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EDITORIAL:

THE BIDS FOR FIVE BATTLESHIPS and six armored cruisers were opened by the Secretary of the Navy on Dec. 7. The most interesting feature of the opening was the entrance into competition for the construction of first-class war vessels of several new builders. Heretofore the bidding for warship construction for the United States Navy has been confined to the Newport News Shipbuilding & Dry Dock Co., Wm. Cramp & Sons Shipbuilding & Engine Co., and the Union Iron Works. The new companies which put in bids for one or more ships of the present contract are: The Fore River Engine Co., of Quincy, Mass.; Moran Bros. Co., of Seattle, Wash; Risdon Iron & Locomotive Works, of San Francisco, Cal.; John H. Dialogue & Son, of Camden, N. J., and the New York Shipbuilding Co. The armored cruisers are the "West Virginia," the "Nebraska," the "California," the "Maryland," the "Colorado" and the "South Dakota." The battleships are the "Pennsylvania," the "New Jersey," the "Georgia," the "Virginia" and the "Rhode Island." Three of the armored cruisers are to be sheathed and coppered. Each of the six vessels in this class is to have a length of 502 ft. The sheathed ships are to have a displacement of 13,800 tons and the unsheathed 13,400 tons. Every armored cruiser will be fitted as a flagship and will have accommodations for 822 officers and men. The speed must be at least 22 knots an hour. The battleships will be the most powerful ever projected. Three of them will have the superimposed or double-deck turret now installed only on the "Kearsarge" and the "Kentucky," and the other two will be sheathed and coppered. The sheathed vessels will be 435 ft. long and have a displacement of about 15,000 tons. The unsheathed vessels will be of the same length and have a displacement of about 14,600 tons. The contract will call for a speed of at least 19 knots an hour. All five of the battleships will be fitted to carry flag officers, and the complement of each will be 703 officers and men.

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A LAKE MICHIGAN-MISSISSIPPI RIVER WATERWAY route, by way of the Illinois River and the Chicago Canal, says the War Department, would cost $7,317.977 for a 7-ft. depth; and $8,653,247 for an 8 ft. depth. The project includes the construction of 12 locks, and two dams, with movable weirs. The estimates presuppose that all land and franchises are ceded free of cost to the United States. The cost of an independent 8 ft. waterway, from Sag Bridge on the Sanitary Canal to Lake Michigan via the Little Calumet and Calumet Rivers, would add $5,680,186 to the above; or, $14,333,433 for an 8 ft. waterway by the Sag route.

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THE YAZOO RIVER DIVERSION CANAL WORK, comprising the excavation of about 7,500,000 cu. yds. of material by dredging, was begun on Nov. 19 by the Atlantic, Gulf & Pacific Co., the contractors. The company now has two hydraulic dredges at work and will shortly put a clamshell dredge in operation. The diversion canal is planned to avoid the bar located at the mouth of the Yazoo River by excavating a new channel or outlet for the river from its former mouth located about 10 miles above the present mouth, through the deep water in Old River, across the neck of low land between Long and Barnett lakes to Lake Centennial, and thence down Lake Centennial around the head of De Soto Island and along the front of Vicksburg and entering the Mississippi River at Kleinston Landing. The total excavation required, exclusive of the removal of logs, stumps, etc., and the excavation of some 277,709 cu. yds. of top soil, which has been done by the government since 1896, is, as stated about 7,500,000 cu. yds. The first contract for this work was let June 14, 1899, but was rescinded owing to the failure of the contractors to maintain the required progress, and was relet on June 28, 1900, at the price of 12.4 cts. per cu. yd.

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THE LATEST ATTEMPT OF O. M. CARTER, ex-Captain U. S. A., to escape further punishment for his complicity in the Savannah Harbor frauds has failed, like all the others. On Dec. 10 the Federal Court in the district where Carter is confined handed down a decision denying the petition for his release on a writ of habeas corpus and remanding him to the Federal penitentiary at Leavenworth. This is the sixth time that Carter's case has been brought before the United States courts since his sentence was approved by the President. In every case the endeavor has been to have him escape through some legal technicality the sentence imposed upon him by the court martial.

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THE MOST SERIOUS RAILWAY ACCIDENT of the week occurred near Suisun, Cal., on the Southern Pacific R. R., on Dec. 4. During a fog a work-train collided with a freight train, resulting in the death of nine workmen and the serious injury of 20 others.

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A BOILER EXPLOSION occurred in the Wells St. power house of the Chicago & Northwestern Ry., at Chicago, Ill., Dec. 3, killing five persons and seriously injuring a number of others. The power house supplies steam heat and electric light for the Wells St. terminal station, compressed air for operating the switches, and electric current for operating the Kinzie St. bridge. It is about two blocks beyond the station, on the north side of the tracks. The main body of the boiler, which was one of four, was driven endways through the south wall of the station, passed through the parlor car of a passing train, and landed on the south side of the tracks. The north wall of the building was blown out, the roof was blown off, and a shower of bricks and debris fell in the streets. The building was a complete wreck. The tracks were blocked, and the switches had to be operated by hand until connection could be made with the compressor plant at the Ada St. power house. The station was lighted by candles and oil lamps until connection could be made with the city wires. The four 150-HP. tubular boilers were insured in the Hartford Insurance Co.; they had been inspected by that company in July, and were to have been inspected by the city boiler inspector in a few days after the accident. The railway company had also made regular inspections, and the boiler that exploded had been tested as well as inspected about a year ago. The heating plant was put in by the L. H. Prentice Co., of Chicago, in 1892, under a five-year guarantee, and no repairs on the boiler were required during that term. We learn from this company that the boiler which exploded was made by the Kewanee Boiler Co., of Kewanee, Ill., using Lukens flange steel, and was provided with a Hawley down-draft furnace. It was 5 ft. diameter and 18 ft. long, containing 48 tubes 4 ins. diameter. The shell was ⅜-in. thick, with double riveted horizontal seams, and the heads were ½-in. thick. The dome was 3 ft. diameter and 3 ft. high. None of the other boilers were injured, though all had the settings blown away.

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THE LOWEST BAROMETER RECORD ever reported at a U. S. Weather Bureau station was reached in the Galveston storm of Sept. 8. The reading was 28.48 ins., which is lower by 0.1-in. than the previous minimum record. The normal reading at sea level is about 29.92 ins. Thus the atmospheric pressure at Galveston was nearly three-quarters of a pound per square inch below the normal.

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DAMAGES FROM VIBRATION, caused by the working of the Central London Underground Electric Railway, are claimed by residents along the line. They have subscribed $50,000 for legal purposes; and they say that though the tube averages 50 ft. below the surface, windows rattle and house ornaments shake every time a train passes, and house occupants are kept awake.

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VIOLATIONS OF THE BUILDING LAWS of New York city have been made the subject of investigation and report by the Tenement House Commissioners, more particularly in reference to tenement house construction. The report shows that almost every provision of the law in respect to tenement houses has been violated in numerous instances since the time that the new Building Ordinance went into force. The report sums up the result of the investigations as follows:

> In order to ascertain how far the evils of our tenement houses were due to the defects of the law or to its non-enforcement the Tenement House Commission during the last summer has had inspected all the new tenement houses in course of construction in the Borough of Manhattan, and most of those in course of construction in the other boroughs—The Bronx, Brooklyn, Queens and Richmond. About 650 buildings were inspected in Manhattan; 317 of these were found to be better class apartment houses, and 333 were found to be strictly tenement houses.
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> Of these 333 tenement houses only 15 tenement houses, or 4% of all, were found where there were no violations of the tenement house law. In one house were found as many as 13 different violations of the law, in another house 9 different violations, in 7 houses 8 different violations in each, in 2 houses 7 different violations, in 21 houses 6 different violations, in 46 houses 5 different violations, in 57 houses 4 different violations, in 56 houses 3 different violations, in 74 houses 2 violations, and in 53 houses 1 violation in each.

The violations are stated in many instances to be very important in character, such as the curtailment of light and air by covering too great an area of the lot, by reduction in the size of the air shafts and failure to provide windows, by constant failure to use fireproof or slow burning construction where required and by failure to provide self-closing fireproof doors for dumb-waiter shafts. Regarding the violations of the requirements respecting fireproofing the report says:

> In all new tenement houses over three stories and cellar in height the law requires that the floors of the public halls shall be constructed of slow burning or fireproof material. Out of 144 new tenement houses of this kind, in 96 cases, or 67%, the floors of the public halls were constructed entirely of wood. (This applies to the floor beams, and not merely to the flooring.)
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> The law also requires that in all new tenement houses over three stories and cellar in height the stairs shall be constructed of slow burning or fireproof construction. Out of 116 new tenement houses in 113 cases, or 97%, the stairs were constructed of wood, instead of slow burning or fireproof construction
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> The law also requires that in new tenement houses over three stories and cellar in height the stairs shall be inclosed with walls of slow burning or fireproof construction. Out of 140 new tenement houses in 86, or 58%, these stairs were inclosed simply by wooden stud partitions, and in only 6 cases, or 4%, were the stairs inclosed by brick walls.

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THE CABLE SADDLES for the new East River Bridge were raised to the top of the Manhattan tower on Dec. 3. These saddles weigh 36 tons each and previous to raising them the roller beds for the saddles, weighing 27 tons each, were raised. As described in our issue of March 8, 1900, the steel work of the towers was raised from an interior timber tower. To raise the roller bed and saddle castings this timber tower was taken down and a strong timber A-frame was erected on the top of the steel tower to which the four-sheave block was attached. An endless hoisting rope passed through this block and around the drums of two hoisting engines. The time required to raise one saddle casting was 27 minutes. On Dec. 9 the 27-ton roller beds for the Brooklyn tower were raised, and as soon as these are placed the saddles will be raised and placed. The contractors for the erection of the Manhattan tower and shore spans were the Terry & Tench Construction Co., of New York city, and those for the corresponding work on the Brooklyn side were the New Jersey Steel & Iron Co., of Trenton, N. J.

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THE WATER PURIFICATION PLANT AT PITTSBURG, Pa., is to be proceeded with at once. The general plans recommended by the filtration commission will be carried out by a bureau of filtration, with Mr. W. F. Miller as engineer and Mr. Allen Hazen, M. Am. Soc. C. E., of 220 Broadway, New York city, as consulting engineer. Mr. Hazen was the consulting engineer to the commission which undertook the filtration experiments conducted at Pittsburg two or three years ago.

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FOR THE PROTECTION OF THE WATER SUPPLY at Johnstown, Pa., the Johnstown Water Co. has bought nearly 2 sq. miles of the 5.5 sq. miles of the drainage area of Mill Creek, above the company's reservoir. The creek is the principal source of domestic supply drawn from by the company. The company desires to buy all the cleared and cultivated land in the drainage, but many of the owners ask too much for it and the statutes of Pennsylvania do not allow the taking of land by condemnation for the protection of a water supply, nor do they seem to afford any effective legal protection from pollution by farm drainage. We are indebted to Mr. A. H. Walters, Secretary of the Johnstown Water Co., for the information here given. Mr. Walters states that his company has consulted Messrs. Tourney and Groves, of the Forestry Division of the U. S. Department of Agriculture, regarding the reforesting of the land bought "and will at an early date follow their suggestions in this matter."

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THE WATER-WORKS OF FRANCE, BELGIUM and Switzerland are to be described in a volume something like "The Manual of American Water-Works," which will be issued at Brussels, about the middle of 1901. The book is being prepared by Messrs. Ed. Imbeaux, Director of the Municipal Services of Nancy; H. Peter, Engineer of the Water-Works of Zurich, and V. Van Lint, Inspector of the Water-Works of Brussels.

THE SNOQUALMIE FALLS WATER-POWER PLANT AND TRANSMISSION SYSTEM.

(With two-page plate.)

Within the past few years a number of plants have been established on the Pacific slope to utilize natural water powers for generating electricity to be transmitted to distant points and there used for lighting and power purposes. Among the most interesting and important of these plants is that at the Snoqualmie Falls, in Washington. For this plant, no long flume or pipe line is required to develop the necessary head of water, as the Snoqualmie River has at the Falls a vertical drop of 270 ft., giving an available energy of 30,000 to 100,000 HP. In this respect the plant resembles that at Niagara Falls, where the vertical drop is 153 ft. and the total power produced with the available head of 145 ft. is over 3,000,000 HP., of which 50,000 HP. are utilized by the present plant. In the placing of the electrical machinery, however, there is an essential difference, for while the Niagara Falls plant has this placed in a building above ground, the Snoqualmie Falls plant has the water wheels and electrical machinery all installed together in a large underground chamber, whose floor is directly above the tail race tunnel which extends to the river below the Falls. The force of the water is used to drive impulse wheels on horizontal shafts instead of turbines on vertical shafts, as at Niagara Falls. Another notable feature of the plant is the use of aluminum wire for the long-distance transmission lines. The entire plant represents an investment of about $1,000,000.

The waterfall and the land on either side were purchased in the autumn of 1897 by Mr. Wm. T. Baker, of Chicago, who organized the Snoqualmie Falls Power Co. early in 1898. Of this company, Mr. Charles H. Baker is President and General Manager, and the other officers are as follows: Vice-President, A. H. Andrews; Secretary and Treasurer, George G. Lyon; Manager at Tacoma, James C. Drake. The company has its main offices at Seattle, Wash., and a branch office at Tacoma, Wash. Mr. Thomas T. Johnston, Consulting Engineer of the Chicago Drainage Canal, was Consulting Engineer during the construction of the works, and Mr. James J. Reynolds was Superintendent of Construction. The Electrical Engineer was Mr. E. M. Tingley, and Mr. Robert McF. Doble was Mechanical Engineer. The construction work was done by the company and not by contract. We are indebted particularly to the President, Mr. Charles H. Baker, for information, drawings, photographs, etc., made use of in this article.

HYDRAULIC AND METEOROLOGICAL CONDITIONS.

The great fall of the Snoqualmie River is about 34.5 miles northeast from Tacoma (in a straight line), 34½ miles southeast from Everett and 25 miles west from Seattle, being situated in the foothills of the Cascade range. The general location is shown by the map, Fig. 1, and in Fig. 2 is given a view of the fall. The river proper commences about three miles above the fall, at the junction of three forks which flow westward down the slopes of the range. Below the Falls the river runs almost due north until it makes a junction with the Skykomish River, the two forming the Snohomish River, which flows into Puget Sound near the city of Everett. The summit of the fall is about 600 ft. above sea level, while the watershed reaches elevations of 8,000 ft. above this level. The area of the watershed is about 500 sq. miles, and extends above the snow line so that the river has a large low water flow in the dry season of August and September. The rainfall, or rather the total precipitation, at the Falls is about 90 ins. per annum, while in the country along the shores of Puget Sound the rainfall averages but about 37 ins. The meteorological reports show that the precipitation over the watershed increases as the crest of the range is approached, reaching 150 inches and over. The flow of the river is about 1,000 cu. ft. per second at its lowest stage, increasing to over 10,000 cu. ft. per second at its flood periods.

At an early stage in the enterprise the company placed in the field a party to determine the hydrographic, meteorological and other features of the watershed, as well as its geological and geographical conditions. One peculiar physical characteristic which was discovered was that some of the streams tributary to the three forks disappear underground occasionally, and reappear again at a distance of about half a mile. By the construction of dams or dikes, some of the large lakes on the watershed can be utilized as impounding reservoirs, so as to ensure a uniform flow sufficient to develop nearly 100,000 HP. throughout the year, should a demand for so much power eventually be found. It has also been determined that by the erection of a 50-ft. dam above the headworks a reservoir could be formed having an area of 15 sq. miles, and an average depth of 25 ft. This would almost double the power, should the growth of the industries served make this desirable in the future.

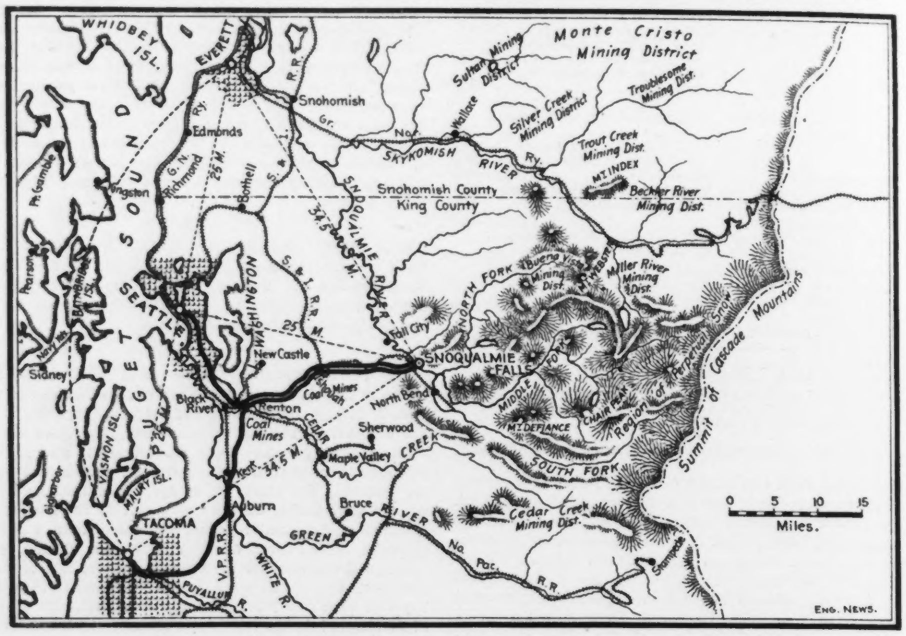

FIG. 1.—MAP OF THE LOCATION OF THE SNOQUALMIE FALLS POWER PLANT AND TRANSMISSION LINES.

