983.15	6	May 21
79.644	350.09	6	" 7	......	......	..	......

* Each temperature, in this table, is the average of the readings of thermometers Nos. 7 and 9.

reputation of the observers for accuracy and care, and upon the fact that all that emanates from the Reichsanstalt, where these measures were made, is distinguished by a faithful attention to details of this sort. According to experiments made at the Reichsanstalt, a cubic centimeter of pure mecury, at 0° C., weighs 13.59593 grammes at sea-level in latitude 45°; and in the absence of further information, we should have to assume that this was the density of the mercury used in the experiments herein described.

We regret that our limited space, and the fact that the subject is far removed from the one at present under discussion, forbids us to enter more fully upon the thermometric work of Holborn and Henning, as this appears to be excellent in character, and it is, moreover, of extreme interest to all who might desire to make use of the modern platinum-resistance method of measuring temperature with precision. In order to guard against error by the use of Callendar's correction-formula, which might reasonably be supposed to be too imperfect for adoption over a wide range of temperature when the greatest refinement is required, Holborn and Henning made several auxiliary investigations, to test the accuracy of their thermometry. In the first place, to aid them in determining Callendar's correction, they made a new and apparently very valuable re-determination of the variation of the boiling point of sulphur with pressure; and to test the accuracy of the correction itself they re-determined the boiling points of naphthalin and benzophenon by their own thermometers, and compared the results with those previously obtained by other experimenters. For the boiling point (under normal atmospheric pressure) of naphthalin, they found 218.04° C., and for benzophenon 306.08° C.; the best values of these boiling points, as previously known, being 218.07° C. and 306.03° C., respectively, on the scale of the hydrogen thermometer; these latter figures being the means of the determinations by Crafts, Callendar and Griffiths, and Travers and Gwyer. Finally, they had a series of direct comparisons made, at temperatures ranging from 150° C. to 204° C., between their platinum thermometers and a constant-volume gas thermometer whose bulb had a capacity of 315 cubic centimeters, and was made of Jena glass No. 59 III, and filled with nitrogen having a pressure of 705 millimeters of mercury at 0° C. The details of these comparisons are not given in the article under review, being reserved for a separate paper. The results are given, however, and they show that the Callendar correction is quite accurate enough for the purpose to which it has been put.

The final thermometric scale of Holborn and Henning is considered, by them, to agree with what is known as the "absolute thermodynamic scale" of temperature. (For information upon this scale, the reader is referred to the *Encyclopedia Americana*, article "Thermodynamics"; and, for a more extensive discussion, to Berthelot's memoir in the *Travaux et Memoires* of the International Bureau of Weights and Measures, Vol. 13.) We do not need to discuss this matter further in the present place, however, because Holborn and Henning's thermometric scale (according to the investigations of Berthelot, just cited) does not differ from the scale of the normal, constant volume hydrogen thermometer by so much as the hundredth part of a degree, at the highest temperature at which they experimented; and hence for our present purposes we may regard their temperature scale as being *identical* with that of the hydrogen thermometer.

Hartford Steam Boiler Inspection and Insurance Company.

ABSTRACT OF STATEMENT, JANUARY 1, 1909.

Capital Stock, . . . $1,000,000.00.

ASSETS.

	Par Value.	Market Value
Cash in office and in Bank, ...		$143,227.09
Premiums in course of collection (since Oct. 1, 1908),		274,020.83
Agents' cash balances, ...		23,011.96
Interest accrued on Mortgage Loans, . . .		25,965.64
Interest accrued on Bonds, ...		35,154.54
Loaned on Bond and Mortgage, ...		1,024,865.00
Real estate, ...		95,100.00
State of Massachusetts Bonds, ...	$100,000.00	88,000.00
County, City and Town Bonds, ...	399,000.00	407,360.00
Board of Education and School District Bonds, .	24,000.00	24,500.00
Railroad Bonds, ...	1,478,000.00	1,576,960.00
Street Railway Bonds, ...	173,000.00	171,010.00
Miscellaneous Bonds, ...	87,500.00	83,450.00
National Bank Stocks, ...	29,300.00	43,840.00
Railroad Stocks, ...	215,900.00	263,901.35
Miscellaneous Stocks, ...	180,100.00	144,060.00
	$2,686,800.00	
Total Assets, ...		$4,424,426.41

LIABILITIES.

Re-insurance Reserve, ...		$1,885,729.16
Commissions and brokerage, ...		54,804.17
Other liabilities (Taxes accrued, etc.), . . .		37,476.54
Losses Unadjusted, ...		28,382.11
Surplus, ...	$1,418,034.43	
Capital Stock, ...	1,000,000.00	
Surplus as regards Policy-holders, .	**$2,418,034.43**	2,418,034.43
Total Liabilities, ...		$4,424,426.41

On December 31, 1908, the HARTFORD STEAM BOILER INSPECTION AND INSURANCE COMPANY had 102,176 steam boilers under insurance.

L. B. BRAINERD, President and Treasurer.
FRANCIS B. ALLEN, Vice-President. C. S. BLAKE, Secretary.
L. F. MIDDLEBROOK, Assistant Secretary.
W. R. C. CORSON, Assistant Secretary.

A. S. WICKHAM, Superintendent of Agencies.
E. J. MURPHY, M. E., Consulting Engineer.
F. M. FITCH, Auditor.

Incorporated 1866. Charter Perpetual.

The Hartford Steam Boiler Inspection and Insurance Company

ISSUES POLICIES OF INSURANCE COVERING

ALL LOSS OF PROPERTY

AS WELL AS DAMAGE RESULTING FROM

LOSS OF LIFE AND PERSONAL INJURIES DUE TO STEAM BOILER EXPLOSIONS.

Full information concerning the Company's Operations can be obtained at any of its Agencies.

Department.	Representatives.	Offices.
NEW YORK, . .	C. C. GARDINER, JR., Manager, R. K. McMURRAY, Chief Inspector,	New York City, N. Y., 100 William St.
BOSTON, . . .	C. E. ROBERTS, Manager, F. S. ALLEN, Chief Inspector,	Boston, Mass., 101 Milk St. Providence, R. I., 17 Custom House St.
PHILADELPHIA, .	CORBIN & GOODRICH, Gen. Agents, WM. J. FARRAN, Chief Inspector,	Philadelphia, Pa., 432 Walnut St.
BALTIMORE, . .	LAWFORD & McKIM, Gen. Agents, R. E. MUNRO, Chief Inspector,	Baltimore, Md., 13-14-15 Abell Bldg. Washington, D. C., 511 Eleventh St., N.W.
ATLANTA.. . .	W. M. FRANCIS, Manager, W. M. FRANCIS, Chief Inspector,	Atlanta, Ga., 611-613 Empire Bldg.
BIRMINGHAM, .	LOUIS V. CLARK & Co., Gen. Agents, H. E. STRINGFELLOW, Chief Inspector,	Birmingham, Ala., 214-216 N. 20th St.
NEW ORLEANS, .	PETER F. PESCUD, General Agent, R. T. BURWELL, Chief Inspector,	New Orleans, La., 833-835 Gravier St.
HARTFORD, . .	H. C. LONG, Special Agent, F. H. WILLIAMS, JR., Special Agent, F. S. ALLEN, Chief Inspector,	Hartford, Conn., 56 Prospect St.
BRIDGEPORT,	W. G. LINEBURGH & SON, Gen. Agts., F. S. ALLEN, Chief Inspector,	Bridgeport, Conn., 1 Sanford Building.
PITTSBURG,	JAMES W. ARROTT, LTD., Gen. Agt., BENJAMIN FORD, Chief Inspector,	Pittsburg, Pa., 401 Wood Street.
CLEVELAND,	H. A. BAUMHART, Manager, H. A. BAUMHART, Chief Inspector,	Cleveland, Ohio, Century Building.
CINCINNATI, . .	W. E. GLEASON, Manager, B. F. COOPER, Chief Inspector,	Cincinnati. Ohio. 67-69 Mitchell Bldg.
CHICAGO, . . .	H. M. LEMON, Manager, JAMES L. FOORD, Chief Inspector,	Chicago, Ill., 169 Jackson St.
ST. LOUIS, . .	V. HUGO, Manager, V. HUGO, Chief Inspector,	St. Louis, Mo., 319 North Fourth St.
DENVER, . . .	THOS. E. SHEARS, General Agent, THOS. E. SHEARS, Chief Inspector,	Denver, Col., Room 2, Jacobson Bldg.
SAN FRANCISCO, .	H. R. MANN & Co., General Agents, J. B. WARNER, Chief Inspector,	San Francisco, Cal., Merchants' Ex. Bldg.
PORTLAND, . .	McCARGAR, BATES & LIVELY, G. Agts., C. B. PADDOCK, Chief Inspector,	Portland, Ore., Failing Building.

The Locomotive

Vol. XXVII. HARTFORD, CONN., JULY, 1909. No. 7.

Boiler Explosion in an Electric Lighting Plant.

On June 15, 1909, a 400-horse-power boiler exploded in the Denver Gas & Electric Company's power plant, Sixth and Curtis streets, Denver, Colo., with very serious results to the employees of the plant, and to the plant itself.

The exploded boiler was of the water-tube type,— one of the kind often designated as "safety boilers," though the present occurrence shows once more how inapt a name this is, and proves anew that there is no such thing as a real "safety boiler."

Fig. 1.— General View of the Plant.
(The cross shows where the boiler originally stood, and the arrow-head shows where it came down.)

The explosion resulted in the immediate death of three men and a boy, and in serious injuries to four other men, of whom, according to report, two could not recover. Four or five other persons were also slightly injured.

The property loss was at first believed to be something like $200,000; but when it became possible to examine the ruins more carefully, it was found that this estimate was a great deal too large, so far as the immediate damage was concerned, and a subsequent and probably more accurate estimate placed it at $60,000. In addition to this sum, however, there was a considerable, though as yet uncertain, loss from damage to wire service and equipment, and through failure to supply power as per contract; and when these elements are all included, it is possible that the total amount may approximate to the figure first stated.

Apart from the interest which this explosion has by reason of its serious consequences, and the possible lessons that may be learned from it respecting the proper care of boilers, it has another feature which should recommend it to the attention of engineers; for we have been able to obtain data sufficient to determine, with some degree of approximation, the path described by the boiler in its flight, and, in particular, the height to which it was thrown by the explosion. Such data are rarely available, although we have known of a few cases in which they could be had. We shall return to this feature of the accident, below.

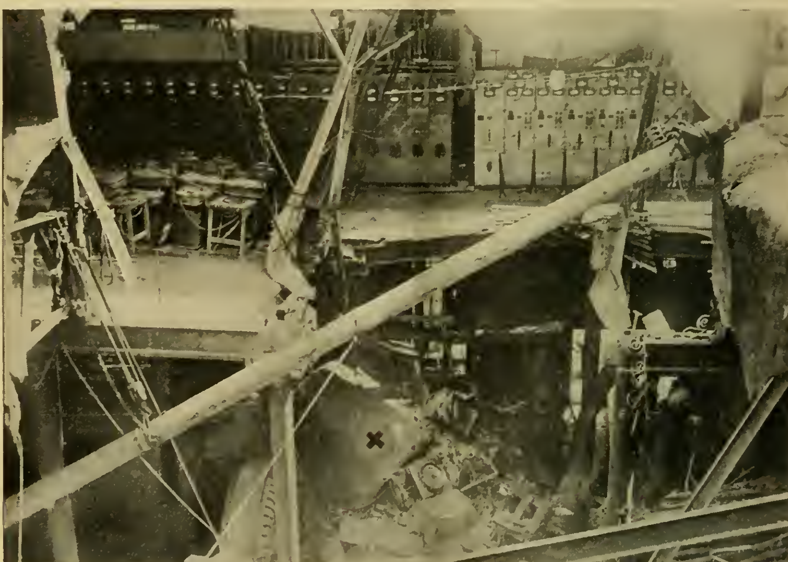


FIG. 2.— SHOWING WHERE THE BOILER LANDED.

DESCRIPTION OF THE BOILER.

The boiler house in which the explosion occurred was built in 1891, but it had been repeatedly enlarged since that date, and at the time of the present accident it contained seventeen boilers, all of the water-tube type, three being like the one that exploded, and the remaining fourteen of a different make. The boiler that exploded was No. 17, or the last one in the room, at the Curtis street end of the building, and was only about three and one-half years old. It was upright in form, consisting essentially of a pair of cylindrical drums, placed one over the other, and connected by a bank of vertical tubes containing water. The drums were each 8 ft. in diameter, and set with their axes (or center-lines) in the same straight line. The upper one was 9 ft. long and the lower one 4 ft. 3 in., each being constructed of steel plate, 11/16 in. thick, and stamped as of flange steel, with a tensile strength of 55,000 lbs. per square inch. The tube-sheets, or inner heads of the two drums, were flat, and were 3/4 in. thick, and were united by 170 tubes, each 4 in. in diameter and 22 ft. long. Each drum had twelve 1 3/4 in. braces running diagonally from the shell to the tube-sheet, and also twelve pairs of head-to-head braces, each separate brace being 3 1/2 in. wide and 1/2 in. thick; and, finally, each tube-sheet was stayed to the side of its drum by two gusset stays, made of quarter-inch plate. The outer heads of the drums were of steel, 13/16 in. thick, bumped to a radius equal to the diameter of the drum, and secured to the drum by a single row of rivets, the joint consisting of about 120 steel rivets, driven in 1 1/16 in. holes, and pitched 2 5/8 in. from center to center. According to the best of our information, the safety-valves, which were of the pop type, 4 in. in diameter,

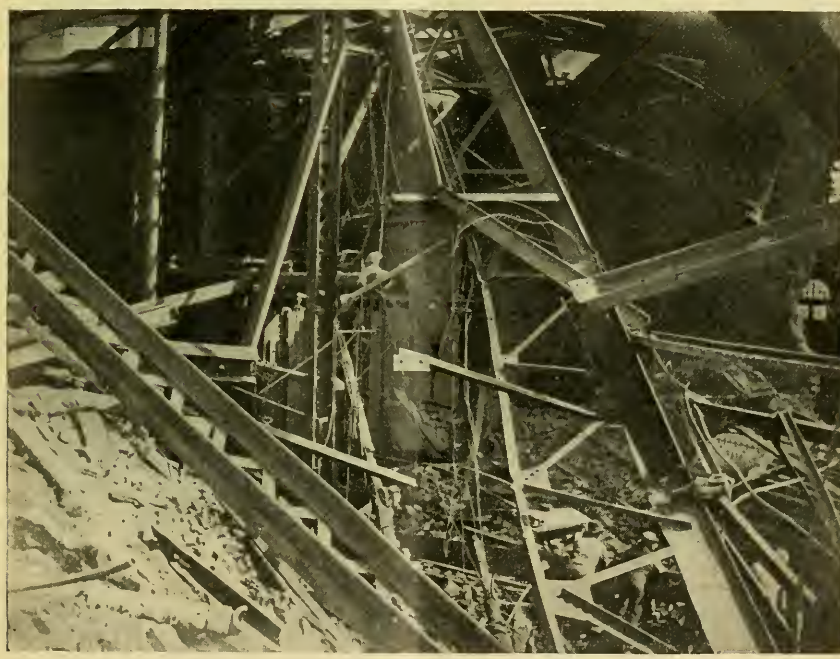


FIG. 3.— SHOWING SOME OF THE WRECKAGE IN DETAIL.

were set to blow at 150 lbs. per square inch, and the ordinary working pressure was about 135 lbs. per square inch. A recording gage that was attached to the steam main showed that the pressure in the main was 115 lbs. at the time of the explosion. This gives no positive information with respect to the pressure in the exploded boiler, however, because the stop valve between this boiler and the main was either just being opened, or else had not been opened at all. We have seen no statement respecting the condition of the stop valve when it was found, and we do not even know that it was found.

Nature of the Explosion.

The boiler failed by the blowing out of the bottom head of the lower drum, the fracture running for the most part through the rivet holes of the drum, as will be seen in Fig. 4, though in places the rivets were sheared instead. The braces in the lower drum did not break, but pulled away from the *tube sheet,* or *upper head* of the lower drum, by fracturing the rivets there. One of our correspondents says that the metal of the lower drum appeared to have changed in physical condition along the line of fracture, so as to be very brittle and hard there. He adds that the plate looks as though it might have been rolled from the upper end of an ingot, and suggests that the hardness might be attributable to excessive vibration, if any cause of such vibration could be assigned.

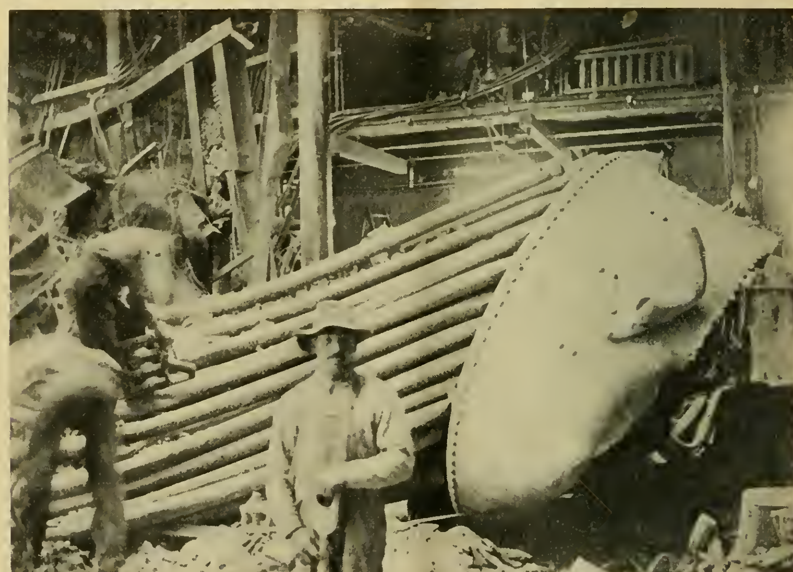


Fig. 4.— The Boiler, after the Explosion.
(Note the line of fracture, on the right.)

The lower head, after becoming detached from the drum, remained at or near its original position, and, save for a few indentations, was not damaged materially. The rest of the boiler, impelled upward, very much after the fashion of a rocket, by the reaction of the steam as it escaped from the lower ends of the tubes, passed through the roof of the building, at the Curtis street end, and soared high into the air, emitting steam as it ascended. It was seen, in its course, by quite a number of persons, and many estimated the height to which it rose, the estimates ranging from 200 feet to something like 500 feet. As we shall see subsequently, these guesses were all too small, the actual height attained being nearer 1,600 feet. All the observers are agreed that at the highest point of its trajectory, the boiler appeared to emit a considerable volume of vapor (or "smoke"), resembling, for an instant, a sort of puff-ball. It is possible that the steam, at this point, was not coming out of the boiler any faster than before, but that it was more conspicuous because for an instant the boiler was motionless, or nearly so, preparatory to its downward plunge.

Falling back again toward the earth, the boiler passed down through the end of the building remote from where it first stood, and came to rest about 175 feet from its original position. In its course through the building it wrecked a thousand-kilowatt Hamilton-Corliss engine and two large direct-current generators, besides doing a great deal of miscellaneous damage.

Cause of the Explosion.

We are not in possession of sufficient data to make any definite statement as to the cause of the explosion, but there is a belief, among some of the experts who have viewed the ruins and considered the facts at first hand and on the ground, that it was due to "cutting in" the boiler with the others, or putting it into free communication with the others by opening its stop-valve, after it had been fired up, and before the pressure within it was fully equal to that prevailing at the time within the other boilers. It is certainly a very dangerous thing to connect one boiler with others that are under steam, without being absolutely sure that the pressure is identically the same in the boiler that is to be "cut in" as it is in the steam main, and there have been many disastrous explosions from this very simple cause.

The plant in which this boiler stood was insured against boiler explosions, though not in the Hartford company, and the exploded boiler is said to have been inspected by the insurance company on June 2, and pronounced to be in good condition. We understand, also, that Mr. William Lawless, the city boiler inspector, inspected it on June 11, finding no defect in the boiler itself, but recommending some repairs to the brickwork. These repairs, we understand, had just been completed, and the boiler was being fired up, preparatory to being put into service again. At about six o'clock instructions were given to one of the men to "cut in" the boiler, and he was seen going toward the ladder leading to the top of the setting, presumably for this purpose. We shall never know what the poor fellow did, for he was killed; but the explosion occurred at 6:05, and there is nothing at all improbable in the supposition that he did cut the boiler in at that time,— assuming that the stop-valve of the boiler, if found, does not controvert this view by being tightly closed.

Height Attained by the Boiler.

One of the Denver newspapers printed the following weird computation respecting the boilers in this plant: "With their total pressure of 6,700 horse-power, they had a combined maximum of about 1,072,000 pounds of pressure, which could have furnished energy enough to have projected the 20-ton boiler, blown through the roof, through a mile of space." We have often seen calculations respecting the fraction of the stored energy in a boiler that would be available for propelling the boiler through space, and we have made a few of them ourselves; but never before have we seen one like unto this one. It reminds us of Mark Twain's sketch called "Mr. Bloke's Item." We have tried to assimilate it, but our intellectual digestion balks at it. If you try to see where the number 1,072,000 comes from, you find that you get it by multiplying 6,700 by 160; but why anyone should want to multiply 6,700 by 160 does not appear. Very likely the reporter thought 160 was the pressure per square inch at which the boiler was run; but even that fact, if fact it be, throws no light on the subject. Philosophers are agreed that there are things that transcend the human understanding, and it may well be that this paragraph is one of them.