The rock at the Falls is basaltic, with no regular cleavage. It is hard and non-absorbent, and is apparently divided by seams into great ledges. These conditions led to the adoption of the plan of placing the machinery in an underground chamber, as already noted. It was at one time proposed to build a power house near the base of the Falls, but this would have been at a disadvantage on account of the clouds of spray which keep everything damp, and coat all of the surroundings with ice in cold weather.

As a part of the preliminary steps of the enterprise, a topographical survey was made of the land within ¼-mile radius from the Falls, including soundings of the river bottom. Gages were set at intervals above and below the Falls, to show the varying elevation of the river, and these gages have been read three times daily during the past three years. Daily records of rainfall, barometer, temperature, and weather conditions are kept by the company at Snoqualmie Falls, Issaquah and Renton, and are reported to the office of the U. S. Weather Bureau at Seattle. The water of the river is usually pure and clear, but occasionally carries some white clay in solution, as well as silt after the freshets. These occur generally in November, owing to the heavy rainfall, and in June, owing to the melting snows. The water level varies between the high and low stages throughout the year, with occasional freshets at different times, but the main floods precede the dry season very closely, so that storage for an increased flow would not have to be maintained for any considerable time. The river does not freeze during the winter, and there is neither floating ice nor anchor ice to be dealt with. At a point about ¼-mile above the Falls, where a uniform cross-section of the river was obtained, the company established a station for measuring the velocity of flow at all stages, an exhaustive series of experiments being made with a current meter. The average velocity is about 10 ft. per second. The law governing the flow of the river is found to be represented by a parabolic curve with the following equation, in which X is the discharge in cu. ft. per second, and Y is the elevation of the water line:

$$X = \frac{Y^2 - 106.8\ Y + 2{,}851.6,}{.01}$$

HEADWORKS.

A plan of the headworks above the Falls is shown in Fig. 3, and this also shows the position of the underground power chamber and the tail race tunnel. The intake bay is a rectangular chamber, about 60 ft. long (parallel with the river), and 20 ft. wide. It has walls and a center pier of concrete masonry 6 ft. thick and 25 ft. high, built upon the solid rock formation, its floor being on a submerged reef and about 5 ft. above the river bed. This bay is protected from the river by a timber grating across the opening, supported by a steel girder construction, bearing against the walls and pier. The timbers are 12 x 12 ins., laid horizontally with 12-in. spaces between them, through which the water flows into the intake. This grating protects the works from floating trees and logs, while just inside the intake are inclined steel screens made of flat bars on edge, which serve to exclude the smaller debris. The intake has two head bays, separated by the pier, having been built for twice the capacity of the present power development. The idle head-bay now affords a place for a water rheostat, capable of taking 2,500 electrical HP. This rheostat is connected with the switchboard in the machinery chamber and is held in reserve for emergency use, should the normal load be suddenly taken off.

A rudder boom 300 ft. long is moored above the intake and extends beyond it. By turning the capstan at the head of the boom, the rudders are thrown out and cause the boom to swing out into midstream, so that it serves as a fender to deflect floating logs, etc., from the intake. The river is 150 ft. wide from the head-bay to the opposite shore, and about 15 ft. deep at ordinary stages. The face of the intake was continued 400 ft. up and 200 ft. down stream in the shape of heavy retaining walls built of sawed cedar timber, tarred. The space behind them is filled with excavated rock, and has a top dressing of soil for a lawn and shrubbery.

At the end of the lower bulkhead, a submerged concrete dam is built across the river, resting on the rock bottom, and this raises the low water elevation of the river 6 ft. at the intake. This dam, whose location is shown on the plan, Fig. 3, is of the form shown by the elevation and section, Fig

4. It was first framed of heavy timbers sheeted over with 6-in. planking, and then filled in solid with concrete. It was built about the time of low water flow, portions of the river bed being laid bare by cofferdams. Preparatory to the construction of the dam, the river bed was thoroughly cleaned of loose rock, and was roughened by occasional blasts so as to afford a good footing. In addition to this, pieces of steel rail were driven in holes drilled 2 ft. deep, the rails extending up into the concrete body of the dam. Old railway cables were also embedded in the concrete to perfect the bond. The dam has a batter of 2 on 1 upstream and ½ on 1 downstream, with a level crest 8 ft. wide. At each end of the dam is an abutment pier of concrete 8 ft. square, these being 210 ft. apart. The dam was built on a natural rock ledge, some 3 ft. above the river bottom. It is always submerged from 2 to 10 ft., according to the stage of the river, but at extreme low water (when the plant shall have been enlarged) it will be possible to construct a bear-trap dam between these piers. This will afford storage to equalize the daily flow, as the water will be backed up in the main river two miles and also in extensive tributary lakes. The dam varies in height from 3 to 10 ft., and in width on bed rock from 16 to 35 ft., according to the conformation of the river bottom. The lower bulkhead is only 5 ft. higher than the dam, so that flood waters have a very considerably increased sectional area of discharge, as shown by the plan. The capacity of this spillway is such as to insure the complete discharge of an extreme flood without the river backing up to an unusual elevation. The top of the upper bulkhead is above flood level.

FIG. 2.—VIEW OF FALL.

FIG. 12.—VIEW ON TRANSMISSION LINE.

About 27 acres of ground covering the works, the brink of the Falls and both banks of the river have been laid out as a park, with lawns, walks and flower beds, the grounds being illuminated by arc lamps. Comfortable cottages and a dormitory, with all modern conveniences, have been erected by the company, and there is also a cottage for the executive officers and for visitors.

SHAFT, CHAMBER AND TAIL-RACE TUNNEL.

The general arrangement of the plant, with its underground power chamber, is shown in Fig. 5. About 300 ft. above the Falls, a shaft 10 × 27 ft. was sunk in the bed of the river on the south side, descending 270 ft. to the level of the river below the Falls. While this shaft was being excavated, a tunnel 12 ft. wide and 24 ft. high, with a fall of 2 ft. in its entire length, was drifted in from the face of the ledge below the Falls, to an intersection with the bottom of the shaft, a distance of 650 ft. Fig. 6 is a view taken during the construction of this tail race tunnel. Beginning at the foot of the shaft and extending over and along the tunnel, a chamber 200 ft. in length, 40 ft. wide and 30 ft. high, with the floor at the elevation of high water below the Falls, was excavated out of the solid rock. This chamber forms the power-house or machinery room in which the water wheels and electric generators have been installed. At average stages of the river the water is about 12 ft. deep in the tunnel, while during flood seasons it nearly fills the tunnel. The tunnel extends under the floor of the chamber, forming a tail race with a concrete roof 5 ft. thick. The walls of the chamber have been left rough and whitewashed, while the floor is covered with concrete.

About 700 incandescent lamps are used to light the shaft, chamber and tunnel. The chamber is ventilated by natural draft through the tail race and up the shaft, the draft being so strong that it has to be curbed. The chamber is said to be cool and perfectly dry, the temperature remaining the same (about 55° F.) throughout the year. This low and uniform temperature contributes to high efficiency of the generators.

Work was commenced as soon as the organization of the company had been perfected. The construction plant included two 125-HP. boilers, an Ingersoll-Sergeant air compressor delivering air at 100 lbs. pressure into a receiver 4½ ft. diameter and 12 ft. high, 10 rock drills working under 60 lbs. pressure, and a sinking pump with 5-in. suction and 4-in. discharge to keep the shaft excavation dry. Owing to the solid character of the rock, however, very little water entered the excavation. It was surrounded by a cofferdam 15 ft. high to prevent flooding in case of high water in the river. Over the shaft was a hoisting trestle 50 ft. high for the cages, which were operated by a 75-HP. double friction-drum engine, which could raise a load of 6,500 lbs. at a speed of 450 ft. per minute. The rock dumped at the trestle was carried by a gravity tramway to a Gates crusher with a capacity of 70 cu. yds. This was driven by a 15-HP. engine, and crushed stone was piled up for future use in the concrete work. All the concrete was mixed by hand.

To supply air to the drills in the tunnel, a pipe line was extended 400 ft. to the edge of the cliff, and a section of pipe lowered to the bottom, a depth of nearly 300 ft. Two men suspended by ropes, and working in the whirling spray and wind of the chasm, put the pipe lengths together, building it up from the bottom and constructing the necessary timbering to support it against the rough face of the cliff. At first, all tools and material had to be carried up and down a winding stairway, but a standing cable was soon put in place, on which ran a box for tools, operated by means of a windlass. All machinery and supplies were delivered by the Seattle & International Ry., which runs close to the works, as shown in Fig. 3. For handling heavy material, a trestle was built over the sidetrack and extending to the shaft; upon this was a traversing hoist, by which the material was raised from the cars and carried to the works. The first drill was set in operation on April 17, 1898, and the work was then prosecuted by day and night until its completion.

HYDRAULIC PLANT.

Each intake bay contains a massive head gate, moving vertically, which controls the flow of water through an opening 8 × 12 ft., through the shore wall into the penstock. The gate is raised and lowered by mechanism connected with the piston rod of a hydraulic cylinder. The shaft is 10 × 27 ft., and at the top has three compartments; the two end compartments are for the penstocks, while the center one, enclosed at the top by a steel bulkhead, forms a shaft 8 × 10 ft. for the hydraulic elevator and the main cables forming the outgoing conductors, and also for raising and lowering machinery, etc. The steel bulkhead which encloses this center shaft extends from the bottom of the intake bay to the surface of the ground. It is built up of steel plates, and is stiffened by horizontal frames of I-beams on the outside, riveted to the plates and to each other at the ends. Below it, the elevator shaft is timbered and sheathed with plank. At the surface, this shaft is surmounted by a small building. The penstock already built is a steel pipe 7½ ft. diameter, passing through a concrete roof which keeps the shaft watertight. The plates are in 8-ft. courses, and are 1 in. thick for the lower half of the pipe; in the upper half, the thickness decreases from ⅞-in. to ½-in. at the top. The joints are heavily riveted, and calked watertight. At a depth of 250 ft., the penstock reaches the chamber and connects with a horizontal cylindrical receiver which rests on a rock bench in the north side of the chamber, 12 ft. above the floor. This receiver extends almost the full length of the chamber. Its diameter is 10 ft. for half its length, and then reduces to 8 ft. It is built up of 1-in. plates, 8 ft wide. The penstock and receiver weigh 225 tons, and the weight of the water column in the penstock is 340 tons. A small independent penstock supplies water to the elevator machinery, as shown in Fig. 5. The penstocks, the receiver, and the steel bulkhead of the elevator shaft were built by the Chicago Bridge & Iron Works, of Chicago, Ill.

At four points in the length of the receiver are 4-ft. branches extending from the side, each branch being fitted with a gate valve made by the Rensselaer Mfg. Co., of Troy, N. Y. These valves weigh 23,000 lbs. each, and are said to be the largest valves in the world operated under such high pressure. Each branch has a cast-iron elbow turning downward, and opening into the horizontal cylindrical receiver of a water motor. These elbows have an inside diameter of 4 ft., and the metal is 2 ins. thick, each casting weighing 8,000 lbs. Owing to the size and form, special care had to be taken to avoid internal strains in the castings which might lead to rupture, especially in view of the high pressure which the castings have to withstand. The elbows were made by the Abner Doble Co., contractors for the hydraulic plant. They were tested to a hydrostatic pressure of 200 lbs. per sq. in. Test pieces cut from the castings showed an ultimate tensile strength of over 41,000 lbs. A 24-in. branch from the receiver is connected with motors operating the exciters, and there are also smaller branches for various purposes.

WATER MOTORS.

The main generating plant consists of four electric generators, each driven by a Doble water motor of 2,500 HP. coupled directly to it. Each motor consists of a shaft carrying six tangential jet wheels, with two nozzles to each wheel. This arrangement is shown by Fig. 7, which represents two of the main units, the generator shafts being connected up to the coupling flanges. Each of the four elbows above referred to is bolted to a flanged ring on a horizontal cylindrical receiver, 48 ins. diameter and 20 ft. 8 ins. long. This is made of two ½-in. steel plates 10 ft. wide, and of sufficient length to make the shell with only one longitudinal seam, which is double-riveted. The heads are of dished steel plates. The receiver is supported by six pipes, each of which carries two nozzles delivering jets at right angles to each other, as shown, the nozzles entering the side and bottom of the wheel casing. The use of the receiver effects an even distribution of the flow from the elbow to the several nozzle pipes, and also a steady and uniform rate of flow. The nozzles and the flanges for the elbow attachments to the receivers are made of so-called semi-steel. From the buckets of the motors, the water falls through draft openings in the floor directly into the tail race channel.

To handle the volume of water necessary to develop the power in each unit requires 12 jets, 3⅞ ins. in diameter, discharging against six wheels. For convenience of bearing and shaft design these wheels are divided into two groups of three wheels each, each group being in a separate housing with a bearing between. This arrangement makes two groups of three vertical nozzle pipes each. Each pipe has flanged wings cast on each side, the flanges being bolted together, and the wings forming the back of the housing in which the wheels revolve.

One of the special features of this plant is the regulating tips used on the nozzles. They not only throw a perfect and unbroken stream, but give absolute control over the quantity of water applied to the wheels, and therefore over the power output of the unit. As these tips are controlled by the governor, the arrangement gives an excellent degree of speed regulation with variable load at high efficiency. The tip has set within it a "needle" of bulb form with parabolic curves running to a point, and this needle is moved in or out to give a greater or less width of the annular opening between the tip and the walls of the nozzle. These tips are shown in Fig. 7. Fig. 8 shows this arrangement applied to the exciter unit, in which, however, the regulation is effected by a hand-wheel. Fig. 9 is from a flash-light photograph taken from the jet of the exciter. The full size of the jet is 3 ins., but when photographed it had been reduced to 2¼ ins. It clearly shows the solid, smooth stream, delivered with a head of 253 ft., entirely free from swirling or other disturbance. This form of nozzle maintains this same condition from full jet size to 1-10 of the jet area. The regulating nozzles are operated from two long rocker-shafts, one controlling the upper, and the other controlling the lower nozzle tips. Both rocker-shafts are operated by a Lombard governor which is connected to the rocker-shaft by cranks and connections. The connections to each rocker-shaft are so arranged with clutches that either or both rocker-shafts can be disconnected from the governor and operated or regulated by the hand-wheel on the pedestal stand. By this governor arrangement, with the regulating nozzle tips, the wheels use water in proportion to the power developed, so that the wheels are of a high efficiency at part load as well as at full load.

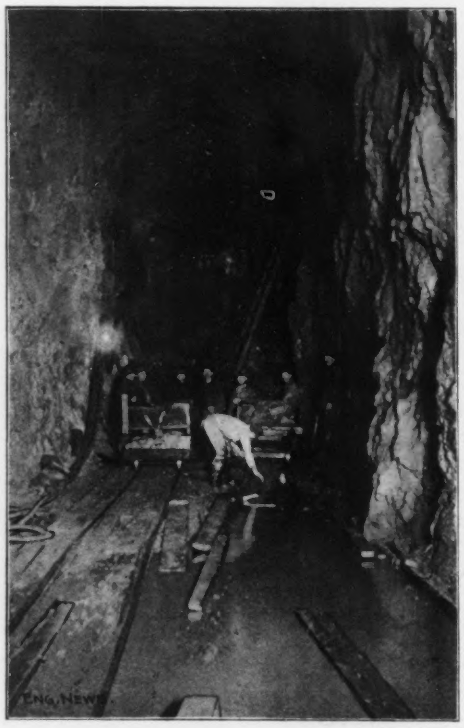

Fig. 6.—Excavation of Tail Race.

The wheels are of the type invented by Mr. W. A. Doble, of San Francisco, Cal., and were described by him in a paper on "The Tangential Water Wheel," read at the California meeting of the American Institute of Mining Engineers in September, 1899. The particular feature is in the form of the bucket, which is termed the ellipsoidal bucket. This has a center rib to split the jet, and two hollow sides formed with correct hydraulic curves to receive the water, reverse its direction and guide it to the edges of the bucket, where it is discharged. The lip of the bucket, however, is deeply notched in the center, so as to straddle the jet, which thus strikes the bucket with full force before it is broken by the lip passing through it. This secures an exceptionally high efficiency from the impinging jet, and the greatest value from the reaction of the water upon the bucket, while the wear on the bucket is reduced to a minimum, with a corresponding reduction in the cost of maintenance. Should the erosion due to silt or gravel in the water reduce the efficiency by wear, the tips and buckets can readily be renewed at little cost. The wheels for the main power units are 45 ins. diameter, with split hubs and solid rims, and are pressed upon the 9-in. shaft, to which they are secured by a steel key. The split hub is drawn tight by four 1¾-in. steel bolts. Each wheel has 13 buckets attached to the rim by turned bolts. Fig. 10 is a view of one of these 45-in. wheels, showing the form of the buckets and the arrangement of the hub bolts. The six wheels are keyed on the shaft in two groups of three wheels each. The shaft is of forged steel, 9 ins. diameter and 24 ft. 5 ins. long. On one end of the shaft is a heavy flange coupling which is bolted solidly to the coupling on the generator shaft with turned bolts. The shaft is supported in two bearings of the ring-oiling, removable shell type. One bearing is at the extreme end of the shaft, and the second in the middle of the shaft length and between the two wheel housings. The generator bearing carries the other end of the shaft through the shaft coupling. The bearings are bolted to heavy sole plates embedded in the concrete foundation.