In attempting to compute the height to which the boiler rose in its flight, we shall make use of certain data that have been furnished to us by friends who have been glad to assist in making this feature of the explosion a matter of definite record. The fundamental observation upon which our calculation is based was made by Mr. Harley, of the firm of Harley & Raleigh, who saw the boiler in the air as he was sitting in his office in the Charles building, on 15th street. The observation, as described by Mr. Harley to our former Special Agent, Mr. C. H. Dennig, and by him forwarded to this office, was as follows: "He sat at his office desk, his chair being about four feet from the window. With the lower sash raised, as was the case that evening, he can just see the ball on the top of the flagstaff of the Audi-

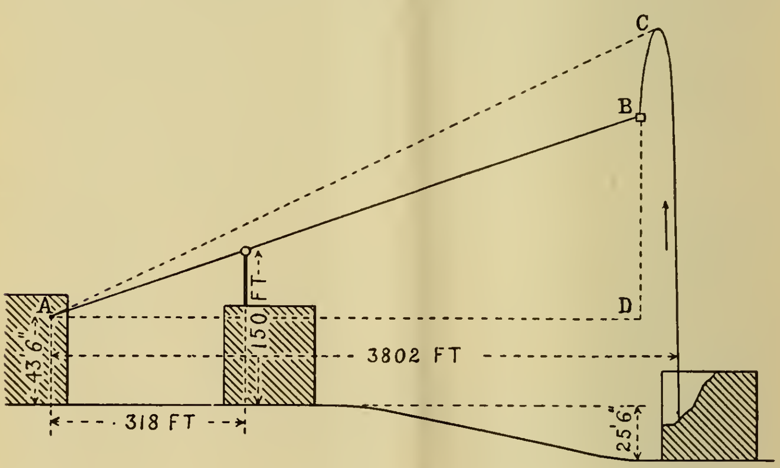


Fig. 5.—Illustrating the Data from which the Height of Projection is Calculated.

torium, *under* the edge of the sash. As the boom of the explosion was heard, he looked out of the window (the sound having meanwhile traveled nearly three-quarters of a mile), and, looking *through the glass* over the four-inch sash, he saw a cloud of smoke or dust, and instantly saw the boiler falling from that cloud, as it came into his line of vision below the sash, and on a level with the top of the flagstaff."

In view of this observation, which is sufficiently exact, evidently, to afford data for an approximate estimate of the height of the boiler, it remained only to obtain certain measurements of height and distance, after which the height to which the boiler rose could be ascertained by a simple proportion. The height of Mr. Harley's window above the ground could not be determined directly, but a measurement was made under Mr. Dennig's superintendence, by dropping a line to the street from the near-by window of Mr. C. B. Scott, in the Charles building. The result found was, that the height of Mr. Harley's eye above the pavement, as he sat in his chair, four feet from the window, was 43 ft. 6 in. Mr. J. B. Hyder, in the office of the City Building Inspector, informs us that the ball on the Auditorium flagstaff is 150 feet above the pavement. The pavement at the Auditorium is on a level with that opposite the Charles building, and Mr. E. M. Beeler, in the City Surveyor's office, certifies that this level is 25 ft. 6 in. higher than the ground at the point where the exploded boiler originally stood. Mr. Beeler also states that the horizontal distance from a point on the surface of the ground directly under Mr. Harley's eye when he saw the boiler, to the original position of the boiler, is approximately 3,802 ft., and Mr. Dennig has personally determined the horizontal distance of the Auditorium flagstaff from the eye of the observer to be 318 ft. Finally, it may be stated that the flagstaff on the Auditorium is very nearly in line with the eye of the observer and the position of the boiler at its highest point, and also that the direction of the boiler's motion was such that the path that it followed was seen almost exactly sidewise by the observer, the plane of the path of the boiler, in other words, being nearly perpendicular to the line of view.

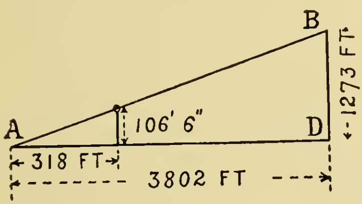


Fig. 6.—The Fundamental Triangle.

The various data here given are shown in Fig. 5, which is not drawn to scale, even approximately, because if it were the buildings would be so small that the significance of the measurements that are shown could not be clearly seen. In this diagram *A* is the position of the observer, Mr. Harley, as he sat in his office, and *B* represents the position of the boiler, as he saw it *under* the sash of the window, when it was admittedly not at the highest point of its path. We shall first calculate the height of the point *B*, and afterwards we shall see what additional allowance must be made for finding the height of the point *C*, which is the highest point attained by the boiler.

If we draw a horizontal line through *A* to a point directly under *B*, as indicated at *AD* in Fig. 5, we shall have a triangle such as is shown in Fig. 6. In this triangle the 106 ft. 6 in. is the height of the ball on the flagstaff above the line *AD* (150 ft. — 43 ft. 6 in. = 106 ft. 6 in.); and to find the height, *DB*, of the point *B* above the horizontal line through *A* we have the simple proportion

318 : 3,802 :: 106.5 : height required.

Solving this proportion we have $3{,}802 \times 106.5 = 404{,}913$, and $404{,}913 \div 318 = 1{,}273$. Hence the height of the point *B* above the horizontal line through *A* was 1,273 ft. To find the height of *B* above the ground directly below *B* we have to add to this the height (43 ft. 6 in.) of the point *A* above the pavement at the Charles building, and the height (25 ft. 6 in.) of this pavement above the ground at the gas company's plant. The total is $1{,}273 + 43.5 + 25.5 = 1{,}342$ ft., which is the height of *B* above the ground immediately below it. The boiler, when Mr. Harley saw it *under* the sash of his window, was, therefore, 1,342 ft. above the spot where it stood before the explosion.

As we have already noted, all the persons who saw the boiler in its course agree that at its highest point it emitted, or appeared to emit, a cloud of steam; and this cloud, as recorded above, was seen by Mr. Harley just over the sash of his window. The sash was four inches in width, so that the vertical distance between the lines *AB* and *AC*, where *AC* passed through the window glass, was certainly not less than four inches, and was doubtless as great as five inches or so; but in order to avoid any seeming tendency towards exaggerating the height attained by the boiler shell in its flight, we shall assume that it was four inches and no more. The window being four feet from Mr. Harley's eye, and the point *D* being 3,802 feet from him, we find, by a proportion similar to that given above, that the vertical distance from *B* to *C* was about 317 feet. Adding this to the 1,342 feet that we have already found to be the height of the point *B* above the ground, we find that the point *C*, or the highest point attained by the boiler in its flight, was 1,659 feet above the ground at the spot where the power house stands.

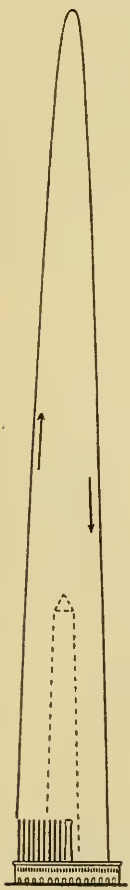


Fig. 7 — Path of the Boiler drawn to Scale.*

Now as to the time that it would take the boiler to rise to a height of 1,659 feet and fall back again. Assuming that the steam in the boiler had so far discharged itself by the time the point *C* was reached that we can neglect any reaction effects that it may have produced after that time, we may treat the boiler as a simple falling body, whose motion is to be calculated by the laws given for falling bodies in all the text-books on physics. To find the time required by a falling body, starting from rest, to fall through a given vertical height, we divide the height, in feet, by 16.1, and then take the square root of the quotient; the result being the time, in seconds, that it would take the body to fall through the given distance. Thus to find the time required for the boiler to fall from *C* to the ground (1,659 feet), starting from a state of momentary rest at *C*, we first divide 1,659 by 16.1, obtaining 103.04, and then we take the square root of 103.04, which we find to be 10.15. The calculated time of fall from *C* to the ground is, therefore, 10.15 seconds; and we may call this 10 seconds without making any serious error, since the difference would amount to an error of only 49 feet in fixing the position of *C*, and we can hardly suppose that we know the position of *C* as closely as that.

The time required for the boiler to ascend to *C* would be the same as the time required for it to fall, if its entire upward impulse were communicated to it at the instant it left the ground, and it were thereafter moving upward purely under the action of gravity. As a matter of fact, however, the reaction effect of the steam, as it escaped from the downwardly-directed tubes of the soaring boiler, would continue to be quite sensible for some distance above the ground, and to make an accurate estimate of the time required for the ascent we should have to go into a somewhat elaborate calculation, which appears to be hardly necessary, since there are a number of circumstances that we should have to know, in order to make the calculation exact, about which we could not know anything at all. For example, we should have to

* For comparison, the Washington monument is shown, on the same scale, by the dotted outline.

know the direction in which the discharging ends of the boiler tubes pointed at each instant of the upward flight, and evidently there is no way to find that out. We shall compromise, therefore, by assuming that the upward impulse of the steam was exerted mainly while the boiler was still near the ground, its subsequent action being negligible. We can then treat the rising boiler as though it were under the influence of gravity alone, and the calculated time of its rise would be equal to the calculated time of its fall, or 10 seconds. The actual time required for the boiler to rise to *C* would be a little longer than 10 seconds, if we were to take account of the way in which the steam actually did act upon it, but the difference would probably not be at all marked, and would probably not exceed a second, or 2 seconds at the outside. It is to be observed that this assumption as to the action of the steam does not affect the calculated height of *C* in the least, this being fixed by entirely independent considerations; nor does it affect the calculated time of the fall, provided the steam can be fairly assumed to be discharged, by the time the boiler has risen to *C*, to such an extent that the subsequent reaction effects from it are negligible.

We have no idea of claiming, for the foregoing estimate of the height to which the boiler rose, a degree of accuracy comparable with what could have been attained by good observations made upon the boiler at its highest point with surveyor's instruments, but yet, owing to the circumstances under which Mr. Harley saw the boiler, and the definite way in which he was able to fix its position by reference to the flagstaff of the Auditorium and to the sash of his window, we are of the opinion that the estimate is a reasonably close one, not likely to be in error by more than a couple of hundred feet.

In order to have some check upon the accuracy of the result, we may compare it with the general statements made by eye-witnesses, leaving out of account the guesses that were made as to the height, and which have been already cited. To begin with, Mr. Harley, when asked to estimate the time that elapsed from the instant he heard the explosion until he saw the cloud of steam at the highest point of the path, replied that the two events came almost simultaneously. In this, however, he is plainly mistaken; for the explosion, being at a distance of 3,800 feet, would be heard by him about 3½ seconds after it occurred (this being the time it takes sound to travel 3,800 feet); and if, in 3½ seconds, the boiler had risen to its highest point, falling back again in another 3½ seconds, the total time of its flight would be only 7 seconds, which would have been entirely insufficient to enable Mr. Casso to accomplish what he did, in the switchboard room, as noted below. Mr. Harley's estimate, moreover, was made ten or eleven days after the actual explosion, so it is not surprising that it does not agree with the calculated time of flight. According to our calculations, it was 10 seconds from the time that the boiler exploded before it reached its highest point; and taking from this the 3½ seconds that were required for the sound to reach Mr. Harley, it follows that it was 6½ seconds after he heard the explosion, before he saw the cloud of steam.

The experience of Louis Casso, switchboard operator at the plant, is of great importance in checking up the calculated time the boiler was in the air. When interviewed by the newspapers immediately after the explosion, Mr. Casso said that when he first heard the explosion and felt the shock to the building, he paused and considered, for a short time, what he ought to do. Then, instead of running for safety, he passed down the entire length of the long switchboard, as rapidly as possible, opening the switches so as to shut off all the current that the plant had been sending out into the city. While his hand was yet on the last switch, the falling boiler came down through the roof of the building and crashed into the basement below, bringing a large section of the roof along with it. It would seem as though 20 seconds was a reasonable time to accomplish all this, if he worked hurriedly, as he certainly did after he had once begun. Furthermore, we find that Mr. Casso gave an estimate, himself, of the time the boiler was in the air, for one of the Denver papers quotes him as saying: "It was less than a minute's time between the explosion sound and the coming down of the boiler." We ask for only 20 seconds, and in view of the known fact that time seems to pass very slowly under conditions of terror and suspense like those to which Mr. Casso was subjected, we feel that his estimate agrees very well with our calculation.

Finally, Mr. Dennig was able to obtain still another bit of evidence which bears out our calculation, although he had no idea whether it would do so or not when he obtained it. "A man in the police department," he says, "told me that he heard the explosion from his front porch. His wife was on the upper porch, where she could see the sky over the trees in the yard. On hearing the noise he called out, 'Wonder what's up?' and she answered, 'I see something going up. . . . Gracious, it's still going up! . . . Why, it's going up yet! . . . My, what a cloud of smoke! [This when the boiler reached its highest point.] . . . Why, something has fallen out of it!'" Mr. Dennig adds, "My informant laughed and said, 'Just figure out for yourself how long that boiler was going up.'"

We feel that this observation and the estimate of Mr. Casso, taken together, form a very good confirmation of our conclusion that the time occupied in the ascent was 10 seconds, and that the total time the boiler was in the air was 20 seconds, and that it rose to a vertical height of 1,659 feet.

Water-Hammer Action in Steam Pipes.

In the designing of steam pipes, the stresses that are anticipated, and for which provision is made, are the steady or slowly varying ones that are due to the pressure, or to the expansion and contraction of the metal from temperature changes, or to the weight of the pipe itself. It is known, however, that steam pipes containing water are often the seat of violent shocks, the water being thrown about by the steam so as to give rise to sudden and very severe stresses, by its impact against the pipe. An action of this kind is technically known as a "water-hammer."

The tremendous mechanical power that water can exercise, when it is projected against a solid body with any considerable velocity, is well known to those who have seen the effects of heavy storms along the coast, sea-walls and lighthouses being sometimes destroyed, though built of heavy masonry. But while we understand very well that large masses of water can do these things, it is sometimes hard to believe, until we are taught by that thorough but expensive teacher, experience, that small bodies of water can do any great harm, when confined in a steam pipe. Yet accidents, attended with the most serious consequences, and undeniably due to this cause, are of frequent occurrence, and it is constantly necessary to look after pipe lines to see that they are properly drained, and to warn employees against turning steam into pipes that may be reasonably suspected to contain water.

Mr. C. E. Stromeyer, of the Manchester Steam Users' Association, has contributed two interesting and important papers to the literature of this subject, and both have been printed in *Engineering*, one in the issue for February 28, 1902, and the other in that for April 9, 1909. In the first of these he discusses the general subject of impact, and gives formulas for calculating the duration and force of a collision between a rigid body and an elastic bar that strikes against it endwise. In this first paper he touches only briefly upon the application of the formulas to the case of water-hammer action in steam pipes, but in the second one he dwells upon it at length, and gives a modified form of his fundamental impact formula, from which we can calculate the pressure that is produced in a steam pipe by a water-hammer.

Mr. Stromeyer's Experimental Apparatus.

In his second paper, Mr. Stromeyer describes an ingenious form of experimental apparatus which he constructed of glass for the purpose of studying water-hammer action in a horizontal pipe. This is shown in Fig. 1. The flask *F* here corresponds to the boiler, and the bent tube *TTT* represents the steam pipe, in which the water-hammer action is to be produced. On account of the rapid heating that the small quantity of water in *TTT* undergoes when the

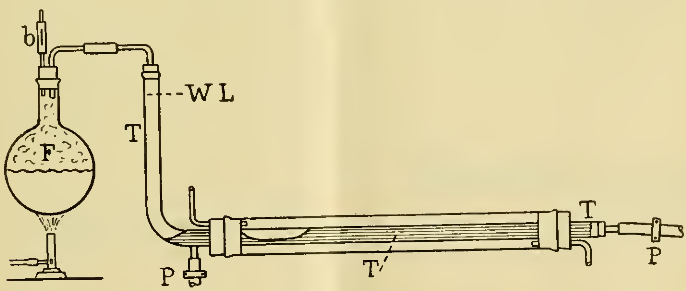


Fig. 1.— Apparatus for Producing Water-Hammer Experimentally.

apparatus is in action, it is surrounded by a water-jacket, as shown, and it is found that with this addition the action of the apparatus can be kept up as long as desired, whereas without the jacket it ceases as soon as the trapped water has become as hot as the steam. The pinch-cocks, *PP*, represent drain-cocks on the pipe. A valve is provided, at *b*, consisting of a piece of rubber tubing, plugged at the top, and provided with a slit. Steam readily escapes through this, so long as the pressure in the flask is greater than that of the atmosphere; but when the conditions are reversed, and the pressure in the flask falls below that of the atmosphere, the slit closes and prevents the entrance of air.

To operate the apparatus, the tube *TTT* is first filled with water to the level *WL*. The water in the flask is then made to boil violently, so that steam escapes freely through the valve *b*. When the flow of steam has continued long enough to sweep out most of the air in the flask, one of the pinch-cocks *PP* is opened until the level of the water in *TTT* sinks to a point just below the top of the horizontal leg. The valve *b* then closes, the steam from the flask being thereafter rapidly condensed by contact with the long surface of cold water in *TTT*,— rushing into the horizontal part of this pipe with high speed, agitating the water as it enters, and throwing it into waves at the left-hand end. When one of these waves blocks the pipe, as shown in Fig. 1, the imprisoned steam is almost instantly condensed, a partial vacuum being formed to the right of the wave, while the steam pressure from the flask continues to act upon it from the left. The result is that the wave is sent forward toward the right with lightning-like speed, delivering a water-hammer blow to the tube and its contents at the instant the vacuum space disappears, and the wave strikes the mass of water to the right. The waves follow one another in rapid succession, and the action is repeated indefinitely.

Case of the Actual Steam Pipe.

The analogy between the experimental apparatus and the case of an actual steam pipe with water standing in it is made evident by comparing Figs. 1 and 2. In the experimental apparatus the pressure in the flask cannot be maintained at anything like atmospheric pressure. by the Bunsen burner, so long as the pipe *TTT* is kept cool, and it may be that the available difference in pressure on the two sides of the wave does not exceed a pound or so per square inch. In actual steam pipes, where the steam is drawn from one or more capacious boilers under a considerable pressure, it is likely that the difference in pressure available for the propulsion of the wave is very considerable, and the action would then be correspondingly more violent. Mr. Stromeyer, in his second paper, discusses quite a number of different arrangements of piping, in addition to the one shown in Fig. 2, and gives many references to reports of the British Board of Trade, in which water-hammer accidents are described.

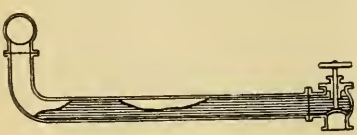


Fig. 2.— Production of Water Hammer in an Actual Steam Pipe.

It is manifestly of the highest importance to drain a steam pipe thoroughly before admitting steam to it, and great numbers of fatal accidents are on record, which were due to the neglect of this simple and elementary precaution. It sometimes happens, however, that the water will not all run out of a pipe, and the attendant is occasionally deceived, by the cessation of the flow from the drain pipe, into the belief that all the water has been removed, when this is not the case. Steam should always be turned into a pipe very slowly, and should be promptly shut off when there is the least indication of the presence of water. Experience has shown that it is highly dangerous to attempt to drain cool water off from a pipe that is also carrying steam, no less than forty-nine of the cases cited by Mr. Stromeyer being due to this cause alone. If water is found to be present after the steam has been turned on, the opening of a drain valve, before shutting off the steam again, may start an agitation in the water that will end disastrously. When, by reason of insufficient pressure in the pipe, the water that has been trapped there refuses to run off, it is recommended that the drain valve and steam valve be opened *alternately* — the steam valve only momentarily, and never more than the *smallest crack*, however, so that it may admit a sufficient quantity of steam to warm any air that may be present in the pipe. After the air has been warmed a little in this way, it will expand and force out some of the water, when the steam valve has been closed and the drain cock opened again; and by careful repetition of the operation the pipe may be freed from the water it contains. It appears to be hardly necessary to say, however, that one of the most elementary principles in pipe designing is to lay out the lines so that there shall be no possible way in which water can accumulate in them. The full realization of this ideal condition may not be practicable in every case, but the designer should aim to approach it as nearly as he can; and when trouble is experienced from the trapping of water, it will usually be found that some small change in the piping — perhaps a very trifling change — will remove the difficulty completely.

Ideal Case of a Cylindrical Plug of Water in a Steam Pipe.

In deriving his formula for calculating the stress thrown upon a pipe by water-hammer action, Mr. Stromeyer first considers the ideal case in which a steam pipe is completely closed, at some point, by a cylindrical plug of water, as illustrated in Fig. 3; the plug being supposed to maintain its form and to be driven towards the closed end of the pipe by reason of the steam pressure behind it (*i. e.*, on the left, in the illustration) being considerably greater than that on the front side. To disarm any captious critic who might insist that water couldn't "stand up" in this way, nor be moved by the steam as though it were a solid plug, we may think of the water-plug as having a frictionless wad on each side of it, like a charge of shot in a gun.

Let us suppose that as the steam from the boiler sends the plug along towards the right, the vapor that is in the closed space between the plug and the end of the pipe condenses, always keeping at the same constant pressure, but turning to water as the plug advances. This is what would actually

Figs. 3 and 4.— Illustrating the Water-Plug in the Rigid Pipe.

happen, of course, if the temperature of the imprisoned vapor were kept constant, by reason of its contact with the pipe, or with the plug itself, or in any other way. The outcome, then, would be, that the water-plug would be blown up against the end of the pipe, stopping suddenly in the position shown in Fig. 4, and simultaneously communicating an endwise shock to the pipe, as well as a lateral shock to that part of it which is sufficiently near to the end to be influenced.

If we knew the velocity with which the plug struck the end of the pipe, we could calculate the momentary force that it would exert against each square inch of the area of the blank flange, by means of the second rule in our article on impact in the present issue; this rule being itself a paraphrase of one of Mr. Stromeyer's formulas. The velocity of striking is not supposed to be given, however, and hence we should have to calculate it, from the known pressure of the steam and various other circumstances, before we could proceed in this way. To make it unnecessary to perform such a double calculation, Mr. Stromeyer has modified his original formula for the pressure produced by an impact, and in the place of it has given another, in which all the necessary arithmetical work is performed at one time. The result, expressed in words instead of symbols, is as follows:

Rule: To find the momentary pressure, in pounds per square inch, produced against the closed end of a rigid pipe by a cylindrical plug of water that is urged forward by a given constant difference in pressure between its two ends, multiply the volume of the space (V in Fig. 3) through which the plug has to travel, by the difference in pressure, in pounds per square inch, between the two ends of the plug, and multiply again by the constant number 600,000. Then divide the product by the volume of the water-plug itself (W in Fig. 3), and take the square root of the quotient. The volumes V and W must both be taken in the same unit,— *i. e.*, both in cubic inches, or both in cubic feet.

As this rule does not remotely resemble Rule 2 in our article on impact, in its general form, a word of explanation as to the relation of the two may be forgiven; those who are not curious on this point, but are content to accept the new rule, without inquiry, being invited to omit the present paragraph, and pass at once to the next one. Mr. Stromeyer first obtains an algebraic expression for the work that the steam does on the water-plug, in pushing it to the end of the pipe. Setting this equal to the gain in the kinetic energy of the plug, he obtains an equation from which he can find the velocity of the plug at the instant of striking. Then he writes down the known formula for the velocity of sound in water, in terms of the density and the modulus of compressibility of the water, assuming the value of the modulus of compressibility to be 300,000 pounds per square inch. Having thus obtained an expression for each of the velocities mentioned in his earlier formula for the pressure due to impact, he eliminates these velocities, finally obtaining a new formula, of which the rule in the last paragraph is a paraphrase.

Application of the Rule to the Actual Case.

It is to be noted that the foregoing rule does not profess to apply to any case except the one in which a cylindrical plug of water, which entirely closes a pipe otherwise containing nothing but steam, is driven against the end of a perfectly rigid pipe. Mr. Stromeyer next proceeds to see what modifications, if any, the rule requires, in order that it may apply under the actual and somewhat different conditions that arise in practice. He finds, firstly, that the rule appears to give sufficiently accurate results, whether the plug of water collides directly with a solid wall at the end of the pipe, or with an intermediate body of water which itself rests against the end of the pipe. Secondly, it is evident from the way in which the rule is derived, that it is not at all essential that the plug should be cylindrical, nor that it should have any other special shape, the rule being applicable to plugs of any form whatever. Thirdly, it is not necessary to suppose that the pipe is actually rigid. If the material of the pipe is not stretched beyond its elastic limit, the stress calculated by the formula does not have to be diminished by more than 25 per cent. or so, in order to take account of the elasticity of the metal, even in an extreme case; and this is doubtless within the limit of uncertainty of the formula itself. In dealing with cast-iron pipe, in particular, we may treat the case as though the rigidity of the pipe were perfect, practically the full pressure as given by the rule being realized on the fitting, and also, laterally, on the pipe itself.

It is when the pipe is capable of *plastic* yielding that the greatest question arises. If we confine our attention to the pipe itself, a solid-drawn copper pipe will doubtless be made to bulge by a severe water-hammer blow, but fracture of the pipe would not be likely to result, except as the final consequence of a long series of blows. A brazed copper pipe would be quite likely to rupture, however, owing to the brittleness of the brazing. A mild steel pipe, according to Mr. Stromeyer's view, would probably swell without rupturing; but we should be of the opinion that a welded steel pipe, if the weld were in any way imperfect, would be likely to split.

The shock received by a *fitting*, at the end of a pipe (like one of copper) that is capable of yielding plastically to a sensible degree, would appear to depend to some considerable extent upon whether the blow was delivered directly against the fitting, or was transmitted to it through an intermediate mass of water. In the former case we do not see how the fact that the pipe is plastic can be supposed to materially diminish the initial force of the blow, as the flange or collar of the fitting would stiffen the end of the pipe so that a short pocket-like space would be formed, within which the full value of the pressure might easily be developed; but where the pressure-wave has to be transmitted through a mass of water in a plastic pipe before it reaches the fitting, the force of the blow against the fitting would doubtless be lessened by a considerable amount.

It appears, therefore, that the rule, as given, may be used to calculate the stress upon a pipe-fitting in all cases, except when the blow has to be transmitted to the fitting, from the point of impact, through a mass of water that is contained in a pipe made of a material which, like copper, yields plastically. In strictness, the rule would need certain corrections in various other cases, but so far as we can see, the error arising from the omission of these corrections is unimportant. As explained elsewhere in this issue, our knowledge of impact is still decidedly faulty, and the fundamental reasoning upon which the present rule is based may have to be revised after a time, when our knowledge of the subject improves. Moreover, the rule itself presupposes a knowledge of certain conditions, as to which we have to make pure and unfounded assumptions. For example, it requires us to know the volume of the water plug that is driven along, or the ratio of this volume to the volume of the space through which the plug passes before impact occurs; and moreover there may be, and often will be, more or less cushioning of the blow, from the presence of air in the pipe. In a word, the most useful purpose of this rule, or of any other rule of like import, is to show the *order of magnitude* of the forces that are called into play by water-hammer action, it being useless, under the more or less unknown conditions that prevail within a pipe, to attempt any great degree of accuracy in the calculation.

As an example in the use of the rule, let us suppose that a wave of water, having a volume of 1,500 cubic inches, is driven forward, in a pipe, through a space of 500 cubic inches, by an effective pressure of 75 lbs. per square inch. Following the rule, we have $500 \times 75 = 37{,}500$, and $37{,}500 \times 600{,}000 = 22{,}500{,}000{,}000$. Dividing this by 1,500 we obtain 15,000,000, the square root of which is

3,873. The calculated momentary pressure that would be produced against the fitting at the end of the pipe is therefor 3,873 lbs. per square inch. Manifestly we may make a generous allowance for the uncertainty of the formula, and yet have a pressure that is highly dangerous.

The Impact of Elastic Solid Bodies.

In the preceding article we discuss water-hammer in steam pipes, pointing out its cause, and showing, in a general way, how to calculate the magnitude of the forces that are concerned in it. We find, however, that impact is a subject that is imperfectly understood by most readers, and hence we have prepared the present article as a sort of supplement to the other one, confining ourselves, herein, to the impact between elastic solids, since the principles that are involved can be brought out better in that way. The case in which one of the colliding bodies is a mass of water is sufficiently discussed in the other article.

The Nature of Impact Between Solid Bodies.

When one solid body comes into violent collision with another one, so that the motion of either (or both) is checked or reversed, a shock is experienced by both bodies. This is familiarly illustrated in the striking of a nail by a hammer, and in many other experiences of everyday life. But in order to calculate the magnitude of the shock or blow, we have to proceed with some consideration and care, or we shall be led into absurd results.

The phenomenon that occurs when two solid bodies collide in this way is known, in theoretical mechanics, as "impact." Immediately upon their coming into contact, a pressure is produced at the point or region where they first touch. If they were both absolutely rigid, so as to be incapable of undergoing even a slight local flattening in this region of contact, the pressure between them would at once become infinitely great, so that both bodies would be instantly shattered to pieces; and this would be the case, no matter how slowly they were moving when they came together. In nature, however, there is no such thing as an absolutely rigid body, for every body yields somewhat to the action of a force exerted upon it. The bodies that we call "rigid," in nature, are merely bodies in which the alteration of form is very slight, when any ordinary force is exerted upon them,— so slight, perhaps, that it cannot be detected without the use of refined scientific instruments.

When two actual solid bodies collide, the total duration of contact may be very short indeed, and we are in the habit of thinking of the impact, in a case such as is exemplified by the collision of a pair of billiard balls, as being instantaneous. It never really is instantaneous, however; and we must think of the bodies as being in contact for a period which, though it may be very short, is nevertheless real, and quite capable of being measured, if we go about it in the right way.

Even after contact has actually occurred, the more remote parts of the bodies continue moving towards each other on account of the momentum they had before the impact began; and it is plain that this cannot be the case without the bodies becoming deformed. In the vicinity of the region of contact there is a local flattening or compression, and the bodies are both thrown into a state of stress in this neighborhood, while, at the same time, the velocity with which their remoter parts continue to approach each other grows less. After a certain interval the bodies will reach their maximum deformation and at the same instant they will cease to approach each other.

If the bodies are perfectly plastic, like soft putty, the impact is now complete, and nothing further happens, the energy of motion that they had, before the collision, being irrecoverably dissipated in the form of heat. If, however, they are both perfectly elastic, so that when deformed they tend to spring back again into their original shape, and to regain that shape perfectly, then the impact is by no means over. The energy that they possessed in virtue of their original velocity, in that case, has not been dissipated in the form of heat, but has become stored up within them, just as the work we do in straining a spring is stored up within the spring, ready to be given out again as soon as the spring is allowed to regain its original form. The elastic bodies continue to press against each other, and, once their speed of approach has been annulled, the pressure between the two begins to make them move apart, and the separation continues to increase until they are again free from contact with each other. The impact is then terminated.

To speak of the "force of a blow in pounds," when we regard the impact as being absolutely instantaneous, is manifestly illogical and without sense; but it is plain that such an expression is quite accurate when we regard the impact as of finite, though very short, duration, for then it signifies the maximum value of the pressure that exists between the bodies during this short interval.

We ordinarily think of an "elastic body" as being one which, like india rubber, yields in shape very readily under the action of a relatively small force, resuming its shape as soon as the force is removed. In theoretical mechanics, however, it is the fact that the body tends to come back to its original size and shape, when the force is removed, which constitutes the real test of elasticity, rather than the readiness with which the shape or volume of the body yields when a given force is applied to it. The amount by which the size or shape changes under the action of a given force is expressed by stating what is called the "modulus of elasticity" of the body, with respect to a change of the proposed character; "modulus" being a Latin word signifying "measure," so that the rather forbidding-looking expression "modulus of elasticity" merely means a number which serves to measure the amount of force which must be applied to the body in order to change its form or bulk to a given extent. Thus the modulus of elasticity of a steel bar, with respect to endwise compression, is the compressive force which would have to be applied to a bar of the same material, one square inch in sectional area, in order to shorten the bar by its entire length, if the compressibility of the bar, during all this change in form, followed the same law that holds true for very slight changes in the length. Of course it would be absurd to suppose that the law for small changes would hold true for enormous ones, or that the bar could be compressed to a zero length by any force whatever; but it is found to be convenient to measure the compressibility by means of a "modulus" as thus defined, it being understood that the modulus is to be employed only in computing very small changes in length, and that it ceases to be of use as soon as the bar has been strained beyond its elastic limit, so as to take a permanent set.

Theories of Impact.

In order to calculate the force, or maximum momentary pressure, that is exerted between two bodies that come into collision, we have to take into account the nature of the bodies, since the pressure that will be produced by the impact will differ according as they are plastic, or perfectly elastic, or intermediate between these states.

According to Newton's view, two perfectly elastic bodies, when they collide, undergo deformation as a whole, and then, when the deformation has attained its maximum value, they spring back again from each other in such a way that all the successive states that occurred during the first half of the impact are repeated again, but in exactly the reverse order. Newton, therefore, does not take into account the possible production of internal vibrations, persisting in the bodies after the impact is completed and the bodies have separated.

Saint-Venant, the great French authority on the theory of elasticity, made highly important contributions to the theory of impact, and gave what was believed to be a far more accurate theory of the subject than Newton's. He took account of the fact that when elastic bodies collide, the impact produces not only a pressure at the region of contact of the two, but also (save when certain special conditions are fulfilled) internal vibratory motions, so that when the bodies have rebounded from each other, each is, in general, in a state of vibration, as well as being in motion as a whole. Nothing is more certain than that this state of internal vibration exists in many cases. For example, when a bell that is suspended by a cord is struck by a hammer, the bell begins to swing on the cord, and at the same time it emits a musical note by reason of the vibrations that are set up within it. In the same way, a bar of steel, when caused to strike endwise upon an anvil, rebounds into the air, and, if the experiment is suitably conducted, also emits a musical note, showing that the bar as well as the bell has been thrown into a state of vibration. Saint-Venant's theory, in which full account is taken, mathematically, of such vibrations, appears, upon the face of it, to yield results of a higher order of precision; but when tested by experiment it is found to be quite unsatisfactory. In the case of two elastic bars colliding endwise, for example, Hamburger found that the actual duration of the contact was several times as long as the duration calculated by Saint-Venant's method.

Voigt, too, has tested Saint-Venant's theory, by causing two elastic bars of the same material and the same cross section to collide endwise, one of them being twice as long as the other. The velocities of the bars, as measured after the impact, were found to differ widely from the velocities calculated by Saint-Venant's theory, but to be in good accord with the older and presumably far less perfect theory of Newton. The order of the agreement and disagreement may be illustrated by the following single example: The longer bar being at rest, the shorter one, moving with the speed of 80.4 inches per second,* was allowed to strike against it endwise. According to Newton, the short bar ought to bound back from the long one with a speed of 26.8 inches per second, and the long one, after the impact, ought to be moving

* We do not recall the actual unit in which Voigt's velocities were expressed, but as we are here concerned with relative values of the velocities, instead of absolute values, the unit employed is of no consequence, and we have, therefore, given his results as though they were expressed in inches per second.

ahead (that is, in the direction of the original motion of the short one) with a velocity of 53.6 inches per second. In the actual experiment, the velocities were found to be in the directions indicated by the Newtonian theory, and to have the respective magnitudes 21.6 inches per second, and 51.4 inches per second. The agreement here is very fair. On the other hand, the "improved" theory of Saint-Venant, when applied to this case, predicts that after the impact the long bar will be moving forward with a velocity of 40.2 inches per second, instead of 51.4 inches per second, as observed, and that the short one will be stationary. The disagreement between Saint-Venant's theoretical results and the actual facts is manifestly great, and the reason for the difference is not known. His theory evidently assigns too much energy to the vibrations of the colliding bars, for in the case cited above the actual amount of vibratory energy that existed in the two bars together, after the impact, was something like 11 per cent. of the energy of motion that the system possessed before the collision, while according to Saint-Venant's theory it should have been 50 per cent. Newton's theory disregards the vibratory energy altogether, and proceeds as though there were no such energy present.

As a result of the experimental investigations mentioned above, Professor Voigt proposed a new theory of impact, which was intended to be intermediate, in a sense, between that of Newton and that of Saint-Venant. Voigt's fundamental assumption is that the skin, or superficial layer, of the metal differs in its properties from the rest of the bar, and his theory can be made to degenerate into that of Newton, on the one hand, or that of Saint-Venant, on the other, by varying the constants that are assumed to characterize the "skin." It might be supposed that a theory with such a wide range of adaptability could be made to yield entirely satisfactory results, but such is not the case, for Hausmaninger found that when the constants of the theory are selected so as to make the calculated velocities of the bars agree well with experiment, the calculated duration of contact is much shorter than the actual duration as found by experiment.

Hertz gave yet another theory of impact, which agrees with experiment much better than either Saint-Venant's or Voigt's, but which, unfortunately, is not well adapted to the problem we have in hand, being especially designed for the attack of problems in which the collision is between two solids that are bounded by curved surfaces, like a pair of spheres. Like Newton, Hertz takes no account of the internal vibrations that may be set up within the colliding bodies by the impact.

From what has been said above, it will be plain that we are in no position to calculate, with any considerable degree of precision, the force that one elastic body exerts when it collides with another body that is either elastic or rigid. The ignoring of the residual internal vibrations in the colliding elastic solids must be regarded as a temporary expedient, to be adopted only until someone finds out how to take these vibrations properly into account; for nothing is more certain than that such vibrations do occur, except under special conditions. Theories which, like Hertz's, omit them from consideration, may give accurate results under the conditions in which such vibrations do not occur, or in which their energy is negligible, but in other cases they can never be in truly close accord with experience.

Theory of Impact Adopted by Mr. Stromeyer.

Mr. C. E. Stromeyer, in his papers on water-hammer action in steam pipes, referred to in our article on that subject in the present issue, adopts a Newtonian form of impact theory which is probably accurate enough for the ultimate purpose he has in view,— namely, for calculating the pressure due to the impact of water against a steam pipe or its fittings. We shall explain the theory, here, in the form it would have when applied to a solid elastic body, its application to the impact of water-masses being given in the preceding article on water-hammer action.

In his first paper, Mr. Stromeyer deals with the case in which an elastic bar strikes, endwise, against a non-yielding, rigid body, which we may call the "anvil," and he treats the impact as though it occurred in the following manner: First, when the contact between the two is primarily established, there is a pressure produced between the bar and the anvil, and this pressure is supposed to remain constant as long as the contact continues. The bar being suddenly stopped at its front end, the back parts continue to press forward, as we have previously described, and the result is that layer after layer of the bar, beginning at the front end and passing backward towards the tail end, come successively to rest, a pressure, equal to the pressure that is prevailing all this time at the front end, being developed in each layer as it comes to rest. Finally, after the lapse of a short but quite definite time, the whole bar is stationary, and all in a condition of uniform compression, from one end to the other. The next instant the bar begins to spring back again, just as a spiral spring would, if it were released from a state of compression at one end, while fixed at the other end. The very outermost layer at the free end begins to move first; and if the bar is perfectly elastic, so that none of its energy is dissipated in the form of heat or otherwise, the velocity with which the first layer starts off will be equal and opposite to the velocity that it had when the bar first struck the anvil. Simultaneously with the starting off of the outermost layer of the bar, the stress in this layer disappears. The next layer at the free end of the bar then undergoes a like transformation, taking up its original velocity but in a reverse direction, and simultaneously losing its stress, and so on, until finally the last layer of the bar, which has all this time been at rest and in contact with the anvil, begins to move with the same velocity, and loses its state of stress. The whole bar is then in the act of leaving the anvil, and is again in motion, in the free air, with a velocity equal and opposite to that which it had before it came into contact with the anvil in the first place.

This view assumes that there are no vibrations in the bar when it is again free; and while we know that this cannot be accurately true, we know also, from experiments, that the amount of energy that is present in the vibratory form is quite small, and hence, so far as this circumstance is concerned, Stromeyer's treatment of the elastic impact is admissible as an approximation.

To calculate, by his method, the duration of the impact, it may be assumed that the bar transmits the wave of compression with the same velocity that a wave of sound would have in the material of the bar, sound consisting merely in a succession of similar waves. Between the instant when the bar and the anvil first come into collision, and the instant when they are again separate, the compressive wave has traveled from the head end of the bar to the tail end, and back again to the head end. The total distance that it has traversed, therefore, is equal to twice the length of the bar. Hence the total duration of the impact, multiplied by the velocity of sound in the bar, must be equal to twice the length of the bar, and so we have the following rule:

Rule 1.— To find the duration, in seconds, of the impact between the bar and a perfectly rigid anvil, multiply the length of the bar, in inches, by two, and divide the product by the velocity of sound in the material of the bar, in *inches per second.*

To find the pressure exerted by the bar upon the anvil, we may proceed thus: By the definition of the modulus of elasticity, given above, we know that the total length of the bar is to the shortening of the bar under impact, as the modulus of elasticity is to the total actual maximum stress in the bar, per square inch of its sectional area. Now the shortening experienced by the bar is equal to the distance that its tail end travels in half of the duration of the collision,— that is, in the time required for a sound-wave to travel through the bar from one end to the other. From these two facts we may deduce the following:

Rule 2.— To find the pressure due to the impact of the bar against the rigid anvil, in pounds per square inch of the cross-section of the bar, multiply the velocity of the bar before impact, expressed in inches per second, by the modulus of elasticity of the material of the bar, in pounds per square inch, and divide the product by the velocity of sound in the material of the bar, in inches per second.

All this supposes that the body against which the bar collides is rigid and unyielding. The calculation could easily be modified to fit the case in which two elastic bars collide endwise, but the case here considered is sufficient for our present purpose,— namely, for investigating the intensity of water-hammer action in steam pipes.

To illustrate the two rules given above, let us take the following numerical example, given by Stromeyer: A bar of steel one foot long is dropped upon a rigid and unyielding anvil, so that it strikes endwise on the anvil, with a velocity of 10 feet per second. What will be the duration of its contact with the anvil, and what will be the "force of the blow,"— that is, what will be the pressure that the bar will exert against the anvil, per square inch of the bar's cross-section, during the period of contact?

The modulus of elasticity of steel may be taken at 30,000,000 pounds per square inch, and the velocity of sound-waves in steel may be taken at 17,000 feet per second.

First, as to the duration of the impact. The velocity of sound in the steel being 17,000 feet (or 204,000 inches) per second, and the length of the bar being 12 inches, we proceed by Rule 1 thus: $12 \times 2 = 24$, and $24 \div 204.000 = 0.0001176$ seconds, or about the 8,500th part of a second, which is the duration of the contact.

Second, as to the force of the blow, or the pressure that the bar exerts upon the anvil, during the short period of its contact therewith. The velocity of the bar, before impact, being 10 feet (or 120 inches) per second, the modulus of elasticity of steel being 30,000,000 pounds per square inch, and the velocity of sound in steel being 17,000 feet (or 204,000 inches) per second, we proceed by Rule 2 thus: $120 \times 30.000.000 = 3.600,000,000$, and 3,600,-

000,000 ÷ 204,000 = 17,647 pounds per square inch. The "force of the blow," or the pressure exerted by the bar against the anvil while the two are in contact, is, therefore, about 17,600 pounds per square inch of the cross-section of the bar.

It is to be especially noted, in connection with these rules, (1) that the duration of the collision does not depend at all upon the velocity of the bar previous to the collision; the greater speed of the bar, when it is moving faster, being exactly compensated for by the greater amount of the corresponding compression. And (2) that the pressure produced by the bar against the anvil does not depend at all upon the length of the bar. This last-mentioned result is one to which criticism would probably be directed, by a critically-minded person. As we have indicated at much length, however, this whole subject is still in an unsettled state, and there is no known formula which gives results that are beyond all cavil.

Our genial and distinguished special agent, Mr. T. W. Hugo, of Duluth, Minnesota, sends us the following newspaper clipping, which hails from a place bearing the pleasing name of Thief River Falls: "The gasoline engine of the large road and ditch machine in the town of Silverton exploded decently. None of the men employed about the machine was injured."

We suppose the original writer said it exploded "recently," and that the printer's devil, or somebody else, got things twisted. Anyhow, Mr. Hugo finds in the item a text for some cheerful sermonizing, as follows:

"*Editor* The Locomotive: — I enclose a clipping from one of our daily papers, which decides the case, for me, as to the relative advantages of the final wind-up of steam and gasoline power plants. You will notice it is stated that 'the gasoline engine . . . exploded *decently*.' Now that is more than I have ever read, in your columns, of a steam plant doing. The steam plant is coarse about it, and has no consideration for the fixed habits of the Eastern folk, nor for the loose ones of the Westerners. When it makes up its mind to explode it doesn't care whether it lands on the carpet of the President of the Hartford Steam Boiler Inspection and Insurance Company and puts its feet on his desk, or descends into the barrel which forms the office throne of the Duluth representative of that company. Heretofore I have thought that the inconsiderate performances of exploding things were inherent in the nature of the cataclysm, but now it appears that some kinds of power plants can do the thing 'decently.' I hope, therefore, that you will urge the adoption of such a factor of safety, or some kind of a coefficient, or a differential calculus rule that even a special agent might guess at, which will prevent, in the future, the unseemly, uncultivated, un-college-educated behavior of steam plants when they go on a tear, or have one. I am afraid that the ethics of explosions have been neglected in the past; and as we expect The Locomotive to lead in all these æsthetic movements, giving the latest Parisian fashion in divided overalls as well as telling the whereat-ness of the Normal-Eichungskommission, I suggest that you get after those oft-repeated breaches in explosion etiquette that you glory in recording.

Yours truly,

T. W. Hugo."

[We will think this thing over. It does seem as though there ought to be some kind of a relation between divided overalls and breaches of etiquette.]