The wheels are incased in sheet steel housings with cast-iron fronts, three wheels in each, so that there are two housings to each unit. The housings are made with the upper half removable to provide access to the wheels when desired. The cast-iron front of each housing is made of such form as to provide a deflector guard, which takes care of the water thrown from the wheels by the centrifugal action, and directs this water into the tail race, and thus prevents its being driven around the housing by the air currents which are created by the rapidly revolving wheels. In the top housing is a guarded opening to permit the indraft of air to replace that driven out of the housing and down the tail race by the rush of the water and the action of the wheels as centrifugal blowers. To prevent water from splashing out where the shaft passes through the side of the housing, the opening is protected with patented centrifugal disks and guard frames. Although this arrangement prevents the outflow of water, it permits a large and free indraft of air at this point also to replace that driven out by the action of the wheels and the water. Before this device was installed, regular packing boxes and glands were used, which required to be accurately in line; the packing required renewing and care; and the bearings required lubrication. Taken altogether, the packing boxes were a source of annoyance and expense, besides setting up some little friction, and it is said that no matter how well the boxes were packed they always dripped water, whereas the large free openings of the centrifugal disk and guard are dry and clean.

Each wheel unit weighs about 100,000 lbs., in addition to the weight of water in the distributing receiver, and the nozzles; and in view of the high speed of the parts and the power developed, careful design and construction were required for the foundations. These are of concrete, built solidly into the floor and one side wall of the chamber. The waste water drops from the wheels directly into the tail race. The lower part of the steel wheel housing is firmly built into the concrete walls. A tunnel is provided under the governor platform for the lower rocker-shaft and connections that operate the adjustable tips of the lower nozzles, and thus make this operating gear accessible. The foundation for each unit is divided into two compartments corresponding to the two wheel housings. A doorway, 2 × 3 ft., is formed in the front wall of each compartment, and four steel rails are built into the concrete across the opening into the tail race to support a temporary floor when it is desirable to enter the foundation to inspect the wheels or the nozzle tips, without removing the top wheel housing. All the hydraulic plant was built and erected by the Abner Doble Co., of San Francisco, Cal.

AUXILIARY APPARATUS.

The exciters are of 75 K-W. capacity, and are directly-connected to Doble tangential ellipsoidal water wheels of 45 ins. diameter, one of these exciter units being shown in Fig. 8. The wheels are mounted in steel housings, and are supplied with water through a regulating nozzle of 3-in. jet diameter, branching from a vertical pipe 12 ins. diameter.

To make the chamber readily accessible for the employees and for the handling of supplies, an elevator is provided. This is operated by a winding drum which is driven by another tangential water wheel of 7 ft. diameter. A regulating nozzle with 1¾-in. diameter of jet is used for this work, and gives perfect control over the elevator cage. To permit cleaning the armatures of the generators while working, compressed air is available, being furnished by a vertical air compressor with cylinder 8 × 10 ins. Traveling the full length of the chamber are two 10-ton electric traveling cranes. These were used in installing the machinery, and are available to handle the upper wheel housings when it is desirable to inspect the wheels and for other purposes. The air compressor and cranes were built by the Abner Doble Co.

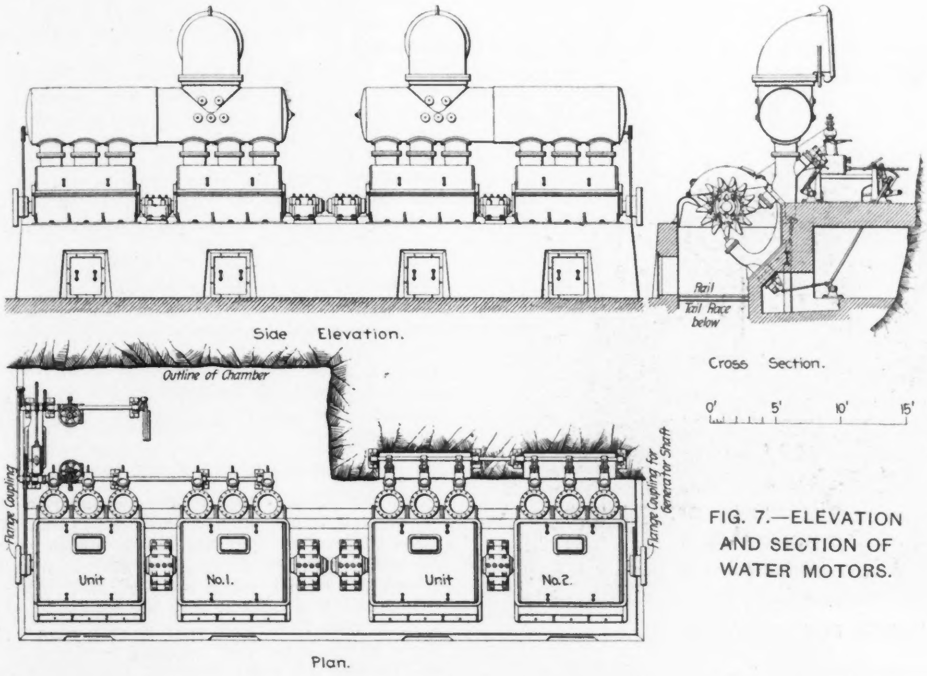

FIG. 7.—ELEVATION AND SECTION OF WATER MOTORS.

ELECTRICAL MACHINERY.

The completed plant comprises four generators of 1,500 K-W. capacity, built by the Westinghouse Electric & Manufacturing Co., of Pittsburg, Pa. These are now working under full load. Each one complete weighs about 100,000 lbs. and stands 14½ ft. high. They are of the revolving armature type and deliver a three-phase current at 1,000 volts, 7,200 alternations. Normal full load current is 1,000 amperes per phase. The armature winding consists of 266 bars with one bar per slot, and is a closed circuit winding. The armatures are 96 ins. diameter and weigh approximately 24,000 lbs. each. The speed is 300 revolutions per minute and the peripheral velocity is accordingly nearly 1½ miles per minute. Massive collector rings of the ventilated type deliver current to the external circuits. Three brushes bear on each ring, and to insure equal division of current between them in case of unequal contact resistance, separate cable leads of considerable length connect the brushes and the outside circuit in order that the fixed resistance with each brush may be large compared with the possible variable resistance. The field magnet frame is split vertically and rests on the bed plate which supports the armature bearings. The two halves may be moved apart laterally for inspection or repair of parts. The pole pieces are laminated and are cast in the field frame. The field winding is of one layer copper strip, bent cold on edge and afterwards insulated. At each end of a coil are brass brackets which rigidly hold it on the pole-piece, exposing both inside and outside surfaces to air circulation to carry away heat. This form of construction produces a coil that is very easily insulated, furnishes a maximum surface for ventilation, and may be easily repaired in case of accident. At no load these generators require a field current of 95 amperes at about 90 volts, and with full non-inductive load, 100 amperes to maintain the same electro-motive force.

Speed regulation in a water power plant depends greatly on the kinetic energy in the moving parts. In these armatures, about 4,500,000 ft.-lbs. of energy is stored at 300 revolutions per minute, and from the construction of the water motors, the moving water column also contributes to the stored energy, since it operates directly upon the revolving parts of the water motor. The water column in penstock and receiver weighs about 600 tons, and with one water motor running has only 67,000 ft.-lbs. of kinetic energy, or about 1½% of that in a generator armature. When all the water motors are in operation the water contains much more kinetic energy, but it is still of little importance compared with that stored in the revolving armatures. The stored energy in a single revolving armature is equal to the electrical output of that armature at full load in four seconds.

Two separate 125-volt exciters of 75 K-W. each are provided for supplying field current to the generators. They are separately driven by two 100-HP. Doble wheels, as already described. No automatic speed regulators are used here, since the load is perfectly steady, but regulation is effected by hand.

The switchboard is constructed of white marble, with mountings of brass and bronze. It is 35 ft. 5 ins. long and 7 ft. 6 ins. high, and has 18 panels, 4 for the generators, 2 for the exciters and 12 for the feeders. Current is conducted by lead-covered cables laid in sewer pipe in the cement floor, from the generators to aluminum bus bars extending along the south wall to the switchboard. These bars are supported by brackets on glass insulators. They are of pure aluminum, 0.2 × 3 ins. in section and in 30-ft. lengths. Three bars carry 1,000 amperes with a very moderate rise of temperature. The joints are lapped and bolted, and connection to the switchboard is made by cables with brass terminals, which are bolted to the bars. The exciter panels carry ammeters, circuit breakers, ground detectors, voltmeter plugs and rheostats. Each generator panel has circuit breakers on two of the three phases, synchronizing pilot lamps, field ammeter, a main ammeter on each of the three circuits, indicating wattmeters of the Niagara type, a field rheostat, double-throw three-pole switches, and voltmeter and ground detector plugs. The feeder panels have circuit breakers and ammeters. The switchboard also carries three alternating current voltmeters on swinging brackets, by means of which the voltage in any phase of any generator may be read, connection with the various panels being made through the voltmeters bus bars. The wattmeters are arranged by a simple combination of series and shunt transformers, so that their indication is the same as if they were on a two-phase circuit. This is of considerable value, as the indications of the meters remain equal with a balanced load even if the power factor on the three-phase circuit is less than one.

Fig. 11 is an interior view of the power chamber reproduced from a perspective sketch. The entire station, with its 10,000-HP. output is regularly operated and cared for by only two men on each shift; one is an electrician at the switchboard and in charge of the station, standing a watch of eight hours; the other is an oiler serving a 12-hour watch, whose principal work is that of inspection and keeping the entire station in good order. To better appreciate the contrast one may consider the crew required in a steam-driven station of equal output, including engineer, oilers, water tenders, firemen and coal passers. The first water wheel and generator in actual operation delivered current into Seattle on July 31, 1899, and into Tacoma, Nov. 1, 1899.

THE ELECTRIC CIRCUITS.

The transformer house at the head of the shaft is a fireproof building of brick and iron, with a concrete floor; it is 40 × 60 ft., 30 ft. high, and stands just east of and contiguous to the intake. In this building, the current is received at an initial voltage of 1,000 and it then passes into Westinghouse step-up transformers where the voltage is raised to 30,000, which is the nominal voltage of transmission. The 1,000-volt current passes from the switchboard to the transformer house by cables of twisted aluminum wires. The conductors run first to the step-up transformers and thence to a second switchboard controlling the transmission lines. An elaborate high-tension plug board has been constructed overhead in this transformer house, by the use of which any combination of transformers and circuits can be arranged. There are similar plug boards at Renton, Seattle and Tacoma, and it is possible by the use of these plugboards conjointly to arrange a combination so that a circuit may be made from the Falls to Seattle and back to the Falls, then to Tacoma and back to the Falls again, a distance of 153 miles.

A RECORD FEAT IN LONG DISTANCE TRANSMISSION.

On Nov. 13, 1900, the company performed the remarkable feat in electric power transmission of driving an electric motor 153 miles distant from the generator. For several hours during the day the various services of the company were cut off and all the transmission lines were connected up in one continuous circuit, commencing at Snoqualmie Falls, running to Seattle, back to the Falls, then to Tacoma and back again to the Falls. The regular transmission is 32 miles to Seattle and 44 miles to Tacoma. The tests were conducted for experimental purposes only, and to show that electrical transmission of power can be made commercially practical at much greater distances than has heretofore been contemplated.

The single continuous three-phase circuit, 153 miles long, was composed as follows:

Aluminum,	264 mils	58.00	miles,	solid
Copper,	No. 1 B. & S. G..........	4.00	"	"
Aluminum,	234 mils.	51.00	"	"
"	No. 2 B. & S. G.	36.66	"	cable
Copper,	No. 2 B. & S. G.	1.66	"	solid
"	No. 0	1.66	"	"
	Total	152.98		

One of the Westinghouse 1,500 K-W. three-phase generators furnished the current, and a similar machine was used as a synchronous motor at the end of the circuit. With the 153-mile circuit open at the incoming end, the tests were made for charging them at different voltages, the alternations (7,200) being kept constant. It was found that as the voltage increased, the charging current rapidly increased; at 22,500 line voltage it required

62 K-W.* to charge the line, at 30,000 volts it required 112 K-W., and at 35,000 volts it required 180 K-W. With the lowering transformers at the Falls cut in and their secondaries open, it was found that the current required to charge the line increased; at 22,500 volts it required 76 K-W., and at 30,000 volts it required 123 K-W. The voltage at the incoming end of the circuit, with charging current only on the line, was greater than at the outgoing; 22,500 volts out, gave 24,600 volts in, and 30,000 volts out, gave 32,100 in. Tests were also made to determine the different amount of charging current required at different frequencies, the voltage being kept constant at 30,000, and it was found that at 6,000 alternations, 100 K-W. were required to charge the line; at 6,600 alternations, 105 K-W.; and at 7,800 alternations, 115 K-W.

The line was then tested for loss of power in transmitting a non-inductive load, consisting of the water rheostat at the Falls at the end of the 153-mile circuit. It was found that the line voltage out was 30,000, incoming 22,500, drop 25%. The amperes per phase at 1,000 volts out was 624; incoming, 354; loss, 11.2%. The total kilowatt outgoing was 1,100; incoming (that is delivered into the water rheostat tanks), 723; loss, 34.2%.

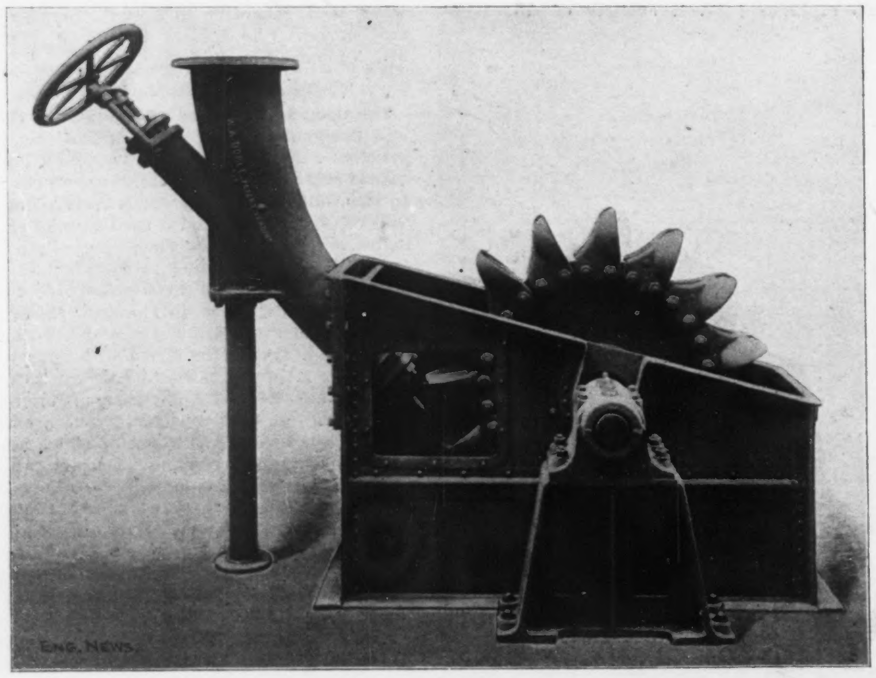

FIG. 8.—NOZZLE AND WATER WHEEL FOR EXCITER.

A test was also made for charging current with the sub-station transformers at Seattle and Tacoma, and the lowering transformers at the Falls in circuit, but with secondaries all open, and it was found that with the 30,000 volts out, there was 31,500 volts in, and that it required 193 K-W. to charge the line. A test was then made of operating a second generator as a synchronous motor at the end of the circuit and the machines were synchronized without any trouble whatever; but they soon began pumping, so that it was found advisable to separate the machines. During this test the outgoing line voltage had varied from 26,700 to 27,600 and the incoming from 24,000 to 26,700, giving approximately a drop of 6%, the amperes per phase at 1,000 volts out being approximately 900; incoming, approximately, 650; loss, approximately, 27.7%. Total kilowatts out, 432; incoming, 374; loss, approximately, 13½%. The figures on this last test are approximate only, as all of the instrument needles oscillated very much, many of the ammeters fluctuating over the entire range of the scale. The foregoing losses would be greater or less according as the loads carried might be increased or diminished.

The experiment was then tried of operating the water rheostat and the synchronous motor in multiple at the end of the 153-mile circuit and the performance of the motor was very much improved. The water was then shut off from the water wheel and the driven motor immediately reverted to a generator driven by its own inertia; the current in the lines was reversed and the first generator became in turn a motor and ran at the other end of the 153-mile circuit until the inertia was expended.

THE TRANSFORMERS.

There are 13 transformers, each of 500 K-W. capacity, in the transformer house, arranged in two rows longitudinally, with an aisle space on each side and a 1,000-volt wire space between. All circuits entering the building are supplied with lightning arresters for the protection of the works, although lightning in that district is said to occur only at intervals of three or four years. Raising transformers are in delta connection for both primary and secondary circuits. Separate primary feeder panels are provided for each transformer, by means of which any transformer may be controlled at the switchboard. Each transformer panel is provided with a circuit breaker, a double-pole, double-throw washer switch, and an ammeter. Voltmeters for the entire board are supported on a swinging arm at one end. Groups of three feeder circuits have each a polyphase integrating watt-meter of the Westinghouse type. Leading up the shaft to the transformer house, are 24 bare aluminum conductors, carried on ordinary glass cable insulators on the timber frame work built in the shaft. The raising transformers are of the standard Westinghouse self-cooling oil-insulated type, and have a capacity of 500 K-W. each at 90% power factor. Their cases are 55 × 72 ins. and 66 ins. high, and contain 500 gallons of oil. This oil is of a brand made specially for transformer use by the New York Lubricating Oil Co., and claimed to be entirely free from acid and other matters injurious to insulation. The primary winding is for 1,000 volts and the secondary winding is for either 15,000 or 30,000 volts. Each complete transformer weighs, approximately, 10,850 lbs., of which 3,600 lbs. are in iron and copper. These transformers have a very low self-induction. With one of the windings short circuited, less than 3% of the normal E. M. F. at 7,200 alternations per minute will send full load current through the other coil. This is due to subdividing and closely sandwiching the primary and secondary coils, which are thin and flat.