The Locomotive.

A. D. Risteen, Ph.D., Editor.

HARTFORD, JULY 25, 1909.

The Locomotive *can be obtained free by calling at any of the company's agencies. Subscription price 50 cents per year when mailed from this office. Bound volumes one dollar each.*

Obituary.

Frank Woodbridge Cheney.

With deep sorrow we record the death of Colonel Frank Woodbridge Cheney, who had been a member of the board of directors of the Hartford Steam Boiler and Inspection Company continuously, since its first organization on October 6, 1866. He was born at Providence, Rhode Island, on June 5, 1832, and passed away, May 26, 1909, at his home at South Manchester, Connecticut.

Colonel Cheney was graduated from Brown University, and was engaged, throughout his business life, in the manufacture of silk, at South Manchester, where he has long been the recognized head of the Cheney Brothers corporation. Colonel Cheney enlisted in the Sixteenth Connecticut regiment, on August 15, 1862, and on September 17 he fought in the battle of Antietam, where he was wounded so badly that he was discharged from the service on December 24 of the same year. He always retained the deepest interest in the veterans, and was life president of the regimental organization, and also life president of the Army and Navy Club.

Colonel Cheney was a man of the highest type, a pillar of honor, and one of New England's noblest sons. His influence will long be felt, not only in direct and visible ways, but also, and even more deeply, in ways that no man can trace; for thousands knew him as a treasured friend, gentle, loving, sympathetic, and kindly, and generous in judgment and deed. The indebtedness of the Hartford Steam Boiler Inspection and Insurance Company to him is great, not alone for the sound, definite, and eminently practical counsel that he has always given so freely, but also for the intense optimism of his nature. This has always been helpful and cheering, but it was of special and immeasurable value to the company in its earlier days, when the foundations of the business were being laid down.

The board of directors of this company, at a meeting held on June 24, adopted the following minute, which was entered upon its records, and also forwarded to the bereaved family:

"Colonel Frank Woodbridge Cheney, a director of this company from its incorporation, died suddenly on May twenty-sixth, nineteen hundred and nine, at his home in South Manchester, Connecticut.

"He was one of its charter members, and among the first to subscribe to its shares when the books were opened to public subscriptions. Notwithstanding it was the first company incorporated in America for the sole purpose of safeguarding and making practicable the general use of steam for power purposes, and was therefore without experience or statistics for its guidance, yet from the first his confidence that there was a need for such a company, and his faith in its ultimate success, never wavered.

"Colonel Cheney was distinguished for his achievements, for his patriotism, and for the breadth and force of his influence. He was naturally reticent and retiring, but when occasion required he was bold and outspoken. His words were few, but always well chosen and to the point. He was a man of broad views, sympathetic in nature, and upright in all his dealings,— a man of even poise, not easily elated and never unduly depressed, always cool and under self-control in an emergency, and seemingly all his emotions were adjusted to a perfect harmony.

"During the nearly forty-three years of his continuous service as a director, he gave this company the benefit of his mature judgment. Every decision was carefully and conscientiously rendered. Every corporate act advised was given the impress of his sterling integrity, and in every decision there were inherent the principles of justice and equity.

"In his death, this company has lost a staunch friend and a safe adviser, and the members of this Board a most congenial and valued associate."

Robert Duncan.

The Hartford Steam Boiler Inspection and Insurance Company has lost a faithful and highly respected employee, in the death, on July 13, of Robert Duncan, an inspector in its New York department. Mr. Duncan was born on April 24, 1835, at Greenock, Scotland, where he lived until he was twenty. In 1855 he went to Buffalo, New York, following the machinist's trade for a time, and afterwards becoming an engineer on steamships plying on the Great Lakes, where he was soon promoted to the position of chief engineer. In 1869 he went to Elizabethport, New Jersey, as chief engineer of the Elizabethport Rolling Mill, remaining there until he removed to New York, in August, 1881, to become an inspector for the Hartford Steam Boiler Inspection and Insurance Company.

Mr. Duncan was a well-informed engineer, and as an inspector he served his company loyally and well. His death is deeply regretted by his associates.

Great care is taken to ensure accuracy in the papers that appear in The Locomotive, from time to time, on the properties of steam. The data that they contain have never been collected, before, in any one publication, and in a number of cases no adequate account of the work has even been printed in the English language. It is important, therefore, that no pains should be spared in the attempt to make the series as valuable and authoritative as possible. In particular, we scrutinize the original papers with care, to detect any typographical errors that they may contain, and such as are found are corrected in our transcription, if their nature is sufficiently evident to be beyond dispute. We regret to say that one obscure error of this kind, in Holborn and Henning's paper, escaped our notice. In the seventh column of the table on page 877 of their paper, the pressures given as 534.48 mm. and 534.65 mm. are each 10 millimeters too great. In consequence of this undetected error in the original, an erroneous pressure is given for the temperature 90.186°, in the table on page 189 of our last issue. The observed pressure at this temperature should be 529.39 mm., instead of 532.25 mm.

Mr. E. H. Warner has resigned his position as general agent for the Hartford Steam Boiler Inspection and Insurance Company, in its Home Department, and in the future will devote himself mainly to the interests of the Industrial Realty Company, of which he is president.

The Properties of Steam.

Eighth Paper.— Marvin's Experiments on the Pressure of Saturated Steam at Low Temperatures.

Among the important and accurate series of observations that have been made upon the relation between the pressure and temperature of saturated steam, is a series made by Professor C. F. Marvin, executed at Washington, and described in Appendix 10 of the *Annual Report* for 1891 of the Chief Signal Officer, Signal Office, War Department, page 351. His work was undertaken primarily for the purpose of providing the Weather Bureau with more accurate data than had been available before, respecting the vapor pressure over ice. Most of his results, therefore, relate to ice-vapor, and we shall have to pass those by, and confine our attention to the relatively few measures that he made upon water in the fluid state.

In executing the work Marvin made use of a form of apparatus that is apparently capable of giving results of high precision. The central feature of it was the glass vessel which contained the water under examination, and which he calls the "tube." Six of these tubes were used at various times, all being of the same general type, though differing among themselves in minor respects. Only two (designated as Nos. 8 and 9, respectively) were used in the work upon water at temperatures above 32° Fahr., and of these No. 9, which is shown in Fig. 1, was distinctly the better, although No. 8 was also excellent. The main idea was to have water-vapor in one end of the tube and as perfect a vacuum as possible in the other end, the pressure of the vapor being determined by observing the difference in the heights of the mercury columns in the central U-shaped portion. Nos. 8 and 9 were made of large tubing, in order that they might be as free as possible from capillary errors: the internal diameter of the U-shaped portion containing the mercury being 30 millimeters (1.18 in.) in the former, and 25 millimeters (0.98 in.) in the latter.

Great care was taken to ensure the purity of the water that was used. In this part of the work a capsule, shown at *a* in Fig. 2, was first blown of thin glass, and joined to a bulb, *B*, by a tube that was drawn out into a slender capillary portion, for part of its length. The end of the capsule opposite to the bulb (*i. e.*, the end to the left in Fig. 2) was also drawn out into a long capillary tube, which was bent at an angle, as shown at *S*, and made crooked between *S* and the capsule itself, in order that it might be quite fragile. The bulb *B* was previously nearly filled with well-boiled, distilled water, to which a few fragments of platinum wire had been added. The whole was then placed in substantially the position shown in Fig. 2, and heat was cautiously applied to the bulb *B*, the flame being allowed to play along the rest of the tube, also, from time to time. When the water in *B* was boiling, and steam had issued freely from the extremity of the tube *S* for some moments, a beaker containing water that was nearly at the boiling point was brought up over the end of the tube, as shown. The steam issuing from the tube was then condensed by the slightly cooler water in the beaker, and any air that might come away with it escaped through the water, into the atmosphere above.

After the boiling had continued under these conditions for half an hour, or until it was judged that all air had been expelled from the capsule *a* and its attachments, the water in *B* was allowed to cool slightly, and the capil-

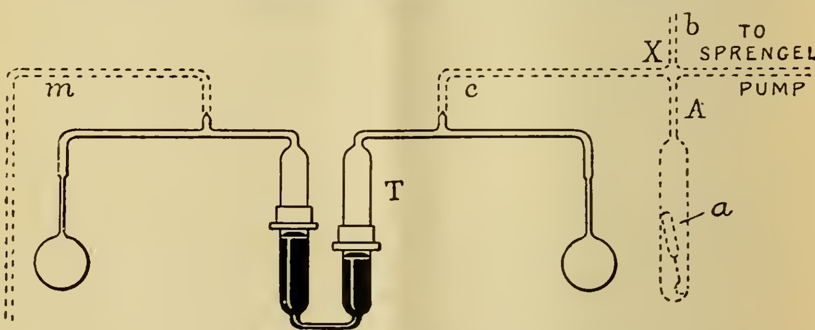


FIG. 1. — MARVIN'S EXPERIMENTAL TUBE, NO 9.

lary portion to the left of the capsule was quickly fused off, by means of a blowpipe flame, close up to the bend *S*.

The experimenter having satisfied himself of the entire absence of air from the capsule and its accessory bulb *B*, the water was all made to return to the bulb, and the capsule was submerged in ice-water, and held there until it had become full of water that had passed over from *B* by low-temperature distillation. When it was full, save for a small vacant space in the capillary neck between itself and the bulb, the capsule was sealed off from the bulb by means of the blowpipe flame, and was then ready for introduction into the experimental tube.

We shall not need to describe each experimental tube separately, for it will suffice to explain the construction and preparation of tube No. 9. This is shown, in its finished form, by the full lines in Fig. 1; but in its manufacture certain other glass parts, which are shown dotted, were fused to it, to aid in preparing it for use. Thus *T* is the tube itself, and attached to its arms were two tubes of small caliber, *c* and *m*. The auxiliary tube *m* was bent at right angles, and served for the introduction of the mercury. The tube *c* had a cross, *X*, fused to it, one arm of which was for attachment to a Sprengel mercurial air pump, while another one, *A*, which was provided with an enlarged portion, was left open at the free end. The purpose of the third branch, *b*, will be explained presently.

The experimental tube having been made and provided with the auxiliary parts, as described, the next step was to clean it carefully on its inner surfaces. For this purpose it was washed out with strong, hot nitric acid and then with ordinary water, after which a cream-like mixture of fine tissue-paper pulp, mixed with water and whiting, and often with caustic potash in solution, was shaken about thoroughly in every part of it. Many changes of ordinary water were then passed through it, followed by several changes of distilled water, and several final rinsings with strong alcohol. The capsule that had been filled with water, as already described, was placed in the auxiliary tube *A*, with its crooked end behind,— that is, downward as shown in the illustration,— and by means of the blowpipe the open end of *A* was neatly and permanently sealed up. The branch tube marked "To Sprengel pump" was then fused to the suction tube of a Sprengel air pump capable of exhausting the air in the experimental tube to the millionth part of an atmosphere, and the branch *b* was connected with an ordinary mechanical air pump, a set of drying tubes, containing anhydrous chloride of calcium and pumice stone

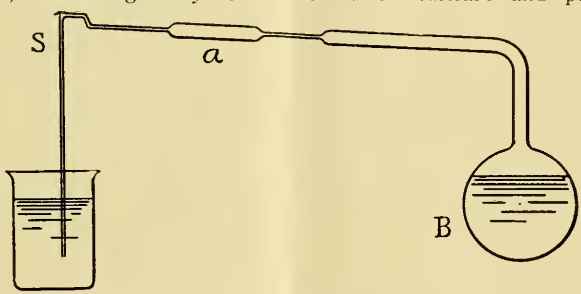


FIG. 2.— FILLING THE CAPSULE WITH PURE, AIR-FREE WATER.

wetted with concentrated sulphuric acid, and a straining tube loosely packed with linen and cotton, being placed between *b* and the pump.

The apparatus was now ready for the drying-out operation, which consisted in exhausting the air from *T* twenty or thirty times with the mechanical air pump, strongly heating all of the parts of the tube meanwhile with a Bunsen burner, and after each exhaustion allowing air to enter the apparatus again through the drying tubes and the strainer. The tube *m*, which was 35 or 40 inches long, meanwhile dipped below the surface of some mercury in a bottle, so that the end of *m* was sealed, so far as the entrance of air was concerned. When the drying-out of the tube was complete, the vacuum was made as perfect as possible by the mechanical pump, which was then sealed off at *b*, and detached permanently from the tube. The Sprengel mercurial air pump, which had been inactive all this time, was then started and allowed to operate for many hours to perfect the vacuum, its action being continued long after the mercury in its fall-tube fell with a metallic click, indicating that it was removing little or no air. The connection between the experimental tube and the Sprengel pump was finally broken by fusing the connecting tube by means of the blowpipe.

The mercury that was to be used in measuring the pressure of the vapor was then introduced through the tube *m*, in which a column of it was already standing at a height of 30 inches or so, owing to the vacuum in the experimental tube. Tests were occasionally made to see if any air was introduced into the experimental bulb with the mercury, but none was found at any time. All the mercury that was used was of the best quality, purified shortly before use by washing with dilute nitric acid, and afterwards distilled in a vacuum. Its density was not directly determined, but as the total pressure to be measured was always small, it was believed that its purity was quite sufficient to ensure that any error due to abnormal density would be insensible or at least unimportant.

The requisite quantity of mercury having been admitted to the apparatus, the auxiliary tube *m* was sealed off, and the experimental tube *T* was cautiously brought into the upright position, in such a way that the mercury within it was made to flow into its proper place in the U-shaped portion. The next step was the liberation of the water from the capsule *a*, in which it had been confined all this time, the liberation being effected either by breaking the crooked capillary end of the capsule by a slight shock or by freezing the water until the capsule ruptured. The water being set free in either of these ways, a small portion of it, usually not more than a third, was next distilled into the spherical bulb of the apparatus on the side towards which *A* lay, by surrounding the bulb with shaved ice. After this last distillation, it was believed that the purity of the water was practically perfect. The tube *A* was then sealed off from the apparatus by fusion with the blowpipe, and the experimental tube was ready for use.

Tube No. 9 was constructed with two bulbs, as shown, with the idea of using it for differential measures,— for example, by placing water in both bulbs, and maintaining one of the bulbs constantly at 32° Fahr. by surrounding it with ice, while the temperature of the other was varied at will. It was never used in this way, however.

In making the observations the tube was supported on a stand, and the standard measuring scale, when used, was suspended in the center, as was also a thermometer for indicating the temperature of the air surrounding the bulbs. To ensure steadiness of temperature the apparatus was wholly surrounded by a box-like case made of blotting paper, only the tops of the mercurial columns being visible.

The upper ends of the mercury columns were compared by means of a cathetometer, and special attention was paid to their illumination. Shade collars were fitted to both arms of the tube, as shown in Fig. 1, and in making a reading these were brought down nearly to the tops of the mercury columns, the clear interval between the top of the mercury and the bottom of the shade collar being rarely more than ⅓ millimeter (1/75 in.) The illumination consisted in a strong white light from an adjacent window screened by tissue paper, and was reflected from behind by a mirror.

The thermometry of the research appears to be very good, the thermometers that were used having been compared directly with the air thermometer of the Signal Service, which has itself been compared with the hydrogen scale of the International Bureau of Weights and Measures, and also, more recently, with that of the National Bureau of Standards, at Washington. The differences are trifling, and so far as the present research is concerned we may disregard them entirely, and consider Marvin's temperatures, at and above the freezing point, to coincide with the scale of the normal hydrogen thermometer. The pressures have been reduced to their equivalent values in ice-cold mercury, and corrections have also been applied to reduce these readings to the values they would have had if made at sea-level in latitude 45°.

Each separate complete observation consisted in four readings of the position of each mercurial column, and either two or four intermediate readings of the temperature; the order of procedure being arranged so as to eliminate, as far as possible, errors due to any slow, uniform change of either the temperature or the pressure. The measures made by Marvin upon the pressure of saturation of water vapor at temperatures above the normal freezing point are summarized in Table 1. Only two reliable tubes were used in this part of the work,— namely, Nos. 8 and 9. We have kept the measures made by these respective tubes separate, in order that the results that they gave may be readily compared. The first and fourth columns give the temperatures, the second and fifth give the corresponding observed pressures, and the third and sixth give the number of complete observations upon which the respective results are based.

The observations made by Marvin upon the vapor pressure of water when the experimental tube was packed in ice, and, therefore, at 32° Fahr., are given in Table 2. Each separate complete observation is here presented, and the tube by which it was obtained is likewise indicated. Tube No. 7 was probably an excellent one. After it had been used at the freezing point it was accidentally broken, but as the central U-portion was uninjured, the tube was remade, being thereafter designated as No. 9. Nos. 4, 5, and 6 were of small size, their mercury U's being only 13.5 millimeters (0.53 in.) in diameter, internally. Each of these had large capillary errors, as was evident from

Table 1.—Marvin's Experimental Results with Water, Above 32° Fahr.

Experiments with Tube No. 8.			Experiments with Tube No. 9.		
Temperature (Fahr.)	Pressure (mm.)	No. of observations.	Temperature (Fahr.)	Pressure (mm.)	No. of observations.
34.96°	5.168	2	......	......	....
39.73	6.240	3	39.70°	6.217	1
44.76	7.574	2	44.94	7.614	1
49.65	9.085	3	50.09	9.239	1
55.04	11.122	3	55.23	11.151	1
59.66	13.105	3	59.58	13.075	2
64.68	15.639	2	64.91	15.764	1
69.74	18.644	2	69.88	18.732	1
74.86	22.112	2	74.93	22.171	1
79.94	26.192	2	......	......	....

TABLE 2.—MARVIN'S EXPERIMENTAL RESULTS WITH WATER, AT 32° FAHR.

No. of experimental tube.	Observed pressure. (mm.)	No. of experimental tube.	Observed pressure. (mm.)
4	4.558	7	4.586
4	4.595	8	4.575
5	4.533	8	4.580
5	4.562	8	4.584
6	4.554	9	4.566

the unequal convexity of the mercury meniscuses in the two branches of the U. The heights of the meniscuses were measured, and corrections taken from the Smithsonian Institution's tables were applied for the purpose of eliminating these errors so far as possible; but the corrections that were required were sometimes as great as a tenth of a millimeter, and hence the indications of these three tubes were decidedly less trustworthy than those of Nos. 7, 8, and 9. Moreover, the vacuum in No. 4 was known to be quite imperfect.

Marvin adopts the average of all these observations (namely 4.5693 mm.) as the best value of the pressure of saturation; but in this respect we cannot follow him, for in view of what has been said, above, of the relative merits of the tubes, we cannot see how tubes Nos. 4, 5, and 6 can properly be supposed to add anything to the value of the results obtained by Nos. 7, 8, and 9, alone. The proof of this pudding, moreover, is established by chewing the string; for if we take the average of the results given by the three best tubes, we find that the concluded vapor pressure at the freezing point is 4.578 mm., which agrees to within the thousandth part of a millimeter (or the 25,000th part of an inch) with the result found by the later researches of Thiesen and Scheel. (See THE LOCOMOTIVE, October, 1907, page 254.)

Marvin made some few observations upon the pressure of saturation of the vapor of water, *below* the normal freezing point. He does not give the details of these measures, but merely tabulates the results, as follows:

TABLE 3.—MARVIN'S EXPERIMENTAL RESULTS UPON THE RELATIVE PRESSURES OVER WATER AND OVER ICE, AT TEMPERATURES BELOW 32° FAHR.

Temperature. [Fahr.]	PRESSURE OF VAPOR.		Difference. (Ice minus water.)	Number of Observations.
	Over ice.	Over water.		
24.83°	3.280	3.419	− 0.139	3
19.87	2.591	2.771	− 0.180	4
14.84	2.042	2.237	− 0.195	4
10.06	1.608	1.786	− 0.178	1

Hartford Steam Boiler Inspection and Insurance Company.

ABSTRACT OF STATEMENT, JANUARY 1, 1909.

Capital Stock, . . . $1,000,000.00.

ASSETS.

	Par Value.	Market Value
Cash in office and in Bank, ...		$143,227.09
Premiums in course of collection (since Oct. 1, 1908),		274,020.83
Agents' cash balances, ...		23,011.96
Interest accrued on Mortgage Loans, . . .		25,965.64
Interest accrued on Bonds, ...		35,154.54
Loaned on Bond and Mortgage, ...		1,024,865.00
Real estate, ...		95,100.00
State of Massachusetts Bonds, ...	$100,000.00	88,000.00
County, City and Town Bonds, ...	399,000.00	407,360.00
Board of Education and School District Bonds, .	24,000.00	24,500.00
Railroad Bonds, ...	1,478,000.00	1,576,960.00
Street Railway Bonds, ...	173,000.00	171,010.00
Miscellaneous Bonds, ...	87,500.00	83,450.00
National Bank Stocks, ...	29,300.00	43,840.00
Railroad Stocks, ...	215,900.00	263,901.35
Miscellaneous Stocks, ...	180,100.00	144,060.00
	$2,686,800.00	
Total Assets, ...		$4,424,426.41

LIABILITIES.

Re-insurance Reserve, ...		$1,885,729.16
Commissions and brokerage, ...		54,804.17
Other liabilities (Taxes accrued, etc.), . . .		37,476.54
Losses Unadjusted, ...		28,382.11
Surplus, ...	$1,418,034.43	
Capital Stock, ...	1,000,000.00	
Surplus as regards Policy-holders, .	**$2,418,034.43**	2,418,034.43
Total Liabilities, ...		$4,424,426.41

On December 31, 1908, the Hartford Steam Boiler Inspection and Insurance Company had **102,176** steam boilers under insurance.

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FRANCIS B. ALLEN, Vice-President. C. S. BLAKE, Secretary.
L. F. MIDDLEBROOK, Assistant Secretary.
W. R. C. CORSON, Assistant Secretary.

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The Locomotive

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Vol. XXVII. HARTFORD, CONN., OCTOBER, 1909. No. 8.

On the Number of Courses in a Boiler Shell.

Prominent among the many problems that arise in designing a steam boiler is that of the construction of the shell. We do not here refer to the way in which the parts should be riveted together, but to the more elementary question of how many parts there should be.

In nearly all of the horizontal tubular boilers that are now met with in practice, the shell is composed of a certain number of "rings," or "courses," each course consisting of a cylindrical section, composed, usually, of a single

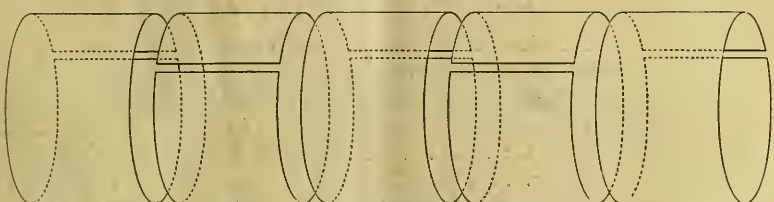

Fig. 1. — Five-course Shell.

plate, curved around so that its two ends meet and are riveted together. It was formerly the custom to have more courses in the shell than are now common, because the plate mills were not equipped to turn out sheets of the large size that may be had at the present time. Thus it was usual, in a boiler (say) sixty inches in diameter and sixteen feet long, to build the shell in five courses, as will be understood from Fig. 1, which represents the several courses as they

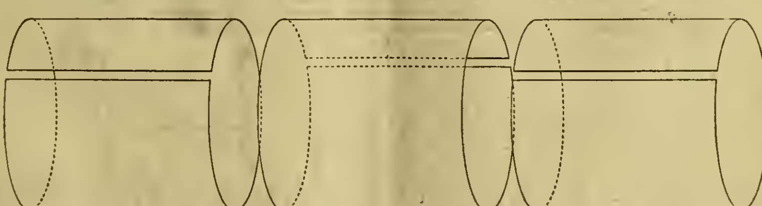

Fig. 2. — Three-course Shell.

would appear when rolled approximately into shape, but not yet riveted together.

As the rolling mills came to put in larger and heavier machinery, so that plates of much greater size could be turned out, the number of sections in the shell was reduced, and boilers presently came to be built in three courses, as indicated in Fig. 2. (The "three-course" boiler, we may say in passing, is the one that is still favored by this company, for reasons given below.)

If we should continue to reduce the number of courses, we should be led, ultimately, to a "one-course" boiler, as indicated in Fig. 3. Small shells, for tanks and drums and the like, have long been made in this way, and for such structures the one-sheet design is excellent. Sheets of enormous size would be required, however, if we were to build large boiler shells in one course, according to the scheme of Fig. 3. Thus for a shell sixteen feet long and sixty inches in diameter, we should have to have a sheet about sixteen feet square. Sheets of this size would be expensive, even if they could be produced commercially, and of a satisfactory quality, and the difficulty of transporting them would practically make it necessary to roll up the shell where the plate was made. Moreover,

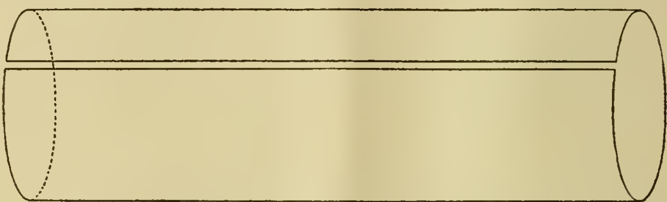

FIG. 3. — ONE-COURSE SHELL.

other and far more serious objections can be urged against building large shells of single sheets, as will appear from the later portion of this article.

As a compromise between the enormous sheet that would be required in making a large boiler according to the plan shown in Fig. 3, and the smaller ones that are used when the shell is built in several courses, we might use the method suggested in Fig. 4, where the shell consists of two sections, each extending the entire length of the boiler. The two sheets need not be of identically the same size, and it would in fact be better, if this construction were to be adopted, to make the bottom one somewhat wider than the top one, so that the riveted joints could be kept high enough to be beyond the influence of the

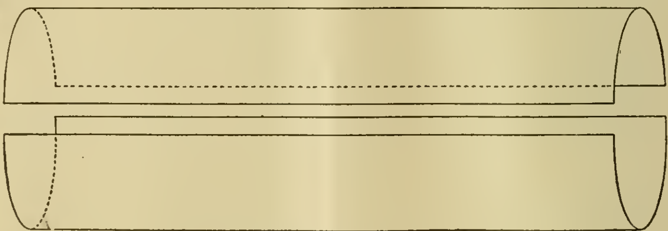

FIG. 4. — DOUBLE LONG-SHEET SHELL.

hot furnace gases. The objections that can be urged against the construction shown in Fig. 3 apply also, however, to that shown in Fig. 4, save that the sheets in Fig. 4, being smaller, would be easier to transport, and would also be somewhat cheaper, pound for pound.

A few years ago it was common for boiler makers to favor the plan of construction suggested in Fig. 5. Here, as will be seen, the bottom part of the boiler is composed of a single sheet, while the top part is composed of two or three smaller ones. This is known as the "single bottom-sheet" design, and at the time it was introduced it was hailed by many as a great advance in boiler construction, inasmuch as a smooth and uniform surface was presented to the furnace gases, and no girth joints were exposed to the direct heat of the furnace except at the very end of the shell, where the rear head was attached. The Hartford Steam Boiler Inspection and Insurance Company, however, never favored this construction, and never made a specification for a boiler of this kind. We discouraged the use of the type from the first, thereby subjecting ourselves to no little criticism from those who fancied themselves to be more "progressive," and considered us to be "ultra-conservative," or worse. Experience has shown, however, that we were correct in our view, and it is now pretty generally admitted that "single bottom-sheet" boilers are short-lived. and that their apparent advantages are illusory. Many of the shops that formerly built them, build them no longer, and we shall soon be able to speak of the type as obsolete. We have accepted such boilers for insurance, when inspection indicated them to be in safe condition. We have always watched them with especial care, however, and we have nevertheless suffered severe losses from them, on quite a number of occasions. Our inspectors have frequently detected fractures along the long joints, before failure actually occurred; and we feel that we can say with confidence that the number of bad explosions that would

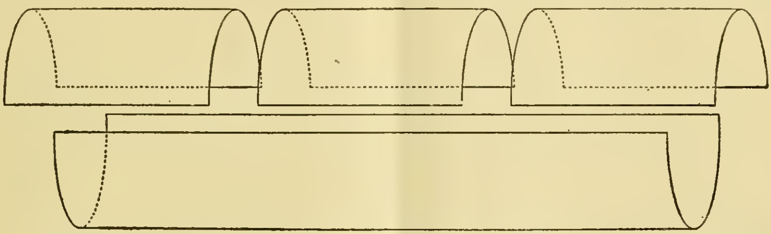

Fig. 5. — Single Bottom-sheet Shell.

otherwise have to be charged up against this type of boiler has been kept down in considerable measure by our inspection service. The terrible explosion at the plant of the Penberthy Injector Co., at Detroit, illustrated in the issue of The Locomotive for August, 1902, is an example typical of the many violent explosions that have occurred, with great loss of life and property damage, in boilers having the single bottom-sheet.

The explosions that have been experienced with the single bottom-sheet boiler have been mainly due, we believe, to the fact that the long joint was not "broken," and to the added but closely related fact that the shell was not stiffened as it is when girth joints are present. The adoption of the long horizontal seams in these boilers was an undoubted mistake, since a shell so made is considerably weaker than one in which the longitudinal joints are broken up into three lengths that are separated from one another as they are in the three-course boilers that we design. Moreover, the stiffening action of the girth joint is quite an important element in a boiler shell, and its absence was doubtless one of the causes of failure of the single bottom-sheet type. (For a more detailed discussion of the single bottom-sheet construction, see the issue of The Locomotive for March, 1895.)

In an attempt to take advantage of the good features of the single bottom-sheet design, so far as this can be done without retaining the bad ones, many boiler makers are now favoring the type shown in Fig. 6. This differs from the three-course design, illustrated in Fig. 2, only in the fact that the shell is built in two courses instead of three, the courses in Fig. 6 being, for a given size of boiler, and style of setting, half as wide again as those employed in Fig. 2. The idea is, that such a construction offers nearly as smooth a surface along the bottom of the shell as the one shown in Fig. 5, while at the same time it has one girth joint in the middle of its length, to provide for the stiffening of the shell. There can be no doubt, we think, but that the preference, among the various designs herein illustrated, lies between the form shown in Fig. 6, and that shown in Fig. 2. It will therefore be of interest to compare these two designs in some degree of detail.

As we have already said, our own preference is distinctly in favor of the three-course shell. We do not mean, by this, that we should decline to insure two-course boilers, for we have insured them in the past, are doing so at the present, and shall doubtless continue to do so in the future, so long as we have nothing to criticise but the *type,* — that is, so long as our inspectors report that such boilers of this type as are proposed for insurance are made of good material, are well constructed, are under good management, and are in satisfactory condition as respects deterioration and the development of special defects of any kind.

Nevertheless, if the adoption of the single bottom-sheet boiler was a

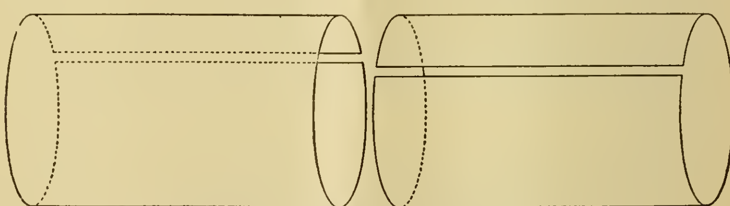

Fig. 6. — Two-course Shell.

mistake, we fear that we are journeying along the same road, to a certain extent, if we adopt a two-course construction, such as is shown in Fig. 6. We believe that the "breaking" of the longitudinal joint into three parts affords a much better and safer construction than is obtained by breaking it merely into two parts, and we believe, further, that the extra girth joint that is obtained in the three-course construction is of much value in stiffening the shell. So far as this latter consideration is concerned, our friends who advocate the two-course design can say, in reply, that more girth joints would stiffen the shell still further, so that, logically, we ought to advocate the old style of construction, with many courses, if our view of the case is a sound one. This would be mere sophistry, however, for the truth must lie between the extremes, here as elsewhere. There is doubtless a medium type that is best and safest, so far as the number of courses is concerned, and we believe that the three-course boiler *is* that best medium type, since it provides a sufficient amount of stiffness in the shell, without making use of an unreasonable number of girth joints.

Builders occasionally advocate the two-course type on the ground that when a boiler is under 18 feet in length, there is very little room left, in a three-course shell, for riveting on the steam flanges and the supporting lugs, after space has been allotted for the head braces at each end. We incline to the belief that there is little force to this argument, however, because relatively

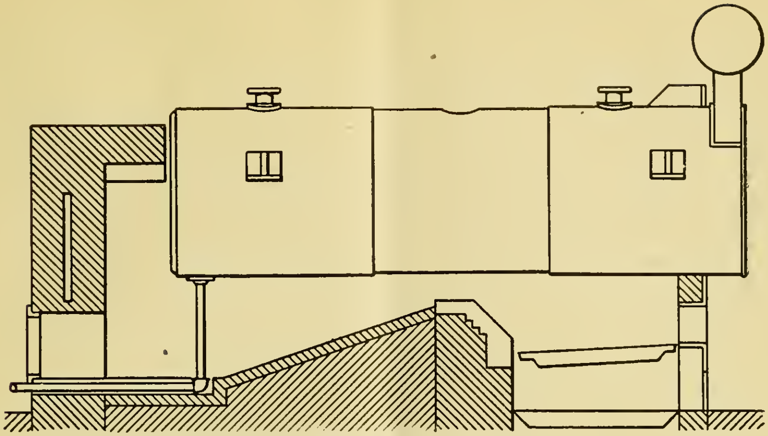

Fig. 7. — Three-course Boiler in Setting.

[Girth joints well away from bridge wall.]

few builders have ever suggested it.

So far as the cost of the boiler is concerned, there does not appear to be any reason for preferring either type; for the slightly increased cost of the plates, in a two-course boiler, is offset by the somewhat greater amount of labor involved in the construction of the three-course one.

The real question appears to be, whether it is better to cut the stiffening effect of the girth joints down by one-half, and thereby save exposing one girth joint to the furnace gases, or whether it is better to keep up the stiffness, at the cost of having two girth joints exposed, instead of one. Our experience indicates that serious trouble is *far* more likely to come from lack of stiffness, than from the exposure of a girth joint to the gases of the furnace. Moreover, it is not altogether the *number* of the girth joints that must be

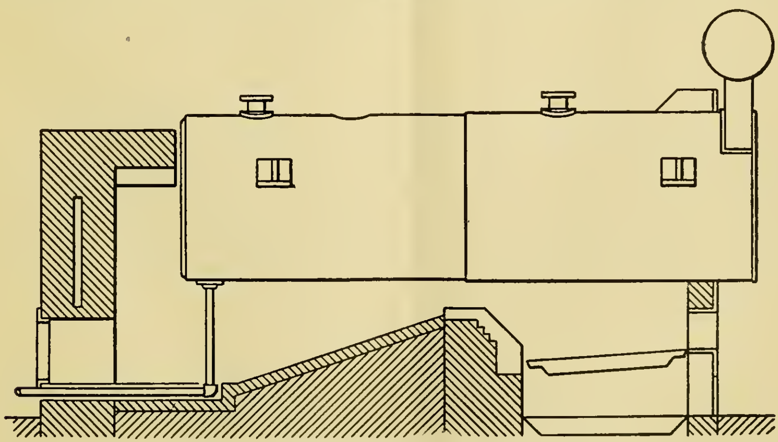

Fig. 8. — Two-course Boiler in Setting.

[Girth joint directly over bridge wall.]

considered, in deciding upon a design, for their *position* with respect to the distribution of the heat in the furnace is also an important factor. At the bridge wall, for example, the highly heated gases from the furnace are concentrated against the boiler shell, and it is desirable, in our judgment, to keep the girth joints well away from this region of concentration. It is only fair to say that with our plan of setting, and the care that we recommend in the construction of bridge walls, we have had little or no trouble from this source with either two-course or three-course shells. A comparison of Figs. 7 and 8, however, will make it evident that in the case of the designs here shown, at all events, the three-course boiler gives the least exposure to whatever danger there may be in the concentration of heat at the bridge wall. Of course we are well aware that the two-course boiler is often built with the dry-sheet bolted to the front head, so that the girth joint can be thrown further back from the bridge wall; but even in that case we feel that it comes too close to the wall for the best practice. Moreover, the setting has to be of the "flush front" form, in order to take advantage of this element in design, and we prefer the "overhanging front" in any event, although we specify either of these fronts, in designing new boilers, as our patrons may desire. We have not selected the design shown in Fig. 8 for the purpose of being unfair to the two-course construction, but because, when the design is *alike* in the two types, save for the single difference of using two courses in one case and three in the other, the danger of which we speak is brought to the attention more directly and forcibly.

Another element to be considered, and by no means a mean one, is the probable expense of repairs in the event of the boiler becoming over-heated from low water, or from the accumulation, upon the fire sheets, of scale, mud, or grease. Our records show that when extreme over-heating occurs in a horizontal tubular boiler, the whole bottom is likely to bag in a boiler having less than three courses, while in a three-course or four-course boiler the resistance due to the stiffening effect of the girth seams materially lessens the extent of the injury; and this means that in the event of an accident from overheating, the cost of repairs is likely to be considerably greater with the wider courses than it is with the narrower ones. Of course this consideration has the greatest weight in the case of the single bottom-sheet type, but it is also worthy of attention in the two-course type.

To sum up our views on this question in a general way, we may say that while the two-course boiler is without doubt a great improvement over the single bottom-sheet type, we believe that it is nevertheless somewhat inferior to the three-course type; and the superiority of the three-course type consists (1) in the greater degree of stiffness afforded by the extra girth joint, (2) in the fact that the longitudinal joints are better "broken," (3) in the smaller probable cost of repairs in the event of severe overheating, and (4) in the greater distance of the girth joints from the bridge wall, as the boilers are ordinarily set.

A TERRIBLE marine accident occurred, on the night of August 23, on the south shore of the Isle of Pines, off the inlet bearing the cheerful name of Caletadel Inferno ("Hell's Cove"). The steamship *Nicholas Castania*, en route from Havana to Cienfuegos, was blown upon the rocks there, and at the same moment her two boilers exploded. Her crew numbered twenty-seven, and she carried two passengers. All were lost.

Boiler Explosions.

April, 1909.

(158.) — The boiler of Edward Lundquist's traction engine exploded, April 2, eight miles west of South Bend, Ind. John Waydell and Edward Robertson were injured.

(159.) — The crown sheet of a locomotive boiler on the Atlantic Coast Line blew out, April 3, at Charleston, S. C.

(160.) — The crown sheet of a boiler of the locomotive type collapsed, April 4, at the Brule Mining Co.'s Chatham Mine No. 2, Stambaugh, Mich.

(161.) — The fishing tug *George A. Floss,* with a crew of seven men, was lost in a storm on Lake Erie, April 6, near Cleveland, Ohio. George McLaughlin, keeper of a crib four miles out, states that there was a fearful explosion on the boat (presumably a boiler explosion), and that she sank immediately.

(162.) — On April 6 a boiler exploded at Boyd, near Chippewa Falls, Wis. George Wilder was seriously scalded.

(163.) — A tube ruptured, April 7, in a water-tube boiler in the plant of the Wardlow-Thomas Paper Co., Middletown, Ohio.

(164.) — The boiler of a locomotive exploded, April 9, on the Salt Lake railroad, at Cima, Cal.

(165.) — A tube ruptured, April 9, in a water-tube boiler in the power plant of the Pueblo & Suburban Traction & Light Co., Pueblo, Colo. J. Maurique was injured.

(166.) — A boiler exploded, April 9, on Morrison St., Portland, Ore. One man was seriously injured.

(167.) — On April 10 a boiler exploded in the Valdese Hosiery Mill, Valdese, N. C.

(168.) — A section ruptured, April 11, in a heating boiler in the Winklepleck block, Brazil, Ind.

(169.) — A tube ruptured, April 12, in a water-tube boiler at the plant of the Dayton Lighting Co., Dayton, Ohio. Clifford Griffith and J. J. Ginn were scalded.

(170.) — A boiler exploded, April 13, on the Clearview Stock Farm, Butler, Pa. One person was fatally injured.

(171.) — On April 13 a tube ruptured in a water-tube boiler at the Marion Paper Co.'s plant, Marion, Ind.

(172.) — A boiler exploded, April 14, at Port Huron, Mich.

(173.) — A heating boiler exploded, April 14, in the Young Men's Christian Association building, Monmouth, Ill. One person was seriously injured.

(174.) — A blowoff pipe failed, April 19, in the Joseph N. Eisendrath Co.'s glove factory, Chicago, Ill.

(175.) — On April 19 a boiler exploded in the Elkenberg Milk Co.'s plant, Marathon, N. Y. One person was severely injured.

(176.) — A boiler exploded, April 19, in the Trexler & Turrell Lumber Co.'s sawmill, Ricketts, Pa. H. A. Barnhart, who was 200 feet from the boiler house, was struck by a piece of flying wreckage and instantly killed. The property loss was $7,600.

(177.) — A boiler exploded, April 19, in the Kaiser wagon shop, Crown Point, Ind.

(178.) — On April 20 a slight accident occurred to a boiler at the bakery of Fred Stohlman, Washington, D. C.

(179.) — A boiler exploded, April 21, at the conservatories of Fred Miller & Sons, at Dracondale, a suburb of Toronto, Ont. The conservatories cover four acres and the property loss was approximately $50,000. A brick smoke-stack, eighty feet high, was completely demolished. One fragment of the boiler, weighing more than half a ton, was thrown to a distance of 900 feet.

(180.) — A tube ruptured, April 21, in a water-tube boiler at the 93d street and Ewing avenue plant of the Calumet & South Chicago Railway Co., Chicago, Ill. Frank Speck and John Gatos were injured.

(181.) — The boiler of a locomotive, drawing the Washington express on the Philadelphia & Reading railroad, exploded, April 24, at Hamilton, ten miles west of Bound Brook, N. J. Engineer Fred De Grof was injured so badly that he died shortly after the accident.

(182.) — A number of cast-iron headers fractured, April 24, in a water-tube boiler at the National Sheet Steel Co.'s plant, Mansfield, Ohio.

(183.) — A heating boiler exploded, April 25, in the convent of the Sisters of the Congregation of Notre Dame, at Cote St. Paul, near Montreal, Que. Florence Nault and Bernadine Dubreuit were injured so badly that they died shortly after the accident, and the superioress, sister Nom de Jesus, was injured so badly that her recovery was considered to be doubtful.

(184.) — On April 26 a boiler exploded in Carroll R. Tiffany's garden implement factory, Franklin Forks, Pa.

(185.) — On April 26 a number of cast-iron headers fractured in a water-tube boiler at the power house of the Dallas Electric Light & Power Co., Dallas, Tex.

(186.) — A boiler ruptured, April 26, in the Eckert Meat Co.'s ice and cold storage plant, Henderson, Ky.

(187.) — A boiler belonging to Jones Bros. & Parker exploded, April 27, at Bath, N. Y.

(188.) — On April 27 a boiler exploded in the warehouse and finishing plant of the Winnebago Furniture Co., Fond du Lac, Wis. Night watchman Ferdinand Wust was blown through a closed window and fatally injured, and Irving Susan, pipeman of city fire engine company No. 3, was reported to be injured by falling walls. Fire followed the explosion, and the total property loss was estimated at $100,000.

(189.) — On April 27 a tube ruptured in a water-tube boiler in the Blatz brewery of the United States Brewing Co., Milwaukee, Wis.

(190.) — A boiler exploded, April 27, in the McGrath & Hogan sawmill, at Kerrick, Minn. Ernest Whitaker, Arvid Bergland, Harry Abbott, and Henry Rentz were killed, Oscar Rostlum was fatally injured, and Homer Martin, Patrick Williamson, Joseph McGrath, and Albert Leyman were injured seriously but not fatally. Some of the debris was blown a quarter of a mile.

(191.) — On April 28 a boiler exploded at a mine at La Salle, Ill. One person was killed.

(192.) — A boiler exploded, April 29, at No. 214 Lenox avenue, New York City. Dr. William W. Niles, a dentist who had a laboratory in the basement of the building, was killed.

(193.) — A tube ruptured, April 30, in a water-tube boiler in the Hanford Produce Co.'s creamery and cold storage plant, Sioux City, Iowa.

May, 1909.

(194.) — A boiler exploded, May 1, on the U. S. S. *Triton*, Washington, D. C. Two persons were severely injured.

(195.) — A tube failed, May 1, on a locomotive of the Lehigh Valley railroad, at Gilbert, N. Y.

(196.) — On May 1 a heating boiler exploded on Sabin street, Providence, R. I.

(197.) — A boiler exploded, May 2, at the Dan Mitchell coal mine, two miles from Buffalo, Wyo. The property loss was about $2,000.