The high tension coils have many layers, and but few turns per layer, and each layer is wound in the same direction, so as to reduce the difference of potential between the successive layers. At the end of each layer, the wire is carried across the face of the coil to the starting side. The low-tension coils are of bars or straps wound on edge and afterwards insulated. The coils are spread at the ends outside of the iron core to facilitate oil circulation which carries away heat, and also to increase the distance between the coils where it is difficult to apply solid insulation. To protect attendants and apparatus in case of accidental contact between high tension and low-tension windings, spark gaps are connected between each low-tension winding and the earth. Each transformer is supplied with two high-tension fuse circuit-breakers by which it may be disconnected either by hand or automatically in case of excessive current load. The fuse circuit-breaker consists of two hinged wooden rods by which the fuse terminals are widely separated, breaking the arc when the fuse is ruptured by the current. The electric arc at 30,000 volts is 6 ft. long. Each incoming line wire is protected by a Wurts lightning arrester, of improved construction. On the front of a vertical slab, 24 x 65 ins., are mounted the spark-gap cylinders (in units of seven) in separate porcelain cases, while on the back of the same panel are six choke-coils mounted on three marble wings which support the coils and insulate them while they are brought in close inductive action with each other.

For the outlets, an insulated wall bushing is provided for each high-tension wire, consisting of a marble slab 24 ins. square set into the wall, through the center of which passes a thick glass tube 24 ins. long and 2 ins. outside diameter which surrounds the wire. This is protected on the outside by a hood. The wires are led out from a cupola on the roof, occupying about a third of the length of the building.

The company has erected a brick building near the transformer house for use as a repair shop, with separate rooms for the machine shop, carpenter shop and blacksmith shop. The machine shop contains a 12-ft., 20-in. Lodge & Shipley lathe, a 28-in. Aurora drill press and a 24-in. Gould & Eberhardt shaper. This building also contains the company's headworks office and a storeroom.

TRANSMISSION SYSTEM.

The country traversed by the transmission lines varies from mountainous to rolling and flat. The right of way for the pole line is owned by the company, with the exception of several stretches where the county roads are occupied under a franchise. The right of way is patrolled daily by men on horseback, each patrolman having a distance of ten miles, and reporting by telephone to Seattle and the Falls from the telephone booths located every three miles. This patrol service has been organized for the purpose of detecting any weakness that may appear in the line, and to protect it from any dangers that may threaten. The right of way is in general 50 ft. wide. In many places, however, the company has a timber right for a distance of 300 ft. on each side of the line, with the privilege of felling timber which might injure its operations. This right has been exercised at considerable expense, and trees 8 or 10 ft. in diameter, 300 ft. high, and 300 ft. from the line have been cut, assuming that if they fell they might reach the line and damage it. No falling tree can now reach the pole lines. Fig. 12 is a view on the transmission line. The circuits are of stranded aluminum cables, and were the first instance of the use of this metal in long-distance transmission. The conductivity is about 60% of that of copper, so that the wire in order to have a capacity equal to copper must have a cross-section about 66% greater, but with this increased size the weight is slightly less than 50% that of copper. Longer spans are, therefore, possible, thus making a saving in poles and insulators. Aluminum is non-corrosive to a high degree, and has great tensile strength. From its larger area, as compared with copper, its radiating surface is larger and the wires keep cooler. Its cost is also less. The tie wires are of soft No. 8 B.

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*These figures are those given us by the managers of the company, but they probably refer to apparent kilowatts, the product of amperes and volts as read on ammeter and voltmeter. The true power would be much less, as the charging current is greatly out of phase with the E. M. F. It may be noted that the energy losses here given as due to charging current are in some cases nearly half as great as those found when transmitting about 1,000 HP. over the same line.—Ed.

& S. gage aluminum wire, and no electrolysis can occur with these ties, as would be the case with iron or copper wire. The aluminum transmission wires stop at the city limits of Seattle and Tacoma, and copper is used beyond these points for distances of 1½ miles and ¾-mile, respectively. The joints of the line conductors are spliced with the McIntyre sleeve, which consists of a flattened aluminum tube 9 ins. long and 1-16-in. thick, the diameter being sufficient to receive the two line wires. When the joint is made, it is given three complete twists by special clamping tools. The aluminum wires were supplied by the Pittsburg Reduction Co., of Pittsburg, Pa.

The poles are of cedar, 9 ins. diameter at the top, stripped of the bark and either burned or tarred at the butt. The standard length is 36 ft., set 6 or 8 ft. in the ground, but the length ranges from 36 to 150 ft., according to the nature of the country. At the crossing of the channel in the harbor of Tacoma there are four poles about 154 ft. long, 47 ins. diameter at the butt and 23 ins. at the top, weighing 25,000 lbs. each. The poles were set in line with a transit and their lengths conform to grades established by the engineers.

The cities of Seattle and Tacoma are reached by separate pole lines. These are parallel and 40 ft. apart, as far as Renton, 19 miles, where they diverge to their respective terminals: Seattle, 31 miles and Tacoma 44 miles. The Seattle lines contain about 67,000 lbs. of wire, and the Tacoma lines 72,000 lbs. The charging current on one of the Tacoma lines on open circuit at 30,000 volts is 7.4 amperes, which is small, compared with the load current, so that no trouble is experienced from static capacity. The lines are of aluminum, approximately 0.26 ins. diameter for the Seattle circuits, and 0.23 ins. for the Tacoma circuits, and are designed to deliver respectively 4,000 and 2,000 kilowatts at 25,000 volt pressure and 80% power factor. Measurements made on the Seattle line show a resistance of 84.5 to 88 ohms, depending on the temperature, and reactance at 7,200 alternations equivalent to 54 ohms, for a circuit composed of any two wires. The resistance of any two wires of the Tacoma circuit measures 152 ohms.

The lines are carried on triple-petticoat Imperial porcelain insulators of the Redlands type, 4½ ins. high and 6½ ins. diameter, weighing 4 lbs. each. The pins are of locust, boiled in paraffin oil, and carry the insulators 4 ins. clear above the cross-arms. Two circuits are run on each pole line, one on each side, with a triangular spacing of 30 ins. between wires. On the lower cross-arm are four wires, the inner ones 75 ins. from the center of the pole, and the others 25 ins. from them; on another cross-arm, 25½ ins. above, are two wires, each 40 ins. from the center of the pole. The cross-arms are 4½ × 6 ins., 8 and 10 ft. long. The whole line is substantially built, with poles braced whenever necessary, while double cross-arms are used on all curves and turns and crossings. The length of span on the Seattle line varies from 90 to 150 ft., but the average is 110 ft. On the Tacoma line, the average span is 150 ft. A sag of about 15 ins. is allowed, this being considerably greater than is common practice with copper wires. The lines are divided into six equal sections on either side of the Renton sub-station by means of transpositions. The spans in which these transpositions are made are between poles set 6 ft. apart, which effectually prevents accidental contact between wires. At each transposition the circuits are given one-third of a turn, always in the same direction.

A telephone line of No. 10 B. & S. gage aluminum wire is carried about 5 ft. below the power circuits on ordinary glass insulators on brackets. It is transposed at every fifth pole. The patrol men carry portable telephones, so that a call can be made by climbing any pole. Telephone booths, containing also line supplies and tools, are located at intervals of three miles. The telephone instruments are of the Stromberg-Carlson type.

SUB-STATIONS.

The first sub-station is at Issaquah, ten miles from the Falls. This is a coal mining settlement of about 1,200 people. Here a small brick station has been erected, from which to distribute current for lighting the town and furnishing power to the coal mines. The station serves also as a residence for the patrolman on this section. The next substation is at Renton, 19 miles, where a brick building, 40 × 40 ft., 22 ft. high, has been erected for the high-tension apparatus and power apparatus, and this also forms the home of the man who has charge of the station and patrols the adjacent section. The high-tension wires enter the building through marble and glass bushings, and there is a high-tension switchboard, similar to that at the generating station, which admits of making any combination of the incoming and outgoing circuits. Each wire has a high-tension fuse switch. The town has a population of 2,000, and is in a farming district. Extensive coal mines in the neighborhood are expected to be eventually operated by electricity furnished from this station.

Fig. 9.—View of Jet.

The Tacoma circuits pass through Auburn and Kent, each having a population of about 1,000, and being in a farming and dairy district. A small sub-station has already been established at Auburn, 31 miles from the Falls, and another is to be established at Kent, 25 miles. The former place is on the Northern Pacific Ry., where its lines from Seattle and Tacoma meet the main overland line. The terminal sub-station at Seattle is a substantial stone building, two stories high. The machinery occupies the basement, while the company's offices and rented offices occupy the first and upper floors. The terminal substation at Tacoma is a red brick structure, occupied jointly with the Tacoma Railway & Power Co. Here a high-tension switchboard has been installed, the current being used for lighting and power purposes.

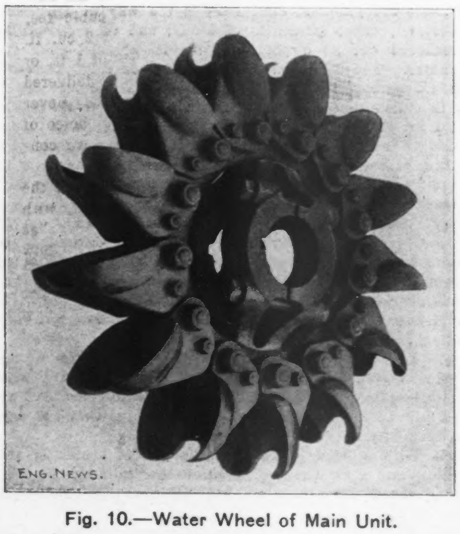

Fig. 10.—Water Wheel of Main Unit.

The Seattle sub-station is in the business district, and the high-tension wires are carried to it on 70-ft. poles, painted blue and black in order to make them distinctive. The wires enter a tower on the third floor, about 40 ft. above the ground, and are led through a terra cotta shaft to the lightning arresters on the second floor. These are six in number and similar to those at the station at the Falls. On the ground floor are high-tension fuse-switches by which the incoming current may be controlled. All of the load may be placed on either transmission circuit, or it may be divided so that the steady load is on one circuit and the fluctuating load on the other, or both circuits may be connected in multiple. The switching apparatus is of extreme flexibility. There are also high-tension fuse switches for the lowering transformers in the basement.

There are at present three step-down static transformers with primaries and secondaries in delta connection, for supplying 350-volt current to the 500-volt rotary transformers. The primary coils may be connected either for 12,500 volts or 25,000 volts. The secondary coils have intermediate terminals by which the E. M. F. supplied to the rotaries may be adjusted when necessary. Otherwise the transformers are similar in construction and capacity to those of the generating station. There are also four pairs of two-phase to three-phase lowering transformers of 300 K-W. capacity each, and two pairs of 500 K-W. each, with 2,000-volt secondaries for general lighting and power distribution, which makes the total station transformer capacity 3,700 K-W. Fig. 13 is a view of the interior of the Seattle sub-station.

White marble switchboards are furnished for controlling the three rotary transformers. Each of the alternating current panels contains a three-pole single-throw washer switch, three ammeters, synchronizing lamps, field rheostat and a switch for the starting motor on the rotary. On each direct-current panel are a circuit breaker, ammeter, volt-meter, plug receptacles, and two single pole washer switches. The feeder panels have circuit breakers, single-pole washer switches and Thomson recording watt-meters. Volt-meters are mounted at the end of the board on a swinging arm.

There are two rotary transformers of 500 K-W. capacity delivering current at 550 volts, which are operated in multiple on both alternating and direct current sides. A third has been ordered. These transformers have 18 poles, and the speed is 400 revolutions per minute. Collector rings and brushes are like those on the generators but of smaller capacity. To bring the rotaries in synchronism without excessive starting current, a small induction motor is mounted on the armature shaft. As this has 16 poles, it is enabled to bring the rotary armature slightly above synchronism, but the final speed adjustment is made by varying the field current which imposes more or less load from iron loss in the rotary armature. Several cross connections in the armature windings insure superior mechanical and electrical performance. For alternating current lighting and power motor work a panel is provided for each set of three-phase, two-phase transformers, containing two 2,000-volt automatic circuit breakers, two ammeters, two Niagara indicating wattmeters, two double pole throw switches and pilot lamps. The feeder panels are the same, except that polyphase integrating watt-meters of the Westinghouse type are used instead of the indicating watt-meters. In making changes on these boards the circuits are first opened by the circuit breakers, as the switches are not designed to break current.

The Tacoma station is equipped with three 500 K-W. transformers and two 200 K-W. transformers, similar in type and style to those at Seattle, making 2,100 K-W. total capacity at Tacoma.

UTILIZATION OF THE POWER.

The Snoqualmie Falls Power Co. furnishes power for both lighting, railway and general power purposes, and it is expected that many of the manufacturing plants of Seattle and Tacoma will soon be operated by the power from Snoqualmie Falls. The power in Issaquah, Renton and Auburn is used for lighting purposes only, for both incandescent and arc lights. In Seattle, all the stationary motors are being operated, and the entire municipal street lighting system; also the Centennial flour mill, 2,000 barrels daily capacity, the Capital flour mill, 300 barrels daily capacity, and about half the street railways. All the street railways will soon be operated from this service. In Tacoma, the municipality owns the lighting system and power is purchased for the purpose of running it. The Snoqualmie power is furnishing nearly all the lighting circuits in Tacoma at present, and the others are to be added as soon as the transformers have been changed to adapt their distribution to the frequency of this plant. The cable railway in Tacoma is also operated by an induction motor applied to the cable driving machinery. All the electric roads are under contract and will take the current as soon as the induction motors which are to drive a line shaft have been installed. An induction motor is also employed at Tacoma in an elevator for loading ships.

The manufacturing plants in Seattle and Tacoma include three flour mills, a smelter, carshops, several iron works, elevators, machine shops, etc. The operation of the municipal waterworks pumping station for Tacoma is also contemplated. Negotiations are also in progress for the establishment of electrolytic and chemical works. Almost the entire output of power was contracted for before the Snoqualmie Falls power plant was in operation. The first customer was the Centennial Flour Mill Co., of Seattle, which contracted for power nearly a year before the completion of the plant. All the machinery for operating the mill, including that for grinding, cleaning, ventilating, receiving and delivering the grain and flour by elevators, etc., is operated by two Westinghouse motors of 200 HP. each, which have entirely supplanted the steam power equipment. A third 200-HP. motor has been ordered, so that the capacity of the mill may be increased.

The plant now installed develops a total of 10,000 HP., of which 66% is for use at Seattle. Taking the energy of the water at the Falls as 100, the percentage available at the time of full load at different points in the system is given in the following table. The first column of this table is computed for a line loss of 15%, but it is intended to increase the amount of wire on the line, so as to reduce the loss to 10%:

	Line Loss. 15%.	10%.
Energy of water	100	100
" from water wheel	80	80
" " generator	75	75
" " step-up transformers	72	72
" to step-down transformers	61	65
" from step-down transformers	59	63
" from rotary transformers	53	57

The city of Seattle has a population of 80,600; Tacoma, 38,500, and Everett, 10,000. These three cities, and the neighboring towns are rapidly growing and increasing in industrial importance, and many small industries and factories, large in aggregate, are being established. The Snoqualmie Falls Power Co. does not engage in the distribution of power to small customers, but sells power in large blocks for this purpose to the Seattle Cataract Co., and the Seattle Electric Co., in Seattle, and the Tacoma Cataract Co. and the Tacoma Railway & Power Co., in Tacoma. It reserves for itself the duty of supplying large plants of every description which can be reached by any of its lines or extensions. A transmission line to Everett is proposed, 35 miles from the Falls, where a paper mill, smelter and other industries in operation would take current amounting to 2,000 HP. The company's policy is to build up a business of large volume at moderate prices, rather than small volume at high prices. The natural conditions are said to make this power one of the cheapest of development in the United States, and therefore the company is able to offer specially low rates.

It has already been noted that the shaft will accommodate another penstock of the same capacity as the one now installed. The intake and tail race have also been built for a plant of double the present capacity. The poles will accommodate twice as many wires; the right-of-way has been bought and improved sufficient for any expansion, and the sub-stations will accommodate machinery for several times the initial power. Another chamber and additional machinery and wires are the only extensions necessary to double the capacity of the plant.

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AMERICAN LOCOMOTIVES FOR CALCUTTA, says the London "Daily Mail," won recently, on tenders asked for by the Port Commissioners. The lowest American bid was £1,200 and six months' time, as against the lowest English tender of £1,544 and nine months' time. An advantage for the American bid, per locomotive, of $1,720 and three months' time.

EXPERIMENTS ON THE MINER'S INCH OF WATER AT THE HYDRAULIC LABORATORY, McGILL UNIVERSITY.