(198.) — A boiler exploded, on or about May 2, at the plant of the W. T. Pyne Mill Supply Co., Louisville, Ky. Daniel Pry was seriously injured.

(199.) — On May 3 several tubes ruptured in a water-tube boiler in the Oklahoma Portland Cement Co.'s plant, Ada, Okla.

(200.) — A boiler exploded, May 3, in the Baldwin Lumber Co.'s mill, Baldwin, La. Two men were injured so badly that it was believed they could not recover. The boiler house was wrecked, together with a battery of six other boilers.

(201.) — A heating boiler exploded, May 3, in the residence of Dr. William H. Newton, Sandy Hill, N. Y. Fire followed the explosion, and the building was almost entirely destroyed.

(202.) — A tube ruptured, May 5, in a boiler at the Kingswood cloth factory, Kingswood, N. J.

(203.) — A boiler exploded, May 6, in Charles Moor's sawmill, in the Nineteenth District, near Fayetteville, Tenn. Albert Danley was fatally injured, and another man was injured seriously but not fatally.

(204.) — On May 6 a blowoff valve ruptured on a boiler in the Angelina County Sawmill Co.'s mill, Lufkin, Tex. A boy named Gilbert was killed, and Manager Henderson was seriously injured.

(205.) — A cast-iron header fractured, May 7, in a water-tube boiler at the Manganese Steel Safe Co.'s plant, Plainfield, N. J.

(206.) — A boiler exploded, May 10, at the plant of the Lincoln Hydraulic Sand & Gravel Co., Lincoln, Ill. One account of this explosion states that the boiler was torn to shreds, "no large pieces of it being found."

(207.) — A boiler exploded, May 10, in the Gregory Drug Mill, on Cherry street, New York City. Harry McGrath was instantly killed.

(208.) — A tube ruptured, on or about May 10, in a boiler at the power house of the Third avenue elevated railroad, 216th street and Third avenue, New York City. Engineer Patrick Murphy was seriously scalded.

(209.) — A heating boiler exploded, May 11, in a schoolhouse at Centralia, Pa., filling the rooms with steam, and causing a panic among the pupils. Many boys and girls jumped from the windows, but the teachers, by strenuous efforts, prevented serious accidents.

(210.) — A boiler exploded, May 11, on the Miller farm, at Claysville, Pa.

(211.) — A tube ruptured, May 11, in a boiler at the Interstate steel mill, East Chicago, Ind. Six men were seriously scalded.

(212.) — The boiler of a Wisconsin & Michigan railroad freight locomotive exploded, May 11, at Menominee, Mich.

(213.) — A flue ruptured, May 12, in a boiler in the basement of the Allentown National Bank building, Allentown, Pa.

(214.) — A boiler exploded, May 14, in the rear of Storms & Co.'s plumbing establishment, on South Fourteenth street, Newark, N. J. James McGovern, Leo McSulle, and James J. Carlow were injured.

(215.) — A tube ruptured, May 15, in a water-tube boiler in the Standard Paper Co.'s plant, Kalamazoo, Mich. C. H. Hoyt was injured.

(216.) — On May 15 a boiler exploded at the King Jack mine, Miami, Okla. Night watchman L. Rice was injured. The boiler was entirely destroyed, and the damage to the plant was considerable.

(217.) — A flue failed, May 15, on the steamer *James H. Hoyt,* three miles off Fairport Harbor, near Painesville, Ohio. Three men were killed, one was fatally injured, and two others were injured seriously but not fatally.

(218.) — A heating boiler exploded, May 17, in the St. Alexis hospital, at Bismarck, N. D. The engineer and fireman were severely injured, and the property loss was heavy.

(219.) — The boiler of a dredge belonging to the Consolidated Gold Co. exploded, May 21, at Redding, Cal. One person was severely injured.

(220.) — The mud drum of a boiler exploded, May 21, on the Alhambra plantation, at White Castle, La. One person was fatally injured.

(221.) — A boiler ruptured, May 22, in the Standard Laundry Co.'s plant, Boston, Mass.

(222.) — Three cast-iron headers fractured, May 22, in a boiler in the Milwaukee Coke & Gas Co.'s plant, Milwaukee, Wis.

(223.) — A boiler used for operating a steam plow exploded, May 24, at Plymouth, Pa. One person was severely injured.

(224.) — On May 24 a blowoff pipe failed in the plant of the Logansport Artificial Ice & Fuel Co., Logansport, Ind.

(225.) — A blowoff pipe failed, May 24, in the plant of the Independent Pure Ice Co., Chicago, Ill. Fireman William Latta was injured.

(226.) — A boiler exploded, May 25, at Keenesburg, Colo. Two persons were killed and one was seriously injured.

(227.) — A blowoff pipe failed, May 25, in Berry Bros.' varnish factory, Detroit, Mich.

(228.) — A boiler exploded, May 26, in Geesey Bros.' hoop and stave mill, Dowagiac, Mich. Deforest Geesey, Frank Geesey, Otto Behnke, Charles Fritz, and Estel Gamber were killed, and Marvin Stewart and Freeman Geesey were seriously injured. The mill was completely wrecked.

(229.) — A boiler ruptured, May 26, in the Upper Hudson Electric Co.'s plant, Coxsackie, N. Y.

(230.) — On May 26 a boiler exploded in the C. W. Kennard handle mill, at Tilton, forty miles south of Jonesboro, Ark. J. Slocum was instantly killed, and R. L. Slocum and Frank Parkerson died shortly afterward. Albert Slocum and A. O. Cagle were also badly injured.

(231.) — A tube ruptured, May 26, in a water-tube boiler at the No. 1 blast furnace of the Illinois Steel Co., Joliet, Ill.

(232.) — On May 28 the boiler of a North Coast railway locomotive exploded at Marshall, Wash. One person was seriously injured.

(233.) — A boiler exploded, May 29, on a dredge, six miles west of Dancy, Wis. Joseph Sellers was instantly killed, and William Roy and Joseph Brey were seriously injured.

June, 1909.

(234.) — On June 1 a vertical tubular boiler exploded at the White Horse mine, four miles south of Joplin, Mo. J. W. Pierce was instantly killed. The explosion consisted in the collapse of the furnace, and was apparently due to overpressure.

(235.) — A tube ruptured, June 1, in a water-tube boiler at the Federal Coal & Coke Co.'s plant, Grays Flats, near Fairmont, W. Va.

(236.) — A boiler exploded, June 4, in a cannery on Hyde and Bay streets, San Francisco, Calif. Vincent Fintola was badly scalded.

(237.) — A small boiler ruptured, June 5, in the silk mill at the corner of Markley and Airy streets, Norristown, Pa.

(238.) — On June 5 a slight explosion occurred at the electric lighting plant, Mansfield, La.

(239.) — A heating boiler exploded, June 5, in the basement of Willard Hall, Northwestern University, Evanston, Ill. Fireman Charles Olsen was slightly injured, and a brick wall was thrown down.

(240.) — A tank used for the storage of cold water under pressure exploded, June 5, at the Nashville Sanitarium, Nashville, Tenn.

(241.) — On June 5 a boiler exploded at Flat River, near Millheim, Mo. Anson Blaylock was killed.

(242.) — A tube ruptured, June 6, in a water-tube boiler at the plant of the Ehret Magnesia Manufacturing Co., Port Kennedy, Pa. Fireman Irvin Famous was scalded.

(243.) — On June 10 an elbow ruptured on a boiler in the office building of the New England Mutual Life Insurance Co., St. Paul, Minn. Fireman Patrick McCarthy was injured.

(244.) — A slight explosion occurred, June 11, in L. E. Boyle & Co.'s paint factory, San Francisco, Calif. Frank Jones and Hector Quade were fatally scalded.

(245.) — A tube ruptured, June 11, in a water-tube boiler at the plant of the Chicago Bridge & Iron Co., Chicago, Ill.

(246.) — On June 11 a slight explosion occurred in the electric lighting station at Greenwich, Conn. One man was injured.

(247.) — On June 11 a blowoff pipe failed at the elbow on a boiler at the plant of the Farmers' Co-Operative Produce Co., Des Moines, Iowa

(248.) — A tube ruptured, June 13, in a water-tube boiler at the Gilbert Paper Co.'s plant, Menasha, Wis.

(249.) — A slight explosion occurred, June 13, in the plant of the Roseliep Bros. Distilled Water, Ice & Cold Storage Co., Platteville, Wis.

(250.) — On June 14 a slight explosion occurred at the Holmes-Franke Co.'s plant, Philadelphia, Pa. One man was seriously injured.

(251.) — The boiler of Charles W. Stone's portable sawmill exploded, June 14, at the foot of Mt. Mousam, three miles from Strafford, N. H. Ronello L. Stevens was killed, and Thomas Lee, John L. Whitehouse, and Walter Campbell were severely injured.

(252.) — On June 15 a tube ruptured in a water-tube boiler at the rolling mill of the American Sheet & Tin Plate Co., Cambridge, Ohio. Frank Lerner was scalded.

(253.) — On June 15 a 400-horse-power water-tube boiler exploded in the Denver Gas & Electric Co.'s plant, Denver, Colo. Three men and a boy were instantly killed, and four other men were seriously injured, two of them so badly that it was thought they could not recover. Four or five other persons were also slightly injured. The total property loss was conservatively estimated at $60,000. (An illustrated account of this explosion is given in The Locomotive for July, 1909, where it is shown that the major portion of the boiler went up into the air to a vertical height of 1,659 feet.)

(254.) — The boiler of a Kansas City Southern Railway locomotive exploded, June 15, at Hornbeck, La. Three men were injured.

(255.) — A hot-water boiler exploded, June 16, in the basement of the Hotel Cushing, at Salisbury Beach, near Newburyport, Mass.

(256.) — A blowoff pipe failed, June 16, at the Rhode Island Coal Co.'s mine, Portsmouth, R. I. Fireman Quinlan Sullivan was injured so badly that he died a few days later.

(257.) — On June 16 several tubes ruptured in a water-tube boiler at the Memphis Street Railway Co.'s power plant, Memphis, Tenn. James Jordan was slightly injured.

(258.) — Two cast-iron headers failed, June 17, in a water-tube boiler at the colliery of the Kingston Coal Co., Plymouth, Pa.

(259.) — A tube failed, June 17, in a boiler at the Garfield plant of the Utah Copper Co., at Coppertown, near Garfield, Utah. Andrew Tennant, Nicholas Paras, and Carlo Vangielosto were injured.

(260.) — On June 18 a boiler failed at the plant of Tyson Bros., Stamford, Conn.

(261.) — On June 21 a boiler used in digging a well exploded at Hamlin, Tex. G. R. White and H. L. White were slightly injured.

(262.) — A tube failed, June 22, in a water-tube boiler at the Susquehanna Coal Co.'s colliery, near Shamokin, Pa.

(263.) — A boiler accident occurred, June 23, in the Hygeia Co.'s ice and cold storage plant, Uniontown, Pa.

(264.) — On June 24 the boiler of a portable sawmill exploded near Blanchester, Ohio, fatally injuring Elijah Shelton and Samuel Guthridge.

(265.) — The boiler of a traction engine exploded, June 24, eight miles northwest of State Center, Iowa. Frederick Voss, Jr., was instantly killed, and his father, Frederick Voss, Sr., was seriously hurt.

(266.) — Four cast-iron headers ruptured, June 26, in a water-tube boiler at the Blatz Brewery, Milwaukee, Wis. The plant is owned by the United States Brewing Co.

(267.) — On June 26 a boiler belonging to the Everett Co. exploded at Lawrence, Mass.

(268.) — Three malleable iron headers ruptured, June 27, in a water-tube boiler at the Secor Hotel, Toledo, Ohio.

(269.) — The boiler of F. A. Dennett's steam automobile exploded, June 28, at Manitowoc, Wis.

(270.) — Two boiler tubes ruptured, June 29, on the U. S. torpedo boat *Hull*, off Alcatraz island, San Francisco bay. B. F. King, J. M. Rober, Francis

Crawford, John R. Carter, and Newton Carish were injured. Mr. King's injuries were said to be fatal.

(271.) — On June 30 a boiler exploded in a sawmill at Headlight, a small station thirty miles south of Valdosta, Ga. J. W. Dames, owner of the mill, was instantly killed, and one other man was fatally injured. Two men also received lesser injuries, and the mill was wrecked.

July, 1909.

(272.) — The boiler of a "Soo" passenger locomotive exploded, July 2, at Eau Claire, Wis. Nobody was in the cab at the time.

(273.) — On July 3 a tube ruptured in a water-tube boiler at the Illinois Steel Co.'s plant, South Chicago, Ill.

(274.) — An accident occurred July 3, to two boilers in the Pardee & Curtin Lumber Co.'s plant, Curtin, W. Va.

(275.) — A tube ruptured, July 4, in a water-tube boiler in the electric light and power plant of the People's Power Co., Moline, Ill.

(276.) — On July 5 two boiler tubes failed on George C. Boldt's steam yacht, on the St. Lawrence river, near Ogdensburg, N. Y. Engineers Samuel Porter and Guy Zoller were fatally injured.

(277.) — On July 5 a threshing machine boiler exploded at Advance, near Mocksville, N. C. Archibald Potts was instantly killed, and his son, George Potts, was fatally injured.

(278.) — Two tubes ruptured, July 7, in a water-tube boiler belonging to the Retail Grocers Ice Co., Little Rock, Ark.

(279.) — A boiler exploded, on or about July 7, in the asylum at Hastings, Neb.

(280.) — A boiler exploded, July 8, in the plant of the Southern Cotton Oil Co., Charlotte, N. C. Three men were injured. The property loss was estimated at from $5,000 to $10,000.

(281.) — A tube ruptured, July 8, in a water-tube boiler at the power plant of the Philadelphia Rapid Transit Co., Thirty-third and Market streets, Philadelphia, Pa.

(282.) — A boiler exploded, July 8, at Muskogee, Okla. One man was injured.

(283.) — The boiler of a Santa Fé railroad locomotive exploded, July 8, at Williams, Ariz. J. S. Watts was scalded so badly that he died a few hours later.

(284.) — On July 10 a tube ruptured in a water-tube boiler at the Chittenden Hotel, Columbus, Ohio. William Floyd and Louis Nicholas were injured.

(285.) — On July 10 a blowoff pipe failed at the elbow, in the Lexington Hotel, Chicago, Ill. John Hare was injured. (See also No. 299, below.)

(286.) — A boiler exploded, July 12, in the linseed oil works, at Merriam Park, St. Paul, Minn. One man was fatally injured.

(287.) — A flue failed, July 12, in a boiler at the Union Light plant, Fargo, N. D. Frederick Martinson was injured so badly that he died within twenty-four hours.

(288.) — A boiler exploded, July 12, at the Bush stone quarry, Denison, Tex. The boiler was blown high in the air, and landed a thousand feet from its starting point, passing over several residences in its course.

(289.) — On July 13 a boiler exploded in Addington's ice cream manufactory, Niobrara, Neb.

(290.) — On July 13 a slight boiler accident occurred in the plant of the Logansport Artificial Ice & Fuel Co., Logansport, Ind.

(291.) — A tube ruptured, July 15, in a water-tube boiler at the plant of the Utica Gas & Electric Co., Utica, N. Y. Richard Hughes and William Ennis were scalded.

(292.) — A heater exploded, July 15, in the city hospital at Indianapolis, Ind. The loss was estimated at $300.

(293.) — A large heater exploded, July 15, in the beet sugar factory at Corcoran, near Visalia, Calif. William Lippert was killed, and a large hole was blown in the side of the building.

(294.) — On July 16 a boiler exploded in the Poteau Lumber Co.'s sawmill, twenty-seven miles north of Antlers, Okla. Two men were instantly killed, and another was fatally injured.

(295.) — On July 17 a blowoff pipe failed at the plant of the Boston Ice Co., Boston, Mass.

(296.) — A boiler exploded, July 19, three miles northeast of Ogden, Ill., on a dredge boat operated by Carter Bros.

(297.) — On July 19 a cylinder of a drier, used for eliminating the moisture from refuse material, collapsed at the Fowler Packing Co. branch of the National Packing Co., Kansas City, Kans.

(298.) — A boiler used in drilling a well exploded, July 20, on I. E. Taylor's place, seven miles north of La Junta, Colo.

(299.) — A blowoff pipe failed, July 21, on a boiler in the Lexington Hotel, Chicago, Ill. Thomas B. Dillon and Joseph Kelley were injured. (See also No. 285, above. The two accidents were on different boilers.)

(300.) — A boiler tube ruptured, July 22, at Provincetown, Mass., on a steam launch belonging to the U. S. cruiser *Prairie*. George E. Brown was critically scalded.

(301.) — The head of a rendering tank failed, July 23, at the plant of the Blumenstock & Reid Co., Cleveland, Ohio.

(302.) — A slight explosion occurred, July 23, in a pumping plant at San Ardo, Monterey county, Calif. Engineer Charles Handy was scalded.

(303.) — A boiler exploded, July 23, at the plant of the Hand Lumber Co., Bay Minette, Ala. One man was seriously injured.

(304.) — A blowoff pipe failed, July 24, at the plant of the Knoxboro Canning Co., Knoxboro, N. Y.

(305.) — On July 25 an accident occurred to a boiler at the Central Iron & Steel Co.'s plant, Harrisburg, Pa., resulting in considerable damage to the boiler.

(306.) — A blowoff pipe failed, July 27, in the A. H. Pugh Printing Co.'s plant, Cincinnati, Ohio. Fireman Preston McGee was scalded.

(307.) — The boiler of a Southern Pacific Railway locomotive exploded, July 29, at Portland, Ore. Three persons were severely injured.

(308.) — A number of cast-iron headers fractured, July 30, in a water-tube boiler at the National Sheet Steel Co.'s plant, Mansfield, Ohio.

(309.) — A boiler belonging to the Lipzinger Chicken Co. exploded, July 30, at Burlington, Ind.

(310.) — A slight boiler explosion occurred, July 31, at the South Side plant of the Wheeling Metal & Manufacturing Co., Wheeling, W. Va.

(311.) — A tube ruptured, July 31, in the D. Heenan Mercantile Co.'s department store, Streator, Ill. Robert White was injured.

August, 1909.

(312.) — A tube ruptured, August 2, in a water-tube boiler at the Superior Steel Co.'s rolling mill, Carnegie, Pa.

(313.) — On August 2, eleven cast-iron headers fractured in a water-tube boiler at the General Electric Co.'s plant, Schenectady, N. Y.

(314.) — A boiler exploded, August 3, on the steamer *Adrelexa,* at Cobalt, Ont.

(315.) — The boiler of a traction engine exploded, August 3, three and one-half miles south of North Industry, Ohio. John Fetters, a boy of twelve, was scalded to death, and Frank Fetters and Ira Peters were injured seriously but not fatally.

(316.) — A tube ruptured, August 3, in a water-tube boiler at the Joliet works of the Illinois Steel Co., Joliet, Ill. Samuel F. Bolls and C. O'Neil were injured.

(317.) — The boiler of a threshing outfit belonging to J. H. Macylin exploded, August 6, at Lake Andes, S. Dak. Charles Johnson, Frank Rohr, and a boy named Talmento were injured.

(318.) — On August 6 two cast-iron headers fractured in a water-tube boiler at the Pittsburg & Butler Street Railway Co.'s power plant, Renfrew, Pa.

(319.) — A boiler ruptured, August 6, at the plant of M. J. Daly & Sons, Waterbury, Conn.

(320.) — A cast-iron header fractured, August 6, in a water-tube boiler at the Bath Portland Cement Co.'s plant, Bath, Pa. Engineer J. D. Parker was slightly burned.

(321.) — A tube ruptured, August 7, in a water-tube boiler at the plant of the Lawton Mills Corporation, Plainfield, Conn. The engineer was slightly scalded.

(322.) — A slight boiler accident occurred, August 7, in the pumping station at North Manchester, Ind.

(323.) — A tube ruptured, August 8, in a water-tube boiler at the Co-operative Canal Co.'s irrigation plant, Blessing, Tex.

(324.) — On August 9 a cast-iron header fractured in a water-tube boiler at the Los Angeles Ice & Cold Storage Co.'s plant, Los Angeles, Calif.

(325.) — A boiler explosion occurred, August 10, at the plant of the Consumers' Brewery Co., New Orleans, La. One man was seriously injured, and the property loss was estimated at $2,000.

(326.) — On August 10 an accident occurred to a boiler in the Worthen & Aldrich Co.'s plant, Delawanna, N. J.

(327.) — A boiler operated in connection with a puddling furnace exploded, August 11, in the Logan Iron & Steel Co.'s plant, at Burnham, near Lewistown, Pa. George W. Stimely and Robert R. Allison were injured so badly that they died a few hours later. Augustus Myers, Harry Arnold, Abram Allison, Robert Goodwin, and John J. Wagner were also seriously injured, and it was thought that some of them could not recover. The property loss was estimated at from $15,000 to $20,000.

(328.) — A boiler exploded, August 13, at Winston-Salem, N. C. One person was fatally injured, and two others were injured seriously but not fatally.

(329.) — A boiler exploded, August 13, in Evans & Stinette's sawmill, at Only, near Centerville, Tenn. John Smith was killed outright, Abner Brown and a man named Walls were fatally injured, and three other men were injured seriously, but not fatally. The mill was destroyed.

(330.) — A boiler ruptured, August 14, in the C. C. Millard Ice & Cold Storage Co.'s plant, Chagrin Falls, Ohio.

(331.) — On August 16 a tube ruptured in a water-tube boiler in the Federal Coal & Coke Co.'s plant, Grays Flats, near Fairmont, W. Va.

(332.) — A boiler exploded, August 17, on the sand-hoist *Boaz*, at West Economy, Pa. Three men were seriously injured, and one of them may die. The superstructure of the boat was completely wrecked.

(333.) — A tube ruptured, August 18, in a water-tube boiler at the north power house of the United Railways Co., St. Louis, Mo. Charles Sellers and Alexander Hopson were injured.

(334.) — A boiler exploded, August 18, in James Gay's sawmill, two miles from Wilson, N. C. The mill was partially destroyed.

(335.) — The boiler of a Père Marquette passenger locomotive exploded, August 19, at Grand Ledge, Mich. Engineer William Bradlee and fireman Frederick F. Graves were killed, and six other persons were injured.

(336.) — The boiler of William Wackerow's threshing outfit exploded, August 21, eight miles southeast of Mellette, near Northville, S. Dak. Roy Lang was instantly killed, and the owner of the machine and three other men were injured.