The uncertainty surrounding the miner's inch of water, laid down in the statutes of some of the States of the Union and the Canadian Provinces, is appreciated by engineers who have practiced in those sections. The statute defining this standard in British Columbia is no exception to the general rule, as was shown by Mr. Thos. Drummond, Assoc. M. Can. Soc. C. E., in a paper presented to that body on Nov. 22, 1900, entitled "The Miner's Inch and the Discharge of Water Through Various Orifices Under Low Heads." After describing the hydraulic laboratory at the McGill University, and the experiments made therein, as denoted by the title of his paper, Mr. Drummond wrote as follows regarding the miner's inch in British Columbia:

> The miner's inch of water, it may be explained, is an arbitrary module adopted in mining districts for selling water. It is variously defined as being the amount of water discharged by an orifice 1 in. square, or an equivalent fraction of a larger orifice with a head of from 6 to 9 ins. The thickness of the orifice is usually 2 ins.
>
> One great difficulty is that it is a variable quantity depending upon the specified head, and therefore all such modules should also define the flow in cubic feet per minute.
>
> In British Columbia it is defined as being 1.68 cu. ft. of water per minute, or that quantity of water which will pass through an orifice ½-in. wide, 2 ins. high and 2 ins. thick, with a constant head of 7 ins. above the top of the orifice, and every additional inch shall mean so much as will pass through the said orifice extended horizontally ½-in. As a definition, unfortunately, this is completely wrong. In the first place, widening the orifice as above changes the coefficient of discharge, and therefore the discharge itself. In the second place, this orifice actually discharges 2.147 cu. ft. of water per minute, instead of 1.68 cu. ft., and this brings out a curious point referred to above (omitted here.—Ed.), that certain shaped orifices, with a thickness of 2 ins., run full like a short tube, the vein is not contracted, and they actually give a greater discharge than they are supposed to give. The orifice in question runs full in the horizontal and vertical positions with heads of from 6 to 12 ins.
>
> A 1 × 2-in. orifice 2 ins. thick is just on the margin between flow with contraction and full bore. If fixed in the vertical position, with longest diameter vertical, the vein contracts. If fixed in the horizontal position, with the longest diameter horizontal, it will also contract, but if rubbed with the fingers on the edge it will run full for a time and then contract again. If kept running full in this way it will discharge about 1 cu. ft. of water per minute more than when full contraction takes place.
>
> There are practical difficulties in the way of delivering absolutely exact quantities of water; and they cannot be measured out as a pound of tea is weighed over the counter. The definition of the module or unit, however, should be correct within a reasonable limit of error. It it is a definition of a single miner's inch from an orifice of 1 sq. in., it should go no farther. If the inch is defined as being some practical part of the discharge from a larger orifice, it should go no farther than the capacity of that orifice, and as it is an unknown quantity to the outside world the discharge should be given in cubic feet per minute. Convenient discharges are 1½ and 2 cu. ft. The flow under low heads is irregular. Heads of 1 ft. or more are not convenient because the water is delivered from ditches or flumes where the depth of water is never great. The question thus resolves itself into a choice of a standard module or unit from a flow under two conditions:
>
> (1) With a low head of 6¼ ins. above the center of the orifice, giving a discharge of 1½ cu. ft. per minute, with the advantage that it is already partially recognized as the miner's inch, and with the disadvantage that the flow is irregular.
>
> (2) With a head of 11½ ins. above the center of the orifice, and a discharge of 2 cu. ft. per minute, the flow being much more regular, but the quantity discharged new to the people.
>
> Definitions of both inches are given, and a choice can be made, but the author favors the last.
>
> Definition No. 1 of the miner's inch: The water taken into a ditch or sluice shall be measured at the ditch or sluice head. It shall be taken from the main ditch, flume or canal, through a box or reservoir arranged at the side. The orifice shall be fixed vertically at right angles to the delivering waterway, and the edges and corners shall be sharp. The vein shall be fully contracted. The distance between the sides and bottom of the orifice and the sides and bottom of the waterway shall be at least three times the least dimension of the orifice. The orifice shall discharge freely into air.
>
> One miner's inch of water shall mean ¼ of the quantity which will discharge through an orifice 2 ins. wide and 2 ins. thick, made in a 2-inch plank, planed and made smooth. The water shall have a constant head of 7¼ ins. above the center of the orifice. It shall mean a discharge of 1½ cu. ft. per minute.
>
> Definition No. 2: The first part is precisely the same, the latter part is changed as follows: One miner's inch of water shall mean ¼ of the quantity which will discharge through an orifice 2 ins. wide, and 2 ins. thick, made in a 2-in. plank, planed and made smooth. The water shall have a constant head of 11½ ins. above the center of the orifice. It shall mean a discharge of 2 cu. ft. per minute.
>
> A 1-in. orifice may run full, but no experiments were made on this point.
>
> These discharges are from a standard brass orifice, and are actually 1.478 and 1.997 cu. ft. per minute. The discharge through a wooden orifice 2 ins. thick is slightly greater than for a standard orifice, so that these discharges should be almost exactly 1½ and 2 cu. ft. per minute.
>
> No attempt was made to reduce the observations to a common temperature. The temperatures for the brass orifice varied between 31.7° and 46.5° F., a range of 9.5°, with an average temperature of 48° F.
>
> The temperature for the wooden orifices varied between 45° and 50° F., with an average of 48° F. The mean temperature for the whole was 45° F.
>
> Every precaution was taken to remove disturbing effects, and to make the work as accurate as possible.
>
> Altogether (the whole series of experiments.—Ed.) some 235 observations were made in sets of from 2 to 5, involving a considerable amount of labor, both in the work and calculations.

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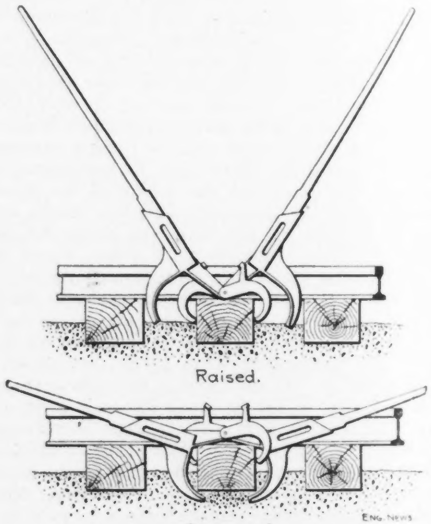
A TRACK TAMPING DEVICE.

Various devices have been invented for tamping ties in the track, in order to do the work more expeditiously, efficiently and economically than it can be done by hand, but so far very little practical progress has been made in introducing machines for this purpose. One of the latest of these devices is illustrated in the accompanying cut. It consists of two curved steel bars, working in opposite direction from the same center, with a radius of 10 ins., the end of each bar being formed with a tamping head of the usual form. The device is attached to the ties by two cant hooks, and is adjustable to ties of different sizes by means of slots in these hooks. In operation, the device is placed on the ties with the levers raised, when the hooks take hold of the tie by their own weight. Two men then work the levers simultaneously, the tamping heads passing under the tie and firmly packing the ballast, which is piled above the top of the tie so as to feed down. The hooks are released from the tie by raising the levers high enough to strike angle lugs on the hooks, so that the device can be removed or shifted along the tie as required. The weight is about 30 lbs. This device is the invention of Mr. Frank Sheppard, 3302 Caroline St., St. Louis, Mo., who informs us that he has tested it and found it to work satisfactorily in properly-crushed ballast. It was patented by him on June 19, 1900, the patent number being 652,195.



A Track Tamping Machine.
Frank Sheppard, St. Louis, Mo., Inventor.

ELECTRIC POWER AND LIGHT FOR THE MACHINE SHOP AND FOUNDRY.*

By Forrest R. Jones, M. Am. Soc. M. E.†

The writer has recently had occasion to investigate the plants of two concerns with regard to electric power transmission and light. In one of these, the floor space over which light and power are required is about 7 acres; in the other, about 4 acres. The output of each establishment is in a way similar, both producing iron machinery chiefly. Both plants were examined to see what requirements would have to be fulfilled by an electric system, or systems, for power transmission and lighting.

DETERMINATION OF KIND OF CURRENT AND VOLTAGE.

The first examination was made with a view to determining whether one or more kinds of current (of the direct, single-phase alternating, or polyphase class) would be desirable. In both cases the same conclusion was reached, namely, that the most feasible way to meet all requirements would be to adopt either one or more systems of electric circuits, the current to be of the same kind in each system if more than one were used, such that any electrical apparatus to be used in the plant, when placed in the location fixed for it, could be individually and conveniently attached to the electric circuit at a near point and operated by current therefrom in a manner suitable to the requirements of the service the apparatus was designed to perform and the limitations of the service for the particular locality, the latter to allow for taking into account the fact that, at some places, a motor must run with a speed varying but slightly from uniformity, while at other places, and for other services, considerable variation of speed might not be objectionable; also, that while the electric light might, in some places, be required to operate with a uniform brilliancy and absence of fluctuation, as in an office or drafting-room, there might be other places to illuminate, such as the foundry, casting-cleaning room, or an emery wheel, where a very considerable variation in its brilliancy would not impair its usefulness.

The selection of a single system from which all apparatus might be operated was based upon the conviction that, for machine shop and factory purposes, it is exceedingly desirable to be able to interchange similar apparatus and to place any piece of apparatus anywhere upon the system, thus obtaining the maximum flexibility and greatest facility for operating portable machine tools at any point, and also to allow for alterations and extensions of the works. The study of the requirements of every form of apparatus that might be brought into use and demand current from the system was naturally necessary in order to decide whether direct current, single-phase alternating or polyphase, should be used.

The oldest of machine tools, the lathe, was taken up first, and since in both establishments it was deemed advisable to have some lathes driven individually by variable speed motors, and that the variation of speed should cover, by small steps, a considerable range, the only thing that seemed satisfactory for this purpose in the present state of speed regulation for different types of electric machinery was the direct-current. And, in order that the range of speed variation might be as great as possible, the multiple voltage system appeared to be advisable, even though the speed regulations were to be made, for a given supply circuit voltage, by rheostatic control of the current in the magnet coils of the motor.

Other machines of a nature in a way similar to the lathe, so far as their driving is concerned, among which may be included the boring mill, drill press, shaper, slotter, gear cutter, and screw machine, can be operated satisfactorily under conditions of speed variation similar to those which answer for the lathe.

The planer, whose reciprocating motion requires the reversal of nearly every part of its machinery, presents a problem which is not yet satisfactorily solved for electric driving by a direct-connected motor. The nearest solution that has been reached is to drive its countershaft in one direction continuously, just as it might be driven from a line shaft, and effect the reversals of the machine in the ordinary method common to mechanical driving. The ability to secure different cutting with maximum return speeds for machines of this type is unquestionably desirable when working upon different kinds of materials, or for taking heavy and light cuts. Different speeds can be obtained readily with many types of direct-current motors by rheostatic control of the field magnet current and, therefore, this feature needs no further attention than already given the lathe.

Nearly all electric hoists and cranes are now operated by constant pressure, direct-current motors. They seem to be at least as satisfactory as those driven by any other type of current.

Constant-potential, direct-current arc lamps have long shown themselves efficient, durable, and otherwise satisfactory. They can be operated individually and economically at any pressure between 100 and 125 volts, even though the pressure fluctuates considerably. (It is not intended that these are the limiting pressures of satisfactory service.) The lamp is, of course, more economical at its rated pressure without any of its rheostatic resistance in circuit. Incandescent lamps have long been operated at from 100 to 110 volts with perfect satisfaction.

Motors for electric cranes and for general power purposes about the machine shop can be operated satisfactorily at any of the ordinary pressures for running motors, but it was not thought advisable, especially in connection with the conditions to be met in operating other apparatus, to give them a pressure greater than from 220 to 250 volts. The higher the voltage, within practical limits, the greater the economy of wire in the electrical circuit, of course. But, even leaving the requirements for other apparatus out of consideration, voltage as high as 500 is not desirable for the machine shop and foundry, for there is always a considerable degree of probability that employees will receive shocks by coming in contact with the wires or machinery. The writer's experience has given him sufficient respect for a 500-volt circuit to make him wish to keep others away from it.

On the whole, it was, therefore, concluded that 220 volts for the majority of motors, and 110 volts for arc and incandescent lamps, would be the most suitable. These voltages can be obtained, as is well known, by the three-wire system which has been so long in use.

POWER CONSUMPTION OF VARIOUS MACHINES.

In order to obtain information as to the amount of power required for driving different parts of the plant, numerous tests were made upon individual machines, groups of machines, sections of line shafting, cranes and elevators.

LATHES.—The power required to drive a couple of lathes, one of 48-in. and the other 36-in. swing, was taken when both were polishing hollow cylindrical columns, one 10 ins. in diameter and the other 12 ins. In both cases the polishing laps gripped the work so tightly as to keep the driving belt of each lathe on the point of slipping. The speed was as high as could be safely used for machines of this size. To drive the two lathes together under these conditions, something over 7 mechanical HP. delivered by the motor to the belt running from its pulley was required. It can be seen that this is considerably more than is required for a lathe performing any of the operations common to machine construction in the ordinary shop.

Although it is well known that the power required to drive a metal-working planer is generally greater on the return stroke than for the forward, or cutting stroke, and that, at the time of reversal, the power demanded is exceedingly greater than at any other time, the following data may not be out of place:

Two planers—one with 22-ft. table and 120 ins. between housings, and the other with 25-ft. table and 72 ins. between housings—were both driven by one motor belted to a jackshaft, which in turn drove the two countershafts of the planers. With a 230-volt pressure the current consumption varied from 20 amperes with one countershaft running to 250 amperes when both planers reversed at once.

Both machines were working upon rather heavy castings and taking comparatively light cuts. The amount of power for reversing the 120-in. planer was about 1.8 times that for its average running at time when not reversing. When it happened that both machines reversed at the same time from the forward, or cutting, to the back, or return, stroke, the power required ran up to a very great amount, more than 60 mechanical HP. This amount of power was not indicated by the instantaneous extreme throw of the ammeter needle, but was the reading at which the ammeter stood steadily for some seconds, a period long enough to make the demand distinctly felt by the engine and generator.

A planer with a 24-ft. table and 60 ins. between housings, showed the following current consumption at 230 volts:

	Amperes.
Shafting only	7
Forward stroke without cut	8 to 9
Light portion cut on rough casting, $^1/_8$-in. feed	10 " 15
1 tool cutting cast iron $^5/_{16}$-in. deep × $^1/_8$-in. feed	15 " 20
1 tool cutting cast iron $^7/_{16}$-in. deep × $^1/_8$-in. feed	20 " 25
Cutting $1^1/_{16}$-in. groove in cast iron with square-nosed tool; feed between $^1/_{32}$-in. and $^3/_{64}$-in.; groove not cored	20 " 25
Reversing from return to cutting stroke	35
Reversing from cutting to return stroke	45

It may be noticed that the power required for reversing this machine, especially from the cutting to the higher speed return stroke, is nearly double that for the forward stroke when cutting.

CRANES.—Of the 20 odd traveling cranes in one establishment, 10 were tested for the power required to drive them. Of these ten, some were driven electrically and some mechanically. The accompanying data, obtained from three electric traveling cranes of 30 tons capacity each, all traversing the same track above the foundry floor, show how great may be the demand, for an appreciable period of time, by some one of the cranes, and, with perfect possibility, by all of them at the same instant. Each of the 30-ton cranes was equipped with four motors: 25 HP. for bridge travel; 8 HP. for trolley travel; 25 HP. for the main hoist, and 16 HP. for the auxiliary hoist.

Current Consumption (in amperes) of 30-ton Electric Traveling Cranes Using Current at 240 Volts.

	Cranes		
	1.	2.	3.
Bridge, starting, no load	125	110	90
Lowering, no load	33 to 40	36 to 50	38
Hoisting, uniformly, no load	36	..	40 to 45
Bridge starting, 20-ton load	145	90	..
Travel'g uniformly, no l'd	50	65	50
Same with 20-ton load	50	50	..
Hoisting,* 10 ft. per min.	95	95	..
Bridge and trolley starting*	..	260	150
General maneuvering.*	150 to 310	..	180 to 350

*20-ton load.

It can be seen from the table that when all the motions on one crane were in operation simultaneously, and when two or more of the movements were started at about the same instant, the demand made for power was very great indeed. The readings given for such general maneuvering for two of the cranes when carrying a load of 20 tons each, running as high as 320 amperes in one case, and 310 in the other, represent demands for current during periods of from 5 to 10 seconds' duration, as shown by the steady reading of the needle of a dead beat ammeter. It not unfrequently happens that such a condition comes about in every-day practice. That two or more of these cranes did, when in regular service, make very heavy demands for current at the same instant, was clearly shown by watching the ammeter at the switchboard of the generator supplying current to the three cranes only. Although this generator had sufficient capacity to operate several 30-ton cranes under what might be called average load, and the magnetic circuit breaker for the generator was set considerably above the steady-load capacity of the generator, it was not an unfrequent occurrence for the circuit breaker to open up the circuit on account of the great momentary demands made for power by the cranes.

Tests upon a 15-ton electric crane, two 5-ton electric cranes, a 15-ton flying-rope crane, a 15-ton square-shaft crane, and a 15-ton square-shaft crane remodelled to be driven direct by an electric motor, all showed similar heavy, momentary demands for current under general maneuvering.

FANS.—Two fans were used in connection with steam coils and hot-air pipes for heating of buildings. They were both of the radial-blade type. The casing of the larger measured 108 ins. in diameter by 60 ins. wide. There were two tangential discharge openings in the case; one at the top, 24×60 ins., and another at the bottom, 54×28 ins. The rotating part of the smaller fan measured 60 ins. in diameter by 28 ins. wide. It had a single outlet, 29×31 ins.

	Fans,						
	108×60 ins.		60×28 ins.				
Mechanical HP.	20.6	23.6	0.8	1.2	4.8	11.4	12.5
Revs. per min.	160	180	120	176	275	360	370

PLANNING THE ELECTRIC CIRCUITS.

By examination of the data given above, it may be seen that the constantly recurring and great momentary demands for power made by cranes and hoists would necessarily affect the pressure in the wires carrying current to them from the switchboard in the power house. Hence the circuit feeding the crane and elevator motors would not be suitable for also furnishing currents to motors required to be run at even a fairly constant speed, nor for incandescent lights even in places where a steady illumination is not essential. It would be difficult to find constant voltage arc lights that would operate with even a fair degree of satisfaction at the points of greatest variation of pressure in the circuit. It, therefore, becomes necessary to have what might be called a "crane circuit" for at least the majority of the larger cranes in an establishment of the proportions of those mentioned earlier in this paper.

The incandescent lights for use in offices, drafting rooms and possibly some parts of the shop itself, as the tool room, and where the small and more accurate parts are manufactured, must have a pressure in the circuit leading to them which, at least, does not fluctuate rapidly, even though it may be allowable for it to vary slowly to a slight extent. A "lighting circuit," primarily intended for incandescent lighting, therefore, also becomes a necessity.

Such machinery as lathes, drill presses, shapers, milling machines, slotters, and gear-cutters do not ordinarily need to be driven at a speed that is even very uniform. Variation of speed on each side of the normal is allowable to a considerable extent in many cases, provided the variation is not a jerky one, such as often comes on line shafting used to drive heavy planers. A third circuit, primarily intended for driving machinery of this class, needs to be installed. This may be conveniently referred to as a "machine-tool circuit."

Whether an iron-working planer may be placed upon the machine-tool circuit depends largely upon the size of the planer. The heavier machines, on account of the great momentary demands they frequently make for power, would be apt to produce sudden and considerable variations of pressure in the machine-tool circuit. Better general operation of the entire plant can be obtained by placing them on the crane circuit. The smaller planers can safely be placed upon the machine-tool circuit, thus obtaining more uniform motor speed for driving them, while not materially affecting the pressure in the latter circuit.

The pressure on the machine-tool circuit would remain

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*Condensed from a paper presented at the New York meeting of the American Society of Mechanical Engineers.

†Worcester Polytechnic Institute, Worcester, Mass.

constant enough to operate constant-pressure arc lamps with perfect satisfaction. Such lamps, therefore, may be placed anywhere upon either the machine-tool circuit or the lighting circuit, and possibly upon some parts of the crane circuit where the fluctuation of pressure is a minimum for that circuit. Incandescent lights can, of course, be placed upon any of the circuits. The pressure in the machine-tool circuit should be sufficiently constant to insure a brilliancy uniform enough for many places in which an incandescent lamp is put.

Certain classes of machine tools, of which the emery grinder for finishing-reamers, mandrels, and accurately formed machine parts, require a very constant speed for the production of well made pieces. A jerky speed, as of a line shaft forming part of a system on which are heavy metal-working planers, causes the grinding wheel to cut deeply into the work in some places, thus making a well-finished product impossible. Power for light machines of this type may be taken from the lighting circuit without detriment to its constant pressure. Desk fans, and even larger ones, can also be connected to the lighting circuit without harm.

On account of the great variation in the amount of power demanded by cranes and other classes of machinery already mentioned it was doubted whether all the circuits leading out through the works could be connected to the same bus-bars in the power house without causing a fluctuation of pressure great enough at the bus-bars to affect appreciably the constant brilliancy of the incandescent lamps placed in locations where the most steady light would be required. Just what would be the effect could not be predetermined. For this reason it was decided that the switchboard should be so made and the generating machinery so divided into units that, if the amount of fluctuation caused in the incandescent lights should be too great when feeding all circuits from the same bus-bars, the crane and heavy planer circuit could be thrown on to one generator, and the other machinery, and lights fed by another generator. If, as was hardly supposed would be the case even with this arrangement, the incandescent lamps should not burn steadily enough, there would still remain the expedient of a separate generating unit for the lighting circuit. The supposition was that, even though such a separate lighting unit might be necessary at the times when the cranes would be performing their heaviest duty, which is while running off a heat in the foundry, there might be other considerable periods of time when the demands by the cranes would not be sufficient to affect the lights appreciably, even though all were operated from the same bus-bars. Such being the case, the lighting unit would have to be operated a small part of the time.

It seems advisable to install at least two generating units exactly alike, and to have one small unit which might be used for furnishing the current to run one or two machine tools, or even a small electric hoist or elevator, when there might be a demand for such service on account of making repairs, or operating some one or two machines on holidays, or in case of a breakdown. Such a unit should be driven independently of the main power plant, so that even though the fires might be dead under the boilers, this extra unit could be operated. A unit consisting of a small generator driven by a water-wheel, or by a gas or gasoline engine, would answer such a purpose. Two large units, running in parallel, for carrying the bulk of the load, or separately for dividing it between them in case the cranes and heavy planers would have to be driven separately from the other machinery, would give a desirable division of the power units for night work and when operating only a part of the plant. This would give an opportunity for repairing the generating units without hindering the running of the entire establishment. Direct-connected units were selected as most suitable. While it is not believed that great multiplicity of generating units is desirable, it is thought certainly better to have at least two main units for the reason already stated.

A motor-generator was decided upon as the best apparatus for balancing the two sides of the three-wire circuit. In a plant where the installment of electrical machinery for power transmission goes on gradually, the motor-generator may be made of an ordinary commercial motor and generator. When the demand upon them becomes too great for their capacity, they may be replaced by larger machines and used for motors in some part of the establishment. It was not thought that a storage battery would be as satisfactory for balancing the system as the motor-generator.

INDIVIDUAL DRIVING COMPARED WITH GROUP DRIVING.

The question of individual driving, or group driving, of the machine tools naturally came up. The solution depended almost wholly upon the ability of arranging the tools for group driving, or the neccessity of driving some individually on account of the location each should occupy in order that it might perform its special functions to the best advantage. As to what would be the most efficient limit for the smallness of motors for driving did not once come up. And the writer has been led to believe by close examination of these two plants and the more general observations of many others, that, except for very light machinery, there is seldom any need of considering which would be the most efficient method of driving, group or individual; or what would be the smallest size of motor to be used for groups, the limit of subdivision being based upon considerations of efficient power transmission. Convenience of operation and the methods of securing the greatest amount of output from operating machinery are of so much greater moment in most cases than economy of driving in pounds of coal saved that the latter sinks into insignificance in comparison with the former. Where it is desirable to have a machine driven at a variable speed of such a nature that it can be obtained only by a corresponding variation of speed in the source of its power, then, in the general case, it is undoubtedly better to drive that machine individually by a variable speed motor, whatever the amount of power required for driving it. On the contrary, if there are a number of machines whose speed regulation can be satisfactorily secured through the ordinary mechanical connection with a uniformly rotating shaft, and they can be grouped together and still perform their functions to the best advantage, then unquestionably the best method of driving is to use, within the limits of convenient arrangement, as large a motor as possible.

HOISTING AND CONVEYING APPARATUS.

The installation of small hoists suitable for serving machine tools when the work handled is generally too large for one man to put in place, is one of the improvements in the modern machine shop which has worked much benefit and saved much time. When the work to be lifted varies in weight from 75 to 500 lbs., it is believed that the pneumatic hoist is generally best for the purpose. To be of most service it should always be available; therefore, one hoist can serve only a small number of machines at most. This being the case, there is no objection to having it attached to the feeder pipe line by a hose of only sufficient length to allow it to reach the machines lying in its field of operation. The cheapness and simplicity of the pneumatic hoist, as compared with the electric or any other form suitable for the purpose, are so strongly in its favor that it seems to have no competitor in this particular field. The air compressor for serving such a hoist is probably best electrically driven when of not too great capacity, but if the size must be large, a steam compressor forming a unit in itself seems best, it being assumed that water-power is not available.

The conveying of materials and machinery from building to building, and through the yards of a large establishment must needs be done, if done expeditiously, by some form of industrial railway. The form of locomotive most suitable for this purpose is not easy to decide upon. The horse hardly enters into consideration, and men are too expensive for the purpose. On account of the necessity of running through shops containing finished product and valuable machines, a steam locomotive cannot be used on account of the deleterious fumes thrown out, not to mention the fire risk. The compresed-air locomotive appears to have proved more expensive than the electric for such purpose, and the choice seems to be guided toward the latter. Current can be furnished for the electric locomotive most conveniently and economically by the overhead trolley system outside of the buildings and wherever else trolley wires can be erected. In most places inside the buildings, however, the trolley cannot be used, so some other means must be obtained for furnishing current to the locomotive. There seems to be two methods that merit consideration, namely, by the storage battery and by the contact system of a shoe underneath the locomotive rubbing against contact points placed alongside or between the tracks. The writer is in doubt as to which would be the more suitable. The storage battery has the advantage that, with it, the locomotive can be run to any part of the track connected with the establishment,even though trolley wires have not been erected, and that it can be operated when the electrical circuits have no current in them and when the plant is otherwise shut down. The period of time during which the locomotive can be operated under these conditions is limited to the capacity of output of the storage battery, of course. The exorbitant price demanded for the storage cell makes the cost of installation heavy, and because the battery itself is liable to rapid deterioration in the hands of such persons as are generally put in charge of it in the machine shop, are points very strongly against it. The underneath contact system has been successfully operated for years in some plants, and new and important improvements have recently been made in it. It is believed to be, so far as its practical operation is concerned, by far the mast satisfactory system that can be used inside the building. While not positively informed upon the cost, it is believed that the expense of installation where there is a great amount of track inside the buildings might be quite large. The electric locomotive of each of the above types could, of course, be satisfactorily operated on a 220-volt electric system.

While watching the operations of electric traveling cranes, frequently when in the cage with the operator, the writer has always been impressed with the need of fewer levers for controlling the different motions. In a traveling crane with a single hoist, there are three controllers, each with its individual lever; one for the motion of the bridge along the stationary track on which the entire crane runs, one for the traverse of the trolley across the bridge, and a third for hoisting and lowering a load. If the crane has an auxiliary hoist, which is very common in practice where two are needed, then a fourth controller and lever aro added. On account of the necessity of quickly grasping and moving one lever after another, the operator is apt to move them more quickly and further than is necessary, thus throwing on a sudden heavy current, which strains and racks the machinery. This is the usual occurrence when quick time must be made.

It would not be a difficult or expensive task to have, for a single-hoist traveling crane, one lever to control any one of the three motions and another to control the remaining two motions. One lever could control the bridge travel and the other both the hoisting and trolley traverse, the hoisting by moving the lever in a vertical plane and the trolley traverse by moving it horizontally. A combination of these two motions of this lever would control both the hoist and traverse at the same instant.

For a crane having a main and an auxiliary hoist, each of two levers could control two motions. One could control the main hoist and traverse, and the other the auxiliary hoist and bridge travel. By such a method of two-lever control the saving of time and machinery would amply repay the extra expenditure necessary for suitably arranged controller levers, the additional cost of which need not be very great.

COMPARATIVE EFFICIENCY OF MECHANICAL AND ELECTRIC TRANSMISSION.

Indicator cards were taken from the five engines furnishing power for the mechanical driving system of one of the plants. These cards were taken at the time when the load upon each engine was at the maximum value that it was found to reach during a period of half an hour to an hour. The aggregate indicated power for mechanical driving thus obtained amounted to something over 500 HP. Cards were taken from the same engines in order to find the power necessary to drive the line shafting, countershafts, jackshafts and all other apparatus which ordinarily ran when no operating machine or crane was at work. It was found that this frictional horse-power was considerably over one-third of the amount found by taking the maximum for each engine, as stated above, when operating the machinery. Cards taken covering a considerable period of time show that in each case the power required of the engine was much less as an average from morning till night than obtained for the maximum load. While no actual calculations were made to determine the ratio of the frictional horse-power to that for this average load, it was very clearly shown that the indicated horse-power of the engine for average load was only about twice that for friction. Each engine drove its own system independently of the other engines. Other engines were used for generating currents for the electric cranes, and a few electrically driven machines and sections of line shafting.

While the results of tests upon several electric motors convinced the writer that as high a degree of economy as is often set forth for such machinery could probably not be obtained in a commercial machine built to withstand heavy loads and rough service, he was certainly convinced that a great saving of the power wasted on friction in the mechanical transmission system could be saved by electric driving.

BRINGING THE TOOLS TO THE WORK.

One great advantage of electric power transmission in the machine shop is that of having a means of furnishing power to portable machine tools, either large or small, at any part of the works where suitable circuits are run. It is such a strong point in favor of electric transmission that it deserves being ever kept before the minds of those who have to do with machine shop and factory. The time that can be saved and the greater accuracy of work that can be secured upon many kinds of large machine members, by setting them upon a machined plane-surface floor with slots and holes for inserting bolts to clamp them down, and then bringing portable machine tools to them with the crane, railway or truck, each to perform its own special operation, makes this method of procedure worthy of consideration by the manufacturer and builder of heavy machinery. The heavy casting can be set upon a flat metallic floor almost invariably more quickly than it can be set before any machine tool occupying a fixed location, and made ready for the tool to operate upon it. If the casting requires the operations of several kinds of machine tools,it must be set again and again, as many times as there are permanently located machines required to do the work. To set a portable machine tool with a plane-machined base upon a level iron floor and bring into position for working upon a casting also upon the floor, occupies but a fraction of the time necessary for setting the casting in position for a permanent machine tool. Moreover, several portable machines may be brought into action upon one casting at the same time. This is seldom true of machines fixed in location.

The writer hopes to see, and believes he will see, in no great period of time, many builders of heavy machinery doing their work in this manner. Why carry a heavy machine member about the shop to this place and that, and waste time setting it again and again before different machine tools, when many of the tools can so easily and quickly be brought to the machine part and put to work upon it?

ANNUAL MEETING OF THE NEW JERSEY STATE SANITARY ASSOCIATION.

The twenty-sixth annual meeting of the association was held at Lakewood, N. J., Dec. 7 and 8. The first paper was on "Higher Education in Hygiene," by Dr. J. L. Leal, of Paterson, N. J. The author said that health officers were generally physicians, either because the law required it or because there was a popular belief that doctors were best fitted for the work. The training of physicians as given by most of the medical schools is generally deficient in those subjects which the health officer needs, but some of the training in these schools is very helpful to those engaged in the work. Aside from this the physician and the layman start out on about the same basis when they take up the work of the health officer, each having much to learn. Executive health officers are generally appointed for political reasons or through personal friendship. It is true that plumbing inspectors are generally plumbers by trade, and meat inspectors are likewise butchers, but this is no guarantee of fitness for the work.

To place the health service on a better basis, means should be provided for training health officers and the employment of men not properly trained should be prohibited. The chief executive officer should have a good general education to begin with, including some knowledge of sanitary engineering, architecture and numerous other subjects. He need not be a practicing physician, but a medical school is or might be the best place for training such officers. There might be a special course in medical schools (leading to some such degree as Doctor of Public Health.—Ed.). The qualifications for subordinate officers need not conform to so high a standard They may be trained to advantage in technical schools.

There should be a state examining board and all inspectors, except those now in service, should be required to pass an examination before such a board before entering upon their work. In discussing this paper, the principles laid down were heartily approved by Dr. Henry Mitchell, Secretary New Jersey State Board of Health; Prof. William Myers, of Rutgers College: and Mr. M. N. Baker, of the editorial staff of this journal.

Other topics discussed at the first session were "Improvements of the Sanitary Inspection Service," by Mr. Louis J. Richards, Sanitary Inspector of Elizabeth, N. J., and the various phases of the milk supply.

The evening session was opened with an address by Mr. G. W. Howell, C. E., of Morristown, N. J., President of the Association. It consisted largely of a discussion of the work of boards of health, and a review of the history of the New Jersey Sanitary Association. The organization of that body was effected prior to the establishment of a state board of health and the association has been largely instrumental, through its educational work and through its committee on legislation, in securing many of the laws now on the statute books of New Jersey relating to public health and sanitation. The membership of the association from the start has included architects, lawyers and school teachers, as well as physicians and engineers.

A particularly good paper was read by Dr. S. H. Durgin, Health Officer of Boston, on "Shall Regulations Relating to the Construction of Buildings be Extended to Include Piping for Gas and Water Supplies?" Dr. Durgin believed that water piping might be very properly, and that gas piping most certainly should be included in building regulations. In discussing water pipes for house service, he classified their qualities under the heads: Solubility, toxicity, durability and cost. He said there were certain pipes that for some waters were unquestionably neither sanitary nor economical. As to gas pipes, it is well known that these are often leaky and that the danger from leaks is greatly increased since the extension of the use of water gas. The evil effects from illuminating gas are a hundredfold greater than those caused by so-called sewer gas. In 1897 the Massachusetts legislature passed an act applying to Boston requiring the licensing of gas fitters, and the securing of permits for gas fitting work, all under regulations to be established by the city board of health and the building commission. The board of health is authorized to inspect gas piping and fixtures. In a certain group of buildings, recently examined, it found from two to ten leaks in 89% of all the buildings inspected, but the pressure used in the test was above the regular working pressure, since the aim of the inspection was to discover places about ready to fail. In making the test a mercury pressure gage is applied to the lowest fixture of the house piping, and, after raising the pressure on the gage to a certain point by pumping, the gage is allowed to stand for a while, after which the change in pressure is noted. Dr. Durgin said that Boston was the first city to adopt regulations relating to gas fitting. At first the manufacturers of gas fittings were not in sympathy with the work, but they now see its value.