(337.) — A boiler exploded, August 23, at the Union mine, at Flat Creek, near Nome, Alaska. Adolph Krupner was killed, and Harris Longfellow and E. E. Ludwig were injured, the former seriously. The boiler house was wrecked.

(338.) — A boiler exploded, August 24, in the Rusk Lumber Co.'s plant, Rusk, Tex. Christie Stovall and Jesse Hogg were killed, and four other men were seriously injured.

(339.) — On August 25 a boiler exploded in the Oregon Lumber Co.'s sawmill, at Hood River, Ore. Robert C. Wilson was killed.

(340.) — A boiler exploded, August 25, on the sea-going tugboat *Bee*, while it was passing beneath the Williamsburg bridge, opposite New York City. George Drinkwater was killed, and Peter Barlan, John Jacobs, and Albert Cardell were fatally injured.

(341.) — A boiler exploded, August 26, at E. O. Baylis's tomato cannery, Kenton, Del. Edward Cramer and Alfred Morgan were injured.

(342.) — On August 26 a boiler exploded at the Elmer Neff sawmill, near Coshocton, Ohio. Three men were scalded, and one of them will die.

(343.) — A boiler exploded, August 27, on the Gibson farm, near Mendota, Ill. Two persons were severely injured.

(344.) — A boiler exploded, August 28, at the pump shaft of the Slow Seven mine, at Neck City, fifteen miles northwest of Carthage, Mo. George Strain and Augustus Witzansky were instantly killed, and Edward Higgins was seriously injured. The boiler house and engine room were completely destroyed.

(345.) — On August 28 several tubes pulled out of the drum of a water-tube boiler at the plant of the Grand Rapids Edison Co., Grand Rapids, Mich. (See the next item.)

(346.) — A tube ruptured, August 28, in a water-tube boiler at the plant of the Grand Rapids Edison Co., Grand Rapids, Mich. Gibson Reed was somewhat injured. (Compare the item preceding. These two explosions occurred in the same boiler house, and on the same day, but at different hours, and in different boilers.)

(347.) — A boiler exploded, August 28, in W. T. Brightman's cotton gin and grist mill, Hayneville, Ala. Two men and a boy were instantly killed, and ten other persons were reported to be injured. The building was considerably damaged, and the property loss was estimated at from $8,000 to $10,000.

(348.) — A tube ruptured, August 28, in a water-tube boiler at the Oklahoma Portland Cement Co.'s plant, Ada, Okla.

(349.) — On August 29 a head blew off a steam mangle, in the laundry of the Hotel Breslin, New York City. The property loss was estimated at $1,000.

(350.) — A boiler ruptured, August 29, in the Natural Ice Co.'s plant, Plainfield, N. J.

Inspection Methods.— Following is a synopsis of a letter received by us from a doubting Thomas in the South, together with a résumé of our reply.

"I have in my possession," says the complaint, "a copy of your letter in reference to an engine which was supposed to have been inspected by your man in this territory a short time ago. I fail to see how this supposedly competent inspector can determine, by simply looking at a boiler, just how much pressure it would stand. I was informed that he made no test whatever, but simply passed an opinion, after looking over the machine. My experience as an old locomotive engineer on the Pennsylvania system was, that the way to arrive at the pressure that a given boiler would stand, was to apply a cold water test at fifteen per cent. above the steam pressure to be carried on the boiler. This engine stood a test of two hundred pounds cold water pressure before leaving my shops, and before any of the repairs now being made were anticipated. Your man who made this inspection has done an injury to my business by a careless examination, and by a report which was in no sense justified."

To this we replied, in substance, as follows: "We enclose a copy of our inspector's report on the boiler in question, and also a copy of the data which he took at the time of inspection. From these you will see that he not only closely scrutinized every accessible part, but also carefully measured all parts, so that calculations of the strength of every portion of the structure could be made, to determine the safe working pressure. These are the methods that are now employed by experts in boiler inspection. The cold water test is certainly useful, but it is merely supplementary, and is properly employed only as a check, after the safe working pressure has been determined by calculation. It can locate leakage, but it does not tell whether corrosive action is going on, nor whether there is scale formation or deposit of sediment. Neither does it point out the existence of such defects as bulges, blisters, and burned plates. These can be found only by 'looking' for them, and in this instance our inspector found enough to convince us that the boiler has seen its best days."

The Locomotive.

A. D. Risteen, Ph.D., Editor.

HARTFORD, OCTOBER 25, 1909.

The Locomotive *can be obtained free by calling at any of the company's agencies.*
Subscription price 50 cents per year when mailed from this office.
Bound volumes one dollar each.

Obituary.

Death has laid a heavy hand upon the employees and friends of this company during the past few years, and we have now to record the departure of four more who have been associated with us, more or less intimately, for long periods.

Mr. William Arrott, of Pittsburg, Pennsylvania, died on July 13, 1909. He was born at Allegheny, Pennsylvania, in 1865, and was educated at Princeton University. In 1884 he became associated with his father, in the insurance business, under the name James W. Arrott, Limited. This corporation has represented the Hartford Steam Boiler Inspection and Insurance Company, in Pittsburg and vicinity, since 1897, and Mr. Arrott, at the time of his death, was its secretary. He was a kind, genial gentleman, pleasant in his dealings with his associates, and his death is greatly deplored by all who had his acquaintance.

Mr. Thomas H. Sears, a boiler manufacturer of more than local reputation, died, July 30, 1909, at his home at Holyoke, Massachusetts. Mr. Sears was born in Ireland, November 15, 1853, coming to this country at the age of twelve, and settling at Holyoke in 1871. There he entered the employ of the Coghlan Boiler Works, where he has remained for thirty-eight years. Eight years ago the business was re-organized, and incorporated under the name of the Holyoke Steam Boiler Works, with Mr. Sears as its president and treasurer. He was a man of the highest type, and from boyhood to the time of his death he had had the confidence of the entire community.

Mr. Francis Adelbia Foster, better known to his associates as Frank A. Foster, died, August 1, 1909, at Bridgeport, Connecticut. He was born at Willimantic, Connecticut, August 29, 1850, and had followed engineering all his life. In 1888 he became an inspector for the Hartford Steam Boiler Inspection and Insurance Company, in the Bridgeport department, and had served us in that capacity, faithfully and well, for twenty-one years. Mr. Foster was widely known on account of his prominent connection with the National Association of Stationary Engineers. He was a member, for twenty-five years, of Lodge No. 10, of New Haven, and was national president of the association in 1886.

Mr. John T. Coleman, Sr., a boiler-maker of the old school, died, September 2, 1909, at Baltimore, Maryland. He was born in England in 1826, but came to the United States early in life, and served his apprenticeship in the shops of

Baltimore. In 1866 he entered the boiler manufacturing business for himself, retiring from it only in 1906, when eighty years of age. Mr. Coleman built the first horizontal tubular boiler installed in Baltimore, and his reputation as a builder of work of that character was always of the best. He was a good friend of the Hartford Steam Boiler Inspection and Insurance Company, particularly in its formative period, and our late president, Mr. J. M. Allen, felt deeply indebted to him for his kindly interest in the days when we were weak and he was strong.

Important Announcement.

The Hartford Steam Boiler Inspection and Insurance Company is now Prepared to Write Fly Wheel Insurance.

For some time past, many of our patrons have urged us to inspect and insure fly wheels, and after several years of careful consideration we have decided to do so. We have therefore organized a fly wheel department, and are now writing policies of this character.

The hazard connected with the use of fly wheels is an unmistakable one, and the frequency of explosions in modern plants has indicated a real necessity for insurance of this character. Moreover, as the risk is one that is connected with the use of steam, it has seemed perfectly logical for us to embark in this line of business. We have always been known as steam specialists, and we desire to continue to be so regarded, but there is no reason why we should confine our activities solely to the steam boiler itself, when the mechanical inspection of any power device is clearly within our field. For over forty years we have maintained the largest corps of mechanical experts employed by any insurance company in the world, and we believe that we can make this unparalleled organization even more useful to the manufacturers of this country than it has been in the past.

The demand for fly wheel insurance has only recently become of sufficient magnitude to justify us in making special provisions for its underwriting. The increase in the demand has been the direct result of modern mechanical tendencies, which exact from every piece of machinery the greatest service it can render. The demand is everywhere for higher speeds and heavier loads, in an effort to secure greater efficiency and an increased output. Power is also being installed in larger units than ever before, requiring heavier wheels for its regulation and transmission. Increased weight or speed in a wheel means greater destruction to surrounding property, when the wheel bursts; so that the danger of accident and the capacity for damage have both been greatly augmented by modern practice.

The hazard involved is a purely mechanical one, however, and it may be minimized by a thorough inspection of the wheels themselves, and of the appliances which control their operation. The harder we press, in our modern demands, upon the possibilities of materials, the more important it is that all points of design, construction, and present condition and management should be passed upon by qualified experts; and the staff of inspectors to which this branch of our service will be entrusted is composed of men who are highly competent to perform work of this special nature. In a word, we propose to maintain, in this branch of the service, the efficiency which has made our steam boiler inspections the standard of the world.

Our fly wheel policy extends the broadest possible protection against damage to the property of the assured, or to that of others for which the assured may be liable, and also against loss of life and personal injuries resulting from the bursting of wheels. It follows the wording of our steam boiler policy as nearly as we could make it do so, in view of the different nature of the risk; and we shall extend to our assured the same liberal treatment, under our fly wheel policy, that has always distinguished the "Hartford" under its boiler policies.

Rates, and general information regarding the whole subject, will be furnished gladly at any of our branch offices.

On September 22 Mr. Horace B. Cheney, of South Manchester, Connecticut, was elected a director of the Hartford Steam Boiler Inspection and Insurance Company, in the place of his father, Colonel Frank W. Cheney, whose death was recorded in our last issue.

Mr. George C. Oliver has been appointed general agent of this company, in the Birmingham branch of the Atlanta department. His office is in the Brown-Marx building, Birmingham, Alabama. Mr. H. E. Stringfellow continues to represent us in the same territory, as chief inspector.

We are indebted to Mr. George S. Godard, State Librarian of Connecticut, for a transcript of the state papers relating to John Fitch, which are given towards the close of the article "Robert Fulton or John Fitch?" in the present issue.

An index is in preparation, for the twenty-seventh volume of The Locomotive, which is completed by this issue. Bound volumes will be on sale shortly, at the usual price of one dollar each. Correspondents will please note that this volume covers the *two years* 1908 and 1909, just as volume 25 covered the years 1904 and 1905, and volume 26 the years 1906 and 1907.

Capt. George H. Atkinson, of Pittsburg, Pa., has resigned his position as inspector of steam boilers, in the office of the inspector of steam vessels. Mr. Atkinson is a veteran of the Civil War, in which he served under Admirals Foote, Davis, Lee and Porter. He is likewise a veteran in the inspection service, for he has been identified with it for forty-one years, except for two years under President Cleveland. We regret that the weight of his seventy-eight years now impels him to resign, and we assure him that he carries with him the deepest esteem and the best wishes of an exceedingly wide circle of friends.

The British steamship *Clan Mackintosh,* belonging to the Madras Steam Navigation Co., is said to have been destroyed at sea by a boiler explosion, late in September, while on her way from Rangoon, Burmah, to Calcutta, India.

Robert Fulton or John Fitch ?

The recent Hudson-Fulton celebration, in New York city and along the Hudson river generally, makes this a timely occasion for calling attention once more to the question of priority in the invention of the steamboat. Much has been written on the subject, and the honor has been claimed for many men; but we think that a dispassionate review of the known facts will eliminate all of the inventors who may have striven to realize navigation by steam, previous to the time of John Fitch. At all events, this must be admitted if the test of priority be made the construction of an actual, serviceable steamboat, which did in fact navigate the water, making regular trips for the accommodation of passengers, or the transportation of freight. It will not be denied that Fulton was the first to navigate the *Hudson river* in this way, and if the idea was to deal only with events in the history of that particular river, it may have been just to render to him, and to the *Clermont*, the honor they have recently received. But we feel that if the object was to celebrate the man who first navigated a vessel for commercial purposes, by the power of steam, the credit should go to "poor John Fitch," now almost forgotten.

The late Dr. William Wood, of East Windsor Hill, Connecticut, took a deep interest in Fitch, and wrote a memoir upon the history of steam navigation, which was printed in the *Hartford Times*, and also in The Locomotive, in 1883. The facts that he collected are of great interest, and we reprint, below, the parts of his article that relate more particularly to the question of priority between Fitch and Fulton.

John Fitch was born at Windsor, Conn., January 21, 1743. "Windsor," says Dr. Wood, "then embraced what is now several towns, both on the east and on the west sides of the Connecticut river; Fitch's birthplace being in South Windsor, near the East Hartford line. On April 15, 1785, John Fitch first conceived the idea of steam as a motive power for carriages, but soon turned his attention to its application in moving vessels, and says: 'I was then altogether ignorant that a steam engine had ever been invented. The propelling of a boat by steam is as new as the rowing of a boat with angels, and I claim the first thought and invention of it.' It was in Cobe Scout's log shop that Fitch made his first model of a steamboat with paddle-wheels. 'The model was tried on a small stream on Joseph Longstreth's meadow, about half a mile from Davisville, in Southampton township, and it realized every expectation. The machinery was made of brass, with the exception of the paddle-wheels, which were made of wood.' After spending some more time to perfect the model, he exhibited it to Dr. John Ewing, provost of the University of Pennsylvania, who gave Fitch the following letter to William C. Houston, formerly a member of Congress:

"'Philadelphia, August 20, 1785.

"'Dr. Sir — I have examined Fitch's machine for rowing a boat by the alternate operation of steam and the atmosphere. The application of this force to turn a wheel in the water so as to answer the purpose of oars, seems easy and natural by the machine which he proposes, and of which he has shown me a rough model.'

"Fitch had numerous letters of recommendation from distinguished gentlemen, who had examined his model. August 29, 1785, Fitch presented the following letter to Congress:

"'August 29th, 1785. Sir: — The subscriber begs leave to lay at the feet of Congress an attempt he has made to facilitate the internal Navigation of the United States, adapted especially to the waters of the Mississippi. The machine he has invented for the purpose has been examined by several Gentlemen of Learning and Ingenuity, who have given it their approbation.'

"On the 27th of September, 1785, Fitch presented a drawing and models of his boat to the American Philosophical Society at Philadelphia. March 18, 1786, the State of New Jersey passed a law, giving Fitch, for fourteen years, 'The sole and exclusive right of constructing, making, using, and employing, or navigating, all and every species or kind of boats, or water craft, which might be urged or impelled by the force of fire or steam, in all the creeks, rivers, etc., within the territory or jurisdiction of this State.' On the 20th of July, 1786, Fitch tried experiments on a skiff with a steam engine of three-inch cylinder, which moved a screw of paddles — the endless chain, and one or two other modes, which were not satisfactory. Disheartened by the failure, and provoked by the scoffs and insults of the spectators, he went to a tavern, and says 'he used considerable West India produce that evening.' The next day he felt very much ashamed of himself, and in the evening retired early. Says Fitch, 'about 12 o'clock at night the idea struck me about cranks and paddles for rowing of a boat, and for fear that I should forget or lose the idea, I got up about 1 o'clock, struck a light, and drew a plan. I was so excited that it was impossible to sleep. At sunrise I sought the residence of Voight [an inventive genius whom Fitch often consulted], and showed him the draught. The plan was somewhat improved by a suggestion of Voight.' The experiment was made in a skiff, July 27, 1786, and worked to the satisfaction of the projectors. The next day he wrote to his friend, Mr. Tracy Potts:

"'Philadelphia, July 28, 1786. — My worthy friend. This may inform you that I completed my experiments yesterday, and find that they exceed my most sanguine expectations. We let out 7 knot of Log line and had not more than half of the purchase that we shall have on a Large Boat.'

"Fitch having exhausted all his resources in experiments on his machinery and boats, applied to the Pennsylvania legislature for a loan of £150, and failing of securing it, by a vote of 28 to 32, he applied to General Thomas Mifflin, who was then speaker of the House, for individual aid. No prophet could have foretold the future of his discovery more accurately than did Fitch in that epistle:

"'Honored Sir: — I am of opinion that a vessel may be carried 6, 7, or 8 miles per hour by the force of steam; and the larger the vessel the better it will answer; and am strongly inclined to believe that it will answer for sea Voyages as well as for inland Navigation, which would not only make the Mississippi as navigable as Tide water, but would make our vast Territory on those waters an inconceivable fund in the Treasury of the United States. Perhaps I should not be thought more extravigent than I already have been * * * , when I assert, that six tons of Machinery will act with as much force as ten tons of men, and should I suggest that the navigation between this [country] and Europe may be made so easy as shortly to make us the most popular Empire on Earth, it probably, at this time, would make the whole very laughable.'

"The state of New York granted Fitch exclusive rights to her waters for fourteen years for the purpose of steam navigation, on March 19, 1787. Similar rights were granted by Delaware on February 3, 1787, by Pennsylvania on March 28, 1787, and by Virginia on November 7, 1787.

"Fitch's second boat was built in 1786, but the machinery was not perfected until 1787. This boat was forty-five feet long, and twelve feet beam. It had six oars or paddles on each side. The engine was a twelve-inch cylinder. The trial took place upon the Delaware, at Philadelphia, August 22, 1787. The convention to frame the Federal Constitution was in session in that city at that time, and witnessed the success of the steamboat. Fitch, in his journal, says that nearly all the members of the convention were present, except General Washington. They were all pleased with the experiment, and letters of congratulation upon the success of the enterprise were given by the prominent gentlemen present — Governor Randolph and Dr. Johnson, of Virginia, David Rittenhouse, Dr. John Ewing, and Professor Andrew Ellicott, of Pennsylvania. Chief-Justice Oliver Ellsworth, of Connecticut, was on board of the steamer, and says the experiment was a success.

"As the speed of the boat was not satisfactory, Fitch, after much trouble and anxiety, succeeded in raising the necessary funds to build a new steamboat, 60 feet long, and 8 feet beam. After many vexatious mishaps in perfecting the machinery, everything was ready for the trial trip about the last of July, 1788. Dr. Thornton, who was deeply interested in the success of the boat, writes to a friend, July 26: 'Our boat will be tried this evening or to-morrow. Ours is moved by paddles placed at the stern, moved by a small steam engine.' Fitch says in his journal, 'We finally got it to work pretty well, and set out upon a journey to Burlington, twenty miles. Henry Voight, Richard Wells, Thomas Say, and several others were on board at this trial trip,' — the longest trip ever made by a steamboat at that time. At every town along the river banks they were greeted with cheers, and waving of handkerchiefs, and when within a few rods of their destination, the pipe boiler sprang a leak, and they came to anchor. The boiler was soon repaired, and the boat made several trips to Burlington and back without any accident. On the 12th of October, 1788, there were thirty passengers on board, and these were taken from Philadelphia to Burlington (20 miles, up stream), in three hours and ten minutes, which fact was certified to, by Andrew Ellicott, Richard Chase, John Poor, and John Ely. This speed did not satisfy Fitch, or those who had a pecuniary interest in the enterprise. It was determined to build a new boat with larger machinery — the cylinder to be eighteen instead of twelve inches in diameter. Various alterations and improvements were made in the machinery before satisfactory speed was attained. On the 16th of April, 1790, a trial trip was made, and, says Fitch, 'although the wind blew very fresh at the northeast, we reigned Lord High Admirals of the Delaware, and no boat in the river could hold its way with us, but all fell astern, although several sailboats which were very light, and heavy sails that brought their gunnales well down to the water, came out to try us.'

"Several equally satisfactory trips were made with members of the company and invited guests; and Fitch, elated with his success, exclaims, 'Thus has been effected by little Johnny Fitch and Harry Voight, one of the greatest and most useful arts that has ever been introduced into the world; and although the world and my country does not thank me for it, yet it gives me heartfelt satisfaction.'

"On the 16th of June, 1790, Governor Thomas Mifflin and the Supreme Executive Council were passengers on this boat, and were so highly pleased that they presented the steamboat company with a suit of flags, the cost of which was £5 6s. 11d. (About $25.) The speed of the boat was eight miles an hour. It afterwards covered ninety miles in one day.

"This boat was now run as a regular passenger boat between Philadelphia and Burlington. The two papers published in Philadelphia, the *Pennsylvania Packet* and the *Federal Gazette,* gave notices of the days and time of sailing. Here is the advertisement that was in the *Pennsylvania Packet* of June 15, 1790:

"'The steamboat is now ready to take passengers, and is intended to set off from Arch street Ferry, in Philadelphia, every Monday, Wednesday and Friday, for Burlington, Bristol, Bordentown and Trenton, to return on Tuesday, Thursday, and Saturday.'

"The same notice was published in the *Federal Gazette,* June 14, 17, 19, 22, and 24, 1790. In the *New York Magazine* is an extract from a letter dated August 13, 1790 — 'Fitch's steamboat really performs to a charm.'

"It is estimated that the boat must have gone at least two or three thousand miles that summer carrying passengers. Was this not a success? The great problem of steam navigation was practically demonstrated.

"Wishing, now, a boat large enough to carry freight as well as passengers, the new company was consolidated with the old, and another boat was contracted for — the *Perseverance* — with the intention of sending it to New Orleans, for the navigation of the Mississippi. It was hoped that it would be finished in time to save the benefit of the Virginia law. (The legislature of Virginia, November 7, 1787, passed a law securing Fitch's rights in the steamboat for fourteen years, conditioned, 'that it should be void at the expiration of three years unless the said John Fitch shall then have in use on some river of this commonwealth, boats or craft of at least twenty tons burden, navigated by steam.') The great value of the Virginia law was, that it gave Fitch the exclusive right of navigating the Ohio river and its tributaries with the steamboat. In this, the company was disappointed. The boat and machinery were nearly completed, when a violent storm arose, causing it to break from its moorings, and it was blown upon Petty's Island in the Delaware, opposite the upper part of Philadelphia. The tide being unusually high, the boat was driven so far upon the land that it was impossible to get it off in season to avail themselves of the benefits of the Virginia law. The stockholders became discouraged and refused to furnish any more funds, and Fitch having exhausted all his resources, the boat was abandoned and remained for four years without any change, and was advertised for sale at auction, August 18, 1795. April 23, 1791, Fitch applied to the Federal Congress for a patent, and this was granted on August 26, 1791, the document being signed by General Washington, and by the Commissioners, Thomas Jefferson, General Henry Knox, and John Randolph.