Another paper which was read at this session was entitled, "The Practical Use of Vital Statistics," by Mr. F. L. Hoffman, of Newark, N. J. He urged that more pains should be taken to secure the occupations of decedents in order that the effect of occupation on disease might be studied to better advantage. He also called attention to the fact that very few of the reports of local boards of health throughout the state contain matter of any general value, Asbury Park, Montclair and some information from Newark being the only exceptions. He also called attention to a most regretable backward step taken by Massachusetts in 1890. After having had the registration of vital statistics in the hands of specialists for 49 years, the work was placed in charge of an unknown individual in 1890, since which time the vital statistics have been full of errors.

At the closing session a paper was presented on the "Ventilation of Buildings," by Mr. W. J. Baldwin, M. Am. Soc C. E., New York city. This was a very comprehensive review of the whole subject with special reference to the ventilation of school rooms. With coal at $5 a ton, and with the range of rise in temperature to be as high as 50°, it costs about 20 cts. per hour per 1,000,000 cu. ft. of air to be heated.

There were a number of other papers presented at the meeting of less interest to engineers than those already mentioned. One of these, by Dr. H. C. H. Herold, President of the Board of Health of Newark, advanced some excellent reasons in favor of co-operation between adjacent sanitary districts.

The following officers were elected for the ensuing year: President, H. B. Baldwin, chemist, Newark, N. J.; Secretary, Dr. James Exton, Arlington, N. J.; Treasurer, Geo. P. Olcott, C. E., East Orange, N. J.

A MECHANICAL INTEGRATOR USED IN CONNECTION WITH A SPRING DYNAMOMETER.*

By Max H. Wickhorst, Jun. Am. Soc. M. E.†

The integrator described herein is one designed by the author for use in the dynamometer car of the Chicago, Burlington & Quincy R. R. for the purpose of automatically and autographically showing the average drawbar pull or the work performed. The dynamometer apparatus of this car consists of a spring dynamometer, with suitable recording apparatus and recording pens for obtaining a record for the compression of the springs, the distance traveled, the time consumed, and now, also, of the work performed in suitable units, such as mile-pounds.

The mechanical integrator consists of a registering wheel, which slides backward and forward in sympathy with the dynamometer springs, and a circular disk, making in this case nearly three revolutions per mile, and on which the registering wheel slides. The arrangement is shown on the attached diagrammatic sketch, Fig. 1. The registering wheel is a small steel wheel 2 ins. in diameter, and the disk is brass, 11 ins. in diameter. The wheel is so placed that when there is no compression of the springs the wheel stands on the center of the disk. Its plane is at all times at right angles to the line of motion of the spring compression. Thus the farther the wheel gets from the center of the disk, the more revolutions will it make for a given number of revolutions of the disk. The sliding of the wheel back and forth on the disk causes no revolving of the wheel. Only the turning of the disk causes the wheel to revolve, and in proportion to the distance the wheel is from the center of the disk.

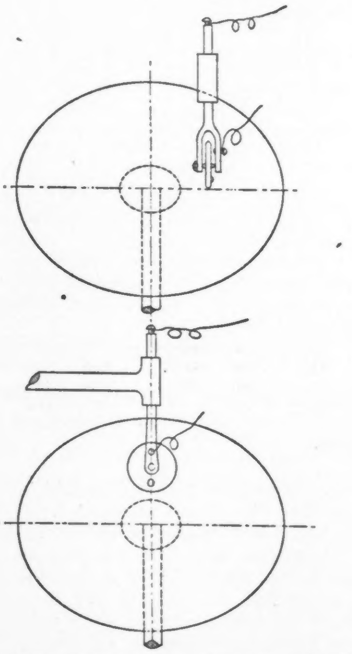

Fig. 1.—Sketch Illustrating Construction of Mechanical Integrator for C., B. & Q. R. R. Dynamometer Car.

In the C., B. & Q. car the dynamometer recording pen makes an ordinate equal to twice the compression of the springs, and the wheel slides back and forth in rigid connection with the same bars which hold the recording pen, and thus moves the same amount as the pen. Thus, if the pen make an ordinate of 1 in., the wheel will make 1 revolution for each revolution of the disk, the wheel being 2 ins. in diameter and revolving on the disk 1 in. from the center. If the disk makes 3 revolutions per mile, the integrator wheel will make 3 revolutions per mile for an ordinate of 1 in. Then an ordinate of ⅓-in. for 1 mile causes 1 revolution of the wheel; that is, 1 revolution of wheel in 1 mile is equal to ⅓-in. ordinate; 3 revolutions, to 1 in. ordinate; 6 revolutions, to 2 ins. ordinate; 15 revolutions, to 5 ins. ordinate, etc. Let a = number of pounds necessary to produce a 1-in. ordinate, then $\frac{a}{3}$ = mile-pounds of work for each revolution of the integrator wheel. The work represented by each revolution of the integrating wheel may be found by the formula shown below.

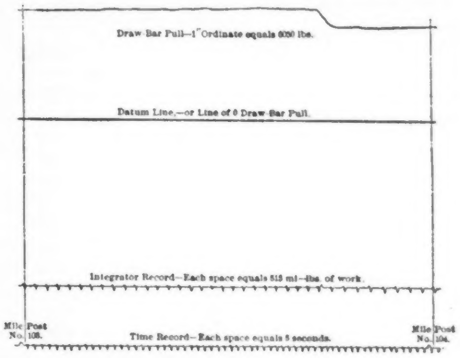

Fig. 2.—Reduced Fac-simile of Record Made by Dynamometer and Integrator.

Let w = mile-pounds of work per revolution of integrator wheel.
o = any ordinate made by pen.
r = pounds resistance for the given ordinate.
i = diameter of integrator wheel in inches.
d = revolutions of disk per mile.
s = space or distance traveled in miles.
p = average drawbar pull for any given distance.
n = number of revolutions of integrator wheel.

Then
$$w = \frac{r}{\frac{2\,\pi o}{\pi i} \times d} = \frac{ri}{2\,d\,o};$$

$$p = \frac{w\,n}{s} = \frac{r\,i\,n}{2\,d\,o\,s}.$$

Where $s = 1$ mile, $p = w\,n$.

Our method of recording the revolutions made by the wheel is to let the wheel close an electric circuit every ¼ revolution. This actuates an electro-magnet, which in turn actuates a recording pen. Thus, when the car moves, the paper moves under the pen at the rate of 12 ins. per mile, the pen making a line, and at every ¼ revolution a notch is made in this line. By counting the number of these notches for any mile, and then multiplying by the proper factor, we get the mile-pounds of work for this mile, and by then dividing by 1, the average drawbar pull.

To show how the integrator record is taken, a facsimile copy, reduced (Fig. 3), of the record taken in the dynamometer car is shown. It will be noticed that this record leaves the integrator readings in such shape that they can be checked by means of the planimeter. Such checkings have shown that with ordinates of 3 or 4 ins., the integrator and planimeter results agree within a fraction of a per cent. With small ordinates the differences amount to 1 or 2%, and occasionally more, depending on the care taken to set the integrator wheel correctly on the center of the disk, when there is no strain on the dynamometer.

Finally, I wish to express my thanks to Mr. P. H. Cummings, who made the necessary shop drawings, and looked after the details of making the instrument, and made many valuable suggestions, and also to Messrs. J. C. Thorpe and E. V. Hanson for their work and suggestions in connection with the same matter.

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*A paper presented at the New York meeting of the American Society of Mechanical Engineers.

†Engineer of Tests C., B. & Q. R. R., Aurora, Ill.

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Tests of the tensile and compressive strength of concrete, with determinations of the modulus of elasticity in each case, are described in a paper by Mr. W. H. Henby, recently read before the Engineers' Club of St. Louis, and printed in the "Journal of the Association of Engineering Societies" for September. These tests were by far the most exhaustive of any tests of a similar nature which have ever been made, and those of our readers who are interested in the elastic strength of concrete will do well to supply themselves with a copy of this paper, which has been separately reprinted, and can be secured at 25 cts. a copy by addressing Mr. Henby, in care of Prof. J. B. Johnson, of the University of Wisconsin, Madison, Wis.

Summarized briefly, the tests were made on both cinder and broken stone concretes, of various compositions, and consisted in determining both the tensile and compressive strengths and their respective moduli of elasticity. It was found that besides the range of strength of the component parts, the other principal factors, which may cause a difference in the physical qualities of any given mixture of concrete, are: Consistency, thoroughness of mixing, the compacting of the concrete in place, and the treatment of the test specimen in seasoning.

In regard to consistency, the conclusion derived from the tests is that, the greatest strength is developed when the mixture is damp enough for a small amount of moisture to be flushed to the surface under heavy ramming. A less amount of water does not ensure a coating of all the coarser components with cement, and a weaker product results. A greater amount of water, on the other hand, gives the mixture such plasticity that the desired density cannot be effected by ramming, and the broken section shows voids of considerable size and of aggregate volume proportional to the excess of water used. From the tests it appears that the decrease in strength due to an excess of water is rather more than proportional to that excess. In regard to density, the tests show that, other conditions being equal, any increase in density effected by compacting in place by ramming, increases very materially both the ultimate compression and the tensile strength.

The specimen made of the right consistency to give greatest strength, and allowed to set in dry air without the protection of damp cloths during the first 48 hours had less ultimate strength and a somewhat lower modulus of elasticity than did the specimen protected from too rapid drying during 48 hours. Stone concrete sets more rapidly in water than in air; cinder concrete develops less strength when set in water than when set in air.

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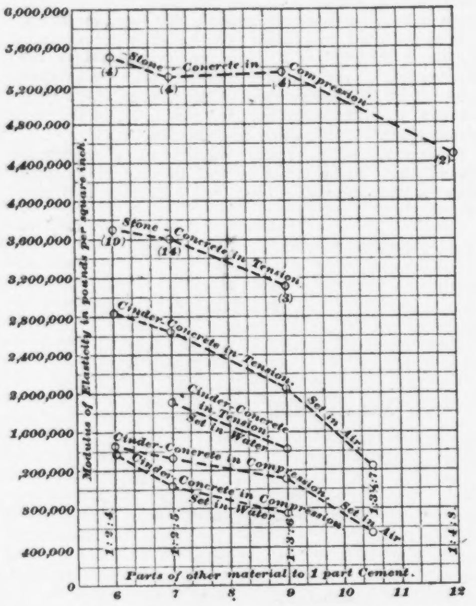
Perhaps the most interesting results of Mr. Henby's tests, however, are those showing the relative moduli of elasticity in compression and tension, of cinder and broken stone concrete. The character of these results is graphically indicated in the accompanying diagrams. In explaining these diagrams, Mr. Henby points out that in attaining the average values from which the curves are plotted, the values obtained from the specimens whose broken section showed them to have been defective, were not included, so that the values plotted may be taken as fairly accurate for well-mixed and well-tamped dry concrete. The numbers in parenthesis at each point on the curves indicate the number of tests averaged to obtain that point. The average density of the stone concrete compression specimens was found to be greater than the average density of the tension specimens. This, it is thought, may account to a great extent for the much higher values of the compression modulus of elasticity of stone concrete. The cinder concrete tension and compression specimens were, however, of approximately the same density, and were in all respects comparable. The higher values of the tension modulus of elasticity were characteristic of cinder concrete, with hardly an exception in a long series of experiments. In conclusion, it may be noted that the diagram also shows the effect of setting cinder concrete in water. Heretofore it has been assumed that the modulus of elasticity for concrete was the same for both tensile and compressive strength, and that this equality was as true for cinder concrete as for broken stone concrete. Mr. Henby's tests indicate, on the contrary, not only that the tension and compression moduli vary for both kinds of concrete, but that the elastic characters of cinder and stone concretes are essentially different. Briefly stated, the elastic modulus of stone concrete in compression is from eighteen to twenty million pounds more than it is in tension, while cinder concrete has a modulus of elasticity of tension from nine to thirteen million pounds greater than its modulus for compression.



Modulus of Elasticity for Various Mixtures of Stone and Cinder Concrete in Tension and Compression.

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That ancient will o' the wisp, a proposed tunnel under the Straits of Gibraltar, is brought into public notice again by a U. S. consular report. According to this, the proposed tunnel would be 25 miles long, of which 20 miles would be under the sea. The maximum grade would be 25%. The projector, one M. Berlier, estimates the cost for a double-track line at $600 per lineal meter, or $24,000,000 for the whole work, and sets the time for construction at seven years, assuming that the tunnel would be driven from each end at an average rate of 2½ miles per year in each heading. He also declares that "the construction is perfectly feasible, as the depth of the sea does not exceed 1,300 ft."

In view of the publicity given to this quixotic scheme by the newspapers, it seems proper that we call attention again to the inherent difficulty in all submarine tunnel work involving a depth of more than 150 ft. or so below the water level, or in other words, a depth beyond that at which compressed air can be used to keep water from the workings. No such tunnel has ever been built, and so far as appliances at present at the command of engineers are concerned, the construction of any such tunnel, unless it be driven through impermeable rock, is an absolute impossibility. We are aware that the projectors of these enterprises usually claim that their particular tunnel has the benefit of a stratum of watertight rock, and no one can deny the possibility that such a thing may exist. On the other hand, all experience in submarine tunneling goes to show that, in all rocks, seams and fissures communicating with the water overhead are almost invariably encountered. The longer and deeper the tunnel, the greater the liability of encountering such seams. With such strong prospects of meeting insurmountable obstacles, no one of intelligence would risk money in a submarine tunneling project below the limit at which compressed air can be used. There is a common idea that modern engineering can accomplish almost anything, provided unlimited funds are available; but it ought to be understood that tunneling to unlimited depths below the water level is a feat as yet beyond the powers of mankind.

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The value to an engineer of having detail drawings of his novel designs published in Engineering News has so often been urged in print and in person by the editors of this journal that it seems almost a work of supererogation to present further argument. A letter recently received from an old reader, however, has so pertinent a bearing upon this important matter that we cannot refrain from publishing it:

> Sir: Will you please forward me a copy of Engineering News issued, I think, in August, 1894, showing the —— —— which I designed and which was put at work on the Chicago Drainage Canal during that year. I am about to get up a similar machine again and have lost my own set of drawings. I would esteem it a favor if you would let me have this copy as early as possible.
> Chicago, Ill., Nov. 30, 1900.

Of course, engineers usually intend to preserve drawings which may be of use at some future day; but fire will consume and moth and rust will corrupt, and it is well in time of need if one can, like our correspondent, turn with certainty to a record which not he alone, but engineers scattered all over the world, have access to through its preservation in permanent form in thousands of engineering libraries.

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In publishing the new classified index to the library of the American Society of Civil Engineers, the Library Committee of the Society calls attention to the need of enlarging and improving this library, and their appeal deserves the attention of engineers generally, and especially of members of the Society. The need of a complete and well-classified library of professional literature, which can be resorted to by engineers with confidence that they will find the bulk of what has been published upon any particular subject in which they may be interested, is too evident to require proof. Without prejudice toward the work being done by other organizations, the library of the American Society of Civil Engineers, having already some 32,000 accessions, would seem to stand foremost in its claim to be selected for development in this direction. The only sources of a vast amount of engineering information are the technical journals; the water-works, sewerage and other reports of cities and towns; the reports of railways and similar corporations, and the records and reports of engineering investigations, and studies made by engineers in their private practice. It is quite out of the question for an engineer to have all or even many of these publications in his private library. The volume of technical literature at the present day is by far too great. The only practicable place for complete files of such publications is in a general library organized and classified for convenient use, such as the American Society of Civil Engineers has planned. The great blemish of this library at present, as is well pointed out by the Library Committee, is that in its somewhat haphazard growth in the past many blanks have been left, not only by the absence of individual books on engineering, but by missing numbers of serial publications, early reports, etc. Evidently one of the best methods of remedying these deficiencies is for engineers to donate, whenever they can, from the spare copies in their own libraries, everything which will fill an existing gap. To make this task easy the Library Committee has indicated in its Classified Index wherever missing numbers exist; and any engineer who may be willing to donate books or pamphlets from his own library, can easily ascertain whether they will supply the deficiencies noted. This is a work which can be more easily done now than at any future time, and its value to those who may use the library in future years will be very great.

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THE DEVELOPMENTS OF THE NINETEENTH CENTURY IN BRIDGE DESIGN AND CONSTRUCTION.

The invention of constructive systems has always preceded their theory. Centuries before theory, as we know it to-day, was even thought of, there were in existence apparatus and structures of all kinds, bridges not excepted. This fact frequently causes engineers as well as others to forget how modern a development the steel bridge of to-day is in material, design and all that goes to make it a scientific adaptation of theory to available structural materials and to human skill in constructive work. The assertion can be boldly made and maintained with remarkable success that all that goes to make up bridge engineering as we now understand it is the development of the last hundred years. At first sight facts may seem to contradict this assertion, but they cease to do so as soon as we look a little further into the comparative history of bridge construction. At all times there have been men born to be inventors, with great imaginative and intellectual powers, who, without theoretical knowledge, have been capable of creating structural systems by closely observing and imitating physical processes. In this way the cantilever, the suspension cable, the arch and even the truss, all of which constructions have existed from very early times, were developed long before the principles of statics upon which their success depended were thought of. A brief historical review of bridge building will help to make clear the truth of this and the other statements made above, and we can well begin this review by considering first structural materials for bridges. For the historical facts presented we shall draw upon the elaborate series of articles by Prof. G. C. Mehrtens, published in "Zeitschrift des Vereines Deutscher Ingenieure" during the present year.