"In 1793, Fitch went to France to build a steamboat, at the solicitation of Aaron Vail, our consul at L'Orient; but he arrived there at the time of the revolutionary troubles, and could not obtain any pecuniary assistance. Depositing his papers and specifications in the hands of Mr. Vail, he went to England, remaining in London for a time with his friend Mr. Leslie, formerly of Philadelphia. In 1794 he returned to the United States, working his passage as a common sailor. He found his way to East Windsor, now South Windsor, to the home of his sister, Mrs. Timothy King, and to the home of his daughter Lucy, Mrs. Kilbourne. After remaining some two years with his sister, he started off again on his steamboat enterprise. In 1796 he constructed a steamboat out of a ship's yawl. The boat was moved by a screw propeller on a large fresh water pond, called the Collect, in the city of New York. This pond, which was afterwards filled in, was located where the Tombs and other neighboring buildings now stand. In the spring of 1798 Fitch built a model steamboat three feet long, at Bardstown, Ky., which was tried upon a small stream near that town.

"Some time between the 25th of June and the 18th of July, 1798, this remarkable man, broken down with misfortunes, disappointments, and discouragements, committed suicide. (His will was made on June 25 and was admitted to probate on July 18.) His remains lie unhonored, in Bardstown, with a rough stone, without inscription, to mark his resting place."

The date of Fitch's death is now believed to have been July 2, 1798.

"I will now examine the merits of later claimants," continues Dr. Wood. "In 1788 Patrick Miller constructed a boat and William Symington made an engine for it, and on the 14th of October, 1788, it was moved by steam in the lake of Dalswinton, in the presence of several spectators. This did not answer their expectations, and the next year (1789) Mr. Miller had a twelve-horse engine made and fixed to his double-bottomed boat, which was tried on the Clyde and Forth canal, with success. This was England's first successful steamboat experiment. Symington continued his experiments, under the patronage of Lord Dundas, and in March, 1802, two vessels of 70 tons burden each were towed by the steamboat, *Charlotte Dundas,* 19½ miles in six hours, against very strong head wind. The English declare that this was the first practical steamboat experiment. Fitch, twelve years prior to that, was carrying passengers regularly, according to advertisements, eight miles an hour. Was not that practical?

"A writer in the Boston *Recorder* of September 23, 1858, in an interesting article on steam navigation, gives Captain Samuel Morey, of Orford, N. H., the credit of being the first man to propel a boat by steam:

"'The astonishing sight of this man ascending the Connecticut river between Orford and Fairlee, in a little boat just large enough to contain himself, the rude machinery connected with the steam-boiler, and a handful of wood for the fire, was witnessed by the writer in his boyhood.'

"I have several times since the publication of the foregoing article seen notices in other papers claiming priority for Morey. The writers evidently were not aware that Fitch, several years prior to that, was making regular trips on the Delaware with his steamboat. Captain Morey was an original thinker and inventor, commencing his experiments with his little steamer on the Connecticut as early as 1790. After working three years in perfecting his machinery, he propelled a small steamer, in the summer of 1794, from Hartford to New York at the rate of five miles an hour. Chancellor Livingston, Judge Livingston, Edward Livingston, and John Stevens went with him from New York to Greenwich. From this time to the time of Fulton's experiments there were many steamboats, constructed by different individuals, prominent among whom were Oliver Evans, Nicholas I. Roosevelt, and John Cox Stevens. To Stevens is due the credit of making the first maritime voyage. He went with his steamer, the *Phœnix,* from New York to Philadelphia in June, 1808. Roosevelt built the first steamboat, the *New Orleans,* that navigated the Ohio and Mississippi, in 1811.

"The next claimant, and one to whom the honor of first practically demonstrating the application of steam for moving vessels is very generally accorded, is Robert Fulton. Only a short time has elapsed since (on February 26, 1883) a statue of Robert Fulton was erected in the National Hall of Statuary, in the Capitol, by Pennsylvania, in honor of the discovery. It was not until 1803 that Fulton, with the assistance of Robert R. Livingston, our minister to France, made his experiment with a steamboat on the Seine, at Paris, which was not a success. Three years later, he commenced building the *Clermont*, at New York, in the shipyard of Charles Browne. It was not completed until August, 1807. This boat was a success, but did not equal the speed of Fitch's boat of 1790 by three miles an hour. Fulton lived in Philadelphia in 1785 and 1786, the time Fitch was making his steamboat experiments in that city, and when he was petitioning Congress for assistance, and the States of Virginia, Maryland, Pennsylvania, Delaware, and New Jersey for exclusive rights to their waters for steam navigation; and as it was in July, 1786, that Fitch made a successful public trial of his skiff steamboat on the Delaware, can it for a moment be doubted that Fulton, with his inquisitive mind, was fully aware of Fitch's inventions? This was more than twenty years before Fulton made his experiments on the Hudson. Some time in 1786, Fulton went to England and spent several years in the family of Mr. West, perfecting himself in the art of painting. After leaving that family, he spent two years in Devonshire, as a painter, and while there became acquainted with the Duke of Bridgewater, famous for his canals, and Lord Stanhope, a lover of mechanics. Owing probably to their influence, Fulton first turned his attention to canals and steam navigation. He then went to France, and spent seven years in Paris. While there, he visited Mr. Vail, with whom Fitch had entrusted his drawings and specifications pertaining to his steamboat, and Mr. Vail says, '*I lent Mr. Fulton, of Paris, all the specifications and drawings of Mr. Fitch, and they remained in his possession several months.*' According to the affidavits made by Robert Weir and Jacob Perkins, Mr. Fulton visited England in 1801, and was on board Symington's boat, on the Forth and Clyde canal. To gratify him, the boat was propelled by steam four miles and back, at the rate of six miles an hour. *Fulton took drawings of the machinery.* Chancellor Livingston, who was aiding Fulton in his steamboat projects, was a passenger on Fitch's boat on the Collect, and was also a passenger on Morey's boat from New York to Greenwich, and no doubt had seen the steamboat experiments of Stevens and Roosevelt on the Hudson. With the drawings and specifications of Fitch, with the drawings and observations made on board of Symington's boat, with the observations of Livingston on Fitch's and Morey's boats, I would ask, to what discovery or invention pertaining to steamboats is Fulton entitled? One writer very justly remarks, '*If the inventions of others which Fulton has copied were removed from his boat, nothing would be left but the hull.*' In 1817, the original patents, drafts, specifications, and models, of Fitch and Fulton were exhibited before a committee of the New York legislature, raised upon the petition of Governor Ogden of New Jersey. Witnesses were examined, and able counsel employed. Fulton and Livingston were represented by Cadwalader D. Colden and Thomas Addis Emmet, Fitch's interests by Samuel A. Southard, Joseph Hopkinson, and Colonel Ogden. Certificates of Dr. Rittenhouse, Andrew Ellicott, Oliver Evans and John Ewing were produced, stating the performance of Fitch's steamboat. General Bloomfield testified, that he 'had been a passenger on board Fitch's boat on the Delaware in 1787 and 1788, and regarded the experiment as successful.' The committee after much deliberation reported to the legislature that '*The steamboats built by Livingston and Fulton were in* *substance the invention patented to John Fitch in* 1791, *and Fitch during the term of his patent had the exclusive right to use the same in the United States.'* What stronger evidence can any one ask than the above, to substantiate the claim of Fitch over Fulton to priority in steam navigation?

"Fulton, when he commenced his experiments, had the advantage of the models, specifications, drawings, and plans of Fitch — had made a successful trip on Symington's and Miller's steamboat and taken drawings of the machinery — had the benefit of Livingston's observations on Fitch's and Morey's boats — had his engine built in England by James Watt — had influential and wealthy friends to assist him. Fitch, when he commenced his experiments, was not aware that there was a steam-engine in the world — made his own engine with the assistance of common blacksmiths — had to experiment as he progressed to know the relative position and power of the parts — was poor, but by selling lands in Kentucky, which he acquired by surveying, and by limited assistance from friends, he surmounted incredible hardships, misfortunes, and discouragements, and overcame every obstacle, and demonstrated to the world the first successful steamboat enterprise. To-day Fulton's memory is honored by a statue in the Capitol, from Pennsylvania. Fitch lies in a lone grave at Bardstown, Kentucky, with a rough stone without inscription to mark his resting place. Let the nation honor the true inventor, John Fitch, by erecting some fitting monument to perpetuate the memory of one of her most useful inventors."

As a sort of supplement to the foregoing matter from Dr. Wood's pen, we offer the following extract from pages 235-8 of William L. Stone's "Reminiscences of Saratoga and Ballston," published in 1880 by R. Worthington, 750 Broadway, New York City:

"At this point the Rev. Mr. Potter (since Rt. Rev. Bishop Potter of Pennsylvania), a young Episcopal divine, who is married to a daughter of the late Robert R. Livingston, and is consequently a nephew by marriage of General Lewis, joined in the conversation.

"'I am not surprised, General, at your remarks,' said he, 'my own observation leading me to believe that many descend into history as successful claimants for public honors, who, if the facts were known, would stand in a very different light. Probably no person has received so much praise, and deserved so little, as Robert Fulton. A man of no practical ingenuity, of no power of conceiving, much less of executing, an original mechanical idea, his friend Golden has succeeded in persuading the public that to him is due the successful navigation of our rivers by steam. The facts, however, as I gathered them from my father-in-law, and which I believe to be substantially correct, are as follows: For thirteen years before the first steamboat was placed upon the Collect [pond] in New York, John Fitch had run a little steamer on the Delaware with great success. During that period he had experimented with various kinds of propelling power, — the screw, the side-wheel, and sweeps or long oars. The most primitive thing about his vessel was the boiler, which consisted simply of two potash kettles, riveted together. [In earlier years Fitch was engaged in the manufacture of potash, though he failed to make a commercial success of the business. — *Editor* THE LOCOMOTIVE.] Mr. Livingston, who was greatly interested in the success of Fitch's experiments, seized the opportunity, when minister to France, to visit the workshop of Watt & Bolton, in England, where, for the first time, he saw a properly constructed boiler. But how was he to introduce it into the United States, unless (which was then impossible) he went there himself? As this crisis he thought of Robert Fulton, who, originally an artist in Philadelphia, was then exhibiting a panorama in Paris. His panorama, however, failing to pay, was attached, and he himself arrested for debt and thrown into prison. Livingston, falling into the error so common to many, of believing that because an artist can draw cleverly he must necessarily succeed equally well on mechanical conception and execution, paid off Fulton's debts, and sent him over to New York with one of Watt's boilers. Fulton, however, failed to rise to the occasion; and when Livingston returned, a year after, he found his pet project precisely where he had left it several years before. He therefore at once took hold of it himself, and by his energy and perseverance finally brought his idea to a successful issue, — Fulton, whom he could not entirely shake off, acting as a kind of general superintendent.'

"These statements, moreover, are confirmed, not only by the late President William A. Duer, in his 'New Yorker' (Letter 7th), but by Mr. Ransom Cook, now (1875) living at Saratoga Springs, N. Y. Mr. Cook informs me that in the summer of 1837 he was engaged upon his electro-magnetic machinery. Among his workmen were two who had been employed by Livingston and Fulton, while those gentlemen were perfecting their steamboat. They surprised him greatly by stating that Fulton was a capital draftsman, and that was all. They added that he was so deficient in a knowledge of the laws of mechanics as to furnish daily mirth for the workmen; and that it was a long time before Livingston could convince him that the 'starting-bar' of an engine should be made larger at the fulcrum end than at the handle."

The State of Connecticut has given its official approval to the priority of Fitch. In 1887 the Connecticut Legislature, by a joint resolution, appointed a committee to look into the matter of "the discoveries and inventions of John Fitch of Windsor." The committee, after examining such evidence as could be had, submitted the following report:

"To the Honorable, The Senate and House of Representatives of the State of Connecticut, in General Assembly Convened:

"The undersigned, appointed a special committee by joint resolution, beg leave to report as follows:

"That in accordance with the instructions of said resolution your committee have carefully investigated the facts rendered available by existing records, indicating the date and extent of the agency of John Fitch of Windsor, in this State, in the practical application of steam as a motive power in the propulsion of vessels on the water, and we find the same sufficient to fully establish the correctness of the following statement.

"1. That as early as April, 1785, John Fitch claimed to have invented a machine, using steam as a motive power to propel vessels.

"2. That in August of the same year Dr. John Ewing, Provost of the University of Pennsylvania, in a letter to Wm. C. Houston, formerly Member of Congress, certifies to having personally 'examined Fitch's machine for rowing a boat by the alternate operation of steam and the atmosphere.'

"3. That on September 27, 1785, Fitch presented a drawing and model of his boat to the American Philosophical Society of Philadelphia.

"4. That on March 18, 1786, the State of New Jersey gave to John Fitch 'the sole and exclusive right, for fourteen years, of constructing, making, using, and employing, or navigating, all and every species or kinds of boats, or water craft, which might be urged or impelled by the force of fire or steam, in all the creeks, rivers, etc., within the territory or jurisdiction of this state.'

"5. That similar rights were granted to John Fitch by the States of New York (March 19, 1787), Delaware (February 3, 1787), Pennsylvania (March 28, 1787), and Virginia (November 7, 1787).

"6. That a boat moved exclusively by steam power applied to paddles placed at its stern, was constructed by Fitch, and made the trip from Philadelphia to Burlington, a distance of twenty miles, up-stream and against the current, in three hours and ten minutes, with thirty passengers on board, on October 12, 1788.

"7. That a second, and larger and more efficient vessel, was constructed by Fitch, and made a trial-trip on April 16, 1790; and that this vessel was thereafter run as a regular passenger boat, during the summer of 1790, between Philadelphia and Burlington, being so completely successful that a regular advertisement of her days of leaving and returning, and her place of departure, with her readiness to convey passengers, may be found at repeated intervals and dates, in the local newspapers of the time — the *Pennsylvania Packet* and the *Federal Gazette*.

"8. That an account of the fine performance of this vessel may be found in the *New York Magazine* of August 13, 1790. Your committee have been unable to find any authentic record of inventions for the successful application of steam to the propulsion of vessels and the actual use of the same, by any person or persons, anywhere in the world, at so early a date as that [which is] clearly and fully established, by the facts hereinbefore mentioned, to the credit of John Fitch; and they therefore deem it a measure of justice, as well as of proper State pride, that such action be taken, commemorative of the great achievements of this native and humble citizen of our Commonwealth, as that proposed by the Joint Resolution of this General Assembly. Your committee recommend that the full and interesting monograph of the late William Wood, of East Windsor, setting forth the facts of the case, be made a matter of record in the archives of the State, in connection with this report.

"All of which is respectfully submitted.

"O. Vincent Coffin, *Senate Chairman.*
"A. Foster Higgins, *House Chairman.*
(By O V.C., by request.)
"Luke E. Wood, *Senate Committee.*
"C. E. Osborne, *House Committee.*"

The foregoing report was accepted in the House of Representatives of the State of Connecticut on April 28, 1887, and in the Senate on May 10, 1887.

The joint resolution referred to in the final paragraph of the foregoing report was entitled "A Resolution providing for a Tablet to the Memory of John Fitch of Windsor," and the text of it was as follows:

"Resolved by this Assembly:

"That the Secretary of the State is hereby directed to have recorded in the Archives of this state the Report of the select committee and accompanying monograph prepared by the late William Wood of East Windsor — relating to the discoveries and applied invention of steam machinery to the propulsion of vessels on the water, by John Fitch of Windsor — and also to transmit a copy of the same to the Secretary of State for the United States, with the request of the State of Connecticut that the same may be recorded in the Archives of the United States for the information of posterity.

"Sec. 2. The select committee is authorized and directed to prepare a tablet, and have the same placed in such spot on the walls of the Capitol as they may decide to be best and proper, in accordance with the joint resolution of the Assembly, heretofore passed.

"Sec. 3. The Comptroller is hereby authorized to pay, on the order of the House Chairman of that committee, the cost of such tablet, not exceeding the sum of two hundred and fifty dollars."

This joint resolution was passed by the House of Representatives on May 4, 1887, and by the Senate on May 10, 1887, and it received the formal approval of Governor Phineas C. Lounsbury on May 18, 1887. The tablet for which it provides was constructed in bronze, and now adorns the east wall of the north entrance to the Capitol building, at Hartford.

In 1796 Fitch prepared a sort of autobiography of himself, sealing it and delivering it to the Library Company, of Philadelphia, with directions that it should be opened thirty years after his death. In this there occurs the following pathetic passage: "The day will come when some more powerful man will get fame and riches from my invention; but nobody will believe that poor John Fitch can do anything worthy of attention." He was a good prophet. He has his bronze tablet, cost not to exceed two hundred and fifty dollars; but up to the present writing we have heard of no plan to celebrate his deeds by long processions, nor by salvos from the guns of warships, congregated from the ends of the earth.

The boiler inspection law now in force in Massachusetts has been watched with interest by engineers all over the country. It is apparently working well, on the whole, and the prospects are that it will be used as a model piece of legislation, by other states, and by cities. Detroit, Michigan, for example, has already adopted it after merely making such changes as were necessary in order to transform it from a state law to a municipal ordinance. The state of Massachusetts has recently issued a neat pamphlet containing its license law for engineers and firemen, its boiler inspection law, and the rules that have been formulated by the Board of Boiler Rules. A copy of this pamphlet may be had by making application in the following manner: First, a letter, enclosing a two-cent stamp for reply, should be sent to the Boiler Inspection Department, Room 3, State House, Boston, Mass., asking for an *application card*. When this is received, it should be filled out properly and re-mailed to the same address, accompanied by *three* cents if the applicant is a resident of Massachusetts, or by *ten* cents if he resides out of the state. The pamphlet will then be forwarded.

Mr. Max Pemberton's story, "The Diamond Ship," is a good enough story in the main, we dare say, although we have not read it. From a steam engineering standpoint, however, it is not altogether perfect. He describes his boat as "a long, wicked-looking yacht," and he adds: "I liked to hear my friends say that. When I took them aboard and showed them the superb engines *which drove the turbines*, . . . then it was of the Hotel Ritz they talked, and not of any wickedness at all." It was certainly polite of them to change the drift of the conversation, when they heard the "boss" make any such break as that.

Hartford Steam Boiler Inspection and Insurance Company.

ABSTRACT OF STATEMENT, JANUARY 1, 1909.

Capital Stock, . . . $1,000,000.00.

ASSETS.

	Par Value.	Market Value
Cash in office and in Bank, ...		$143,227.09
Premiums in course of collection (since Oct. 1, 1908),		274,020.83
Agents' cash balances, ...		23,011.96
Interest accrued on Mortgage Loans, . . .		25,965.64
Interest accrued on Bonds, ...		35,154.54
Loaned on Bond and Mortgage.		1,024,865.00
Real estate, ...		95,100.00
State of Massachusetts Bonds, ...	$100,000.00	88,000.00
County, City and Town Bonds, ...	399,000.00	407,360.00
Board of Education and School District Bonds, .	24,000.00	24,500.00
Railroad Bonds, ...	1,478,000.00	1,576,960.00
Street Railway Bonds, ...	173,000.00	171,010.00
Miscellaneous Bonds, ...	87,500.00	83,450.00
National Bank Stocks, ...	29,300.00	43,840.00
Railroad Stocks, ...	215,900.00	263,901.35
Miscellaneous Stocks, ...	180,100.00	144,060.00
	$2,686,800.00	
Total Assets, ...		$4,424,426.41

LIABILITIES.

Re-insurance Reserve, ...		$1,885,729.16
Commissions and brokerage, ...		54,804.17
Other liabilities (Taxes accrued, etc.), . . .		37,476.54
Losses Unadjusted, ...		28,382.11
Surplus, ...	$1,418,034.43	
Capital Stock, ...	1,000,000.00	
Surplus as regards Policy-holders, .	**$2,418,034.43**	2,418,034.43
Total Liabilities, ...		$4,424,426.41

On December 31, 1908, the Hartford Steam Boiler Inspection and Insurance Company had 102,176 steam boilers under insurance.

L. B. BRAINERD, President and Treasurer.
FRANCIS B. ALLEN, Vice-President. C. S. BLAKE, Secretary.
L. F. MIDDLEBROOK, Assistant Secretary.
W. R. C. CORSON, Assistant Secretary.

A. S. Wickham, Superintendent of Agencies.
E. J. Murphy, M. E., Consulting Engineer.
F. M. Fitch, Auditor.

Incorporated 1866. | Charter Perpetual.

The Hartford Steam Boiler Inspection and Insurance Company

ISSUES POLICES OF INSURANCE COVERING

ALL LOSS OF PROPERTY

AS WELL AS DAMAGE RESULTING FROM

LOSS OF LIFE AND PERSONAL INJURIES DUE TO STEAM BOILER EXPLOSIONS.

Full information concerning the Company's Operations can be obtained at any of its Agencies.

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BOSTON, . . .	C. E. ROBERTS, Manager, F. S. ALLEN, Chief Inspector,	Boston, Mass., 101 Milk St. Providence, R. I., 17 Custom House St.
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HARTFORD, . .	H. C. LONG, Special Agent, F. H. WILLIAMS, JR., Special Agent, F. S. ALLEN, Chief Inspector,	Hartford, Conn., 56 Prospect St.
BRIDGEPORT, . .	W. G. LINEBURGH & SON, Gen. Agts., F. S. ALLEN, Chief Inspector,	Bridgeport, Conn., 1 Sanford Building.
PITTSBURG, . .	JAMES W. ARROTT, LTD., Gen. Agt., BENJAMIN FORD, Chief Inspector,	Pittsburg, Pa., 401 Wood Street.
CLEVELAND, . .	H. A. BAUMHART, Manager, H. A. BAUMHART, Chief Inspector,	Cleveland, Ohio, Century Building.
CINCINNATI, . .	W. E. GLEASON, Manager, B. F. COOPER, Chief Inspector,	Cincinnati, Ohio. 67-69 Mitchell Bldg.
CHICAGO, . . .	H. M. LEMON, Manager, JAMES L. FOORD, Chief Inspector,	Chicago, Ill., 169 Jackson Bvd.
ST. LOUIS, . .	V. HUGO, Manager, V. HUGO, Chief Inspector,	St. Louis, Mo., 319 North Fourth St.
DENVER, . . .	THOS. E. SHEARS, General Agent, THOS. E. SHEARS, Chief Inspector,	Denver, Col., Room 2, Jacobson Bldg.
SAN FRANCISCO, .	H. R. MANN & CO., General Agents, J. B. WARNER, Chief Inspector,	San Francisco, Cal., Merchants' Ex. Bldg.
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