The modern structural material for bridges is steel. The first metal bridge actually built was the cast-iron arch of 102 ft. span erected over the River Severn in England in 1776-9. In 1794 a similar cast-iron structure was built in Germany. Both of these bridges are still doing service. During the 20 years of the eighteenth century, after the building of the Severn Bridge, many cast-iron arch bridges were erected in England. Despite the success of these early cast-iron bridges in proving the fact, which was frequently disputed at that time, that iron was a material worthy of comparison with stone and wood for bridge building, the modern development of iron bridge construction really began with the production of wrought iron in large quantities early in the present century. For a good many years after wrought-iron bridges had been built in considerable numbers however, there was much dispute as to the comparative value of that material, cast iron and stone and timber. This conflict of opinion was in fact not fully settled until the elaborate tests of Stephenson, Fairbairn and Hodgkinson in 1840 to 1846, and the previous tests of a score of other English and Continental engineers, had proved beyond doubt the great superiority of wrought iron to cast iron. Not until the beginning of the second half of the nineteenth century, therefore, was the position of wrought iron fully established as a material for bridges.

Meanwhile the growing success in the production of steel in considerable quantities had turned the attention of a few engineers to the possibility of substituting this material for wrought iron. Very little encouragement toward such action was found, however, until the invention of the Bessemer process in 1855, and the Siemens-Martin process almost immediately afterwards. Indeed, the first use of Bessemer steel in bridge building was made in 1862, and, curiously enough, was in Holland. The unfavorable experience with these Dutch railway bridges, however, served rather to delay than to advance the use of steel in bridge building. In fact, the distrust aroused in the material was so great that it was not taken up again by bridge engineers until 1880, long after steel had been successfully employed in making ship plates. It is worth remembering at this point that the engineers of the Forth Bridge were among the very first to venture upon the use of steel after the setback it had received from the unfavorable results of its use in Holland, and that their example did much to encourage others to make similar trials of the new material. About the same time the use of steel for all structural work received a great impulse through the invention of diphosphorizing iron in the Bessemer converter by Thomas in 1878. This process was applied to the open hearth process in 1882. The rapidly increasing use of steel for bridges until it is now the universal structural material for all but masonry arches, which followed Thomas's notable invention, is a matter familiar to every engineer. Looking back at the development of structural materials for bridges we find, therefore, that the nineteenth century is to be credited with practically the entire evolution of the material that now reigns supreme in bridge construction.

Turning now to the development of structural systems, we will consider first the braced girder or truss. It is generally conceded that the modern bridge truss was developed in imitation of timber roof trusses which date back to very early times, and it is reasonable to assume that braced girders were used for bridges at a similarly early period. In fact, we actually know this to have been the case. It was not, however, until the very last years of the eighteenth century that the movement began to which the modern bridge truss is directly traced. This movement began in America and was carried on by Palmer, Burr, Town, Long, Howe and Pratt. All these names are too familiar to the American bridge engineer to require explanation here. The first marked step toward bridges of the modern truss form is considered by so high an authority as Mr. Theodore Cooper, M. Am. Soc. C. E., to have been the wooden lattice bridge patented by Town in 1820. Until 1847, however, when Mr. Squire Whipple published his book giving methods of computing stresses, these truss bridges were built without any accurate knowledge of the stresses to which the different members were subjected. In 1851 the German engineers Culmann and Schwedler published their analysis of braced girders which accomplished for European bridge engineers what the work of Whipple did for those of America. The perfection of the knowledge of statics as applied to the design of bridge trusses from the theories of Whipple and his German contemporaries need not be dwelt on here, the main fact to be noted is that the perfection of braced girders or the truss system, for bridge construction is entirely the work of the nineteenth century.

Strictly speaking, the hinged continuous truss or cantilever, so far as the history of its development is concerned, belongs under the braced girder or truss system, but its individual importance warrants its consideration briefly by itself. It was, as is well known, an attempt to secure the theoretical advantages of the continuous girder and avoid its practical disadvantages by hinging the chord so as to render the structure statically determinate. The idea of hinging continuous girders with the object just described is said to have been suggested in 1846. The advantage of being statically determinate was not sufficient to encourage its use to much extent, however, until the very great practical advantage of being able to erect cantilever structures without falseworks was established. The first actual proof of this possibility was supplied by American engineers in the erection of the Kentucky viaduct and the Michigan Central cantilever at Niagara Falls in 1877 and 1883. By the development of the cantilever the bridge engineer had placed at his command not only a structural system which freed him from the necessity of falseworks, but one which was particularly suited to the construction of single clear spans of dimensions which, previously, it had been thought possible to approach by means of suspension bridges only. The great Forth Bridge of Scotland, with its spans of 1,710 ft., and the 1,800-ft. span bridge just begun across the St. Lawrence River at Quebec, Canada, are built after a structural system which is distinctly modern, both in its inception and its practical application.

The idea of the suspension bridge dates from the primitive ropeway of prehistoric times. At the beginning of the nineteenth century there were several suspension bridges in England, all of which had cables of wire rope or iron links from which the roadway platform was hung by means of vertical tie-rods or wire rope. In his design for the Menai bridge the English engineer Telford provided for a system of cross-bracing between the suspension cables and also between the parapet beams of the platform, but the bridge was constructed without either. In 1836 cross-bracing between the cables was used for the first time in the bridge across the River Weser, in Germany. The first stiffened suspension bridge was that built to carry the Grand Trunk railway over the Niagara River, and in this and subsequent structures Mr. John Roebling inclined the planes of the cables and used inclined stays from the tops of the piers to the platform. In recent years, as is well known, the inclined stays have been abandoned principally because they inevitably produce some uncertainty in the transmission of the load to the cables, but the other improvements invented by Roebling remain. The suspension bridge with stiffened cables is perhaps the most recent development in this class of bridges, and it is one about which much difference of opinion exists. In respect to the material used the suspension bridge is now essentially a steel structure.

To summarize briefly, it was not until the middle of the present century that the suspension bridge was developed from a structure deficient in rigidity and suitable for highway purposes only to the stiff structures capable of carrying railway trains such as the Niagara bridge of the Grand Trunk railway and the more recently proposed North River Bridge at New York city.

The modern steel arch bridge is a hinged structure. At first, following the example of stone arches, hinges were entirely dispensed with, the arch being consequently statically indeterminate. Until 1841, the application of hinges to the few hinged arches previously built, was entirely a matter of empiricism. In 1854, however, a two-hinged wrought-iron arch bridge was built over the St. Denis Canal, on the Paris-Aire railway, with the design based on exact calculations of the effects of the hinges. This bridge was followed in 1864 by a three-hinged arch over the River Wien in Germany. From these examples all the numerous steel arches of the modern hinged type have developed. It is only within the last 40 years, therefore, that the hinged steel arch has been developed upon a basis which at present makes it one of the handsomest and most efficient bridge types now available to the bridge engineer.

In the preceding paragraphs we have reviewed briefly the historical developments in design and construction of the principal types of modern metal bridge systems. It is a very common notion that many of the structural features which distinguish modern bridge types are only belated ideas of what is really very old. In proof of this, we often have it triumphantly pointed out that the arch, the cantilever, the suspension cable and the truss were used centuries ago, and that, therefore, the bridge engineer of to-day is not so very much ahead of the earliest practitioners of his art. One of the most effective ways to adjust ourselves to a correct mental attitude toward such notions is to make an inventory of progress such as has been done very briefly in the preceding paragraphs.

LETTERS TO THE EDITOR.

What is a 100% Grade.

Sir: In your issue of Nov. 29 I note with surprise the statement of Mr. J. L. Campbell that a 1% grade is not a rise of 1 ft. vertically to 100 ft. horizontally; for per cent. in grades means just that and nothing else. Mr. Campbell appears to think that per cent. in grades means the ratio of the force required to pull a body up an inclined plane to the weight of the body, friction neglected, and he accuses Wellington of error in stating that a 1% grade gives a resistance to traction of 20 lbs. per ton. Wellington, on pages 538 and 539 of his "Economic Theory of Railway Location," expressly states that this rule is only approximately correct; but even for a 10% grade it is within ½% of the truth, and therefore for all grades used on steam railways Wellington's rule is practically correct. Mr. Camphell's little diagram may be useful, but his misapprehension of the meaning of the word per cent. in connection with grades should not go uncorrected.

Yours truly, H. P. Gillette.

751 Powers Block, Rochester, N. Y., Dec. 4, 1900.

The Bacterial Studies of Pavements at Lafayette, Ind.

Sir: While not wishing to become involved in any controversy, I cannot help replying to Prof. Luten's remarks relating to my comments upon his article about the sanitary qualities of different pavements He says that I am in error in almost every statement made, but fails to instance the mis-statements; he says also that had I proceeded a step further I would have assumed that the wood-block was dirter and dustier than the asphalt, and that this conclusion would have required revision. Further on, in his reply, he says that the asphalt was nearly always clean and the cedar-block pavements "rough, hard to clean and consequently dirty," so that a conclusion such as he predicts would be more than half correct from his own statement.

As to the amount of traffic, I simply took his own table which, under tha head of "Remarks," opposita tha Oct. 12th observations, when tha greatest number of bacteria on asphalt was found, gives "Dry, heavy traffic."

Prof. Luten mistakes entirely my proposition for obtaining the bacteria on a pavement. It was not by analyzing the sweepings from a given area, but by taking the sama amount of sweepings from different pavements. As to the language of my description of a sanitary pavement being that of an idealist, I can only say that a pavament such as described is not only practical, but is fulfilled by good asphalt and brick pavements, and that its conditions being easily complied with proves it to be practical. He is mistaken in thinking I would like pavements flushed with an antiseptic fluid, but if I wera living on a street where the cedar block pavement was eleven years old I should certainly offer no objections to its being disinfected twice a week.

Prof. Luten in his reply says also that this discussion must ba from the germ standpoint only and that I was mistaken in applying my conclusions to thesa pavements under all conditions and that I should hava applied them to the Lafayette pavements only. Had this statament appeared in the original article my comments would never have been written, but the tenor of that article was towards general not special deductions, as the following quotation would indicate: "Certain forms of wood-block might bring about such conditions, but, on the other hand, the death rate of cities having a large percentage of wood-hlock pavements do not seem to show any increase over other cities." My point is that the average reader would take the original article as an argument in favor of wood-hlock pavement, from a sanitary standpoint, over one of either asphalt or brick, and that is the impression that I wish to correct. As I said in my first communication, the conditions of the tests are given in such detail that any one can intelligently draw his own conclusions, and all I ask is that your readers study the article closely before making their deductions.

Geo. W. Tillson, M. Am. Soc. C. E.

Brooklyn, N. Y., Dec. 4, 1900.

The Original Subaqueous Viaduct.

Sir: A copy of the "New York Journal" Sunday supplement of Sept. 16 haa just attracted my notice, but please do not put down my letter unread because of the unprofessional character of my referenca. (I confess I often read the Sunday papers during Revolutionary times).

Well, this paper tells of a "Twentieth Century Engineer" who has patented a subaqueous viaduct, a Mr. F. W. Fitzpatrick, of the Treasury Department, at Washington. Now, I cannot allow my "crank" laurela to be wrested from me without a struggle, and I would refer you to Engineering News of April 11, 1891, with the editorial nota and description of my tunnel. Please be merciful and remember that I was nearly ten years younger then, than I am now. You will find Mr. Fitzpatrick has only added some highly ornamental, but wholly unnecessary, stonework to my tunnel and patented the whols thing. I am scandalized, for if anyone else ever did forestall me, I don't know it, but it is possible, as many great minds think alike. At any rate, I am the original inventor as much as any predecessors that may hereafter be unearthed. I have seen Zerab Colhurn's scheme and another hy Bateman and Revy, and another by Strom, but they all differ essentially from mine, and I saw them all subsequently to the publication of mine. I did not apply for patents, thinking benevolently, that the world was not yet ready for my great genius, and I would generously give away my ideas to posterity. Many great geniuses have been born ahead of their time, so I don't complain; but if it be true that the world is ready for the "Twentieth Century Engineer" and if Mr. Fitzpatrick has got along as far as my authority makes out, I wish to notify tha world through you, that my tunnel is the best and only really reliable and true original subaqueous suspension tunnel. What is the "Greathead" forsooth, to my "Greaterhead Tunnel!" and crank or no crank, I, as a "Nineteenth Century Engineer" only, am prepared to construct such a tunnel anywhere, to unite New York with Jersey City, or anywhere else, Gibraltar with Ceuta, Dover with Calais, England with Ireland (really united, just think of it), Denmark with Sweden, etc., or even to reunite the two continents of North and South America, immediately after they shall have been "brutally severed" by the United States government (at Panama I devoutly hope), or to build a dozen water tunnels for Chicago or other lake cities for water supply at one-fifth the cost of the existing ones, and superior in every way. Tha details are all perfectly studied out and I only await the recognition due to my genius by some other progressive "cranks" who will put up the money and call me to the front, "palmam qui meruit ferat," so do tell me if my time haa really come. Is there any serious schema afoot for New York such as is described in tbe New York Journal of Sept. 16? If so I ought surely to be in it. Won't you help me? My ambition is to "go Cecil Rhodes one or two better" on his little "Cape to Cairo Railway." Mine would be "London to Lots of Places Railway unlimited," via Calais, Gibraltar, Copenhagen, Behring Straits, etc. Yours very truly,

J. T. Ford, M. Inst. C. E.

Cartagena, Colombia, Oct. 25, 1900.

(We regret to state that the Sept. 16 number is missing from our files of "The New York Journal," and the publishers inform us that the number is out of print. We are, therefore, even more in the dark than our correspondent as to the nature of Mr. Fitzpatrick's invention. We submitted a proof of the above letter to Mr. Fitzpatrick, however, and his reply states that there were several "journalistic frills" in connection with the "Journal's" description of his invention. To Mr. Ford's query whether he "means business," he replies that it is a serious proposition, and is assuming tangible shape. Negotiations in connection with the control of certain patents are now in progress, and his engineers are preparing working drawings. Fuller information he promises at an early date.—Ed.)

Allowance for Shrinkage of Embankments.

Sir: As one who has set many slope stakes but never hy an elegant text-book formula, I have been an amused and interested reader of the controversy over slope stakesetting recently appearing in your journal. In the letters of Messrs. Gillette and Johnson, in your issue of Nov. 15, the rule for allowing for shrinkage of embankment appearing in "Johnson's Surveying," of which I have a copy, is brought into the subject and adds additional interest and gives new evidence as to the appropriateness of your editorial "sermon" touching the character of instruction in our engineering schools. I believe entirely in a thorough theoretical education as given in our best engineering schools, if that is all and the best that can be had there, and I believe the engineering profession is to be congratulated on the great number of valuable text books at its command, of which Professor Johnson's books are not among the least valuable, if such books are the best that can be produced.

But all that is but the beginning of the making of a good engineer, and the fact that the new graduate fresh from his professors and text books, may generally be relied on to maka ridiculous blunders in attempting a literal application of the rules and formulas which were so satisfactory and sufficient in the class room, is reason quite sufficient for the questions raised in your "sermon."

Professor Johnson stands as a representative professor of civil engineering and his books should he subject to a fair criticism. His rule in question says: "A contractor should have his poles or stakes set one-fifth (20%) larger than the corresponding fill, so that when filled to the tops of these a settlement of one-sixth (16⅔%) will bring the surface to the required grade."

Now, if fills would settle one-sixth vertically and do it by the time trains were running, this rule would be fine. But they will do no such thing. Not in railroading at least. Yet the new college graduate has a right to assume that they will (if his instruction counts for anything) and to believe that this rule is a necessary one, in so far as it may have entered his engineering education.

Suppose he goes out to stake his first embankment and it is 20 ft. high. He must, according to rule, mark it 24 and set out the slope stakes 6 ft. farther to maintain proper width of roadhed. That fill would simply stand 4 ft. above grade with a most unsightly and inadmissible "hump," particularly if the fill is only 400 or 500 ft. long and, so far as settlement is concerned, will remain there forever. If there were many such fills, that engineer's head would come off.

Again, the rule is not even theoretically correct on the assumption of 20% shrinkage of volume. The volume of a 20-ft. fill for 100 ft. is, for a 14-ft. roadbed, and 1½ to 1 slopes, 3,259 cu. yds. The volume of a 24-ft. fill on the same basis is 4,444 yds., an increase of 26⅔% in terms of the larger volume. A fill of 22.8 ft. would have 4,070 cu. yds., and, if it shrank 20% in volume, would equal a 20-ft. fill.

I cannot agree that railway embankments will sag "as much as several feet," on either side of bridges. I have never seen that excess on work as actually put up and that is what we are concerned with. I do know that it is a common practice to set hridges a few inches high (as I am now doing) to provide against the inevitable surfacing up of track by section men. This latter practice in maintenance of way will easily and safely provide for all settlement in all but special cases. Bridges frequently become low but rarely high. Every surfacing of track tends to raise, not lower it.

The fact that levees are huilt for a 17% settlement vertically, as mentioned by Professor Johnson, proves nothing unless it is also shown that they settle to grade, which has not been done.

It appears that the defense of the rule in question consist essentially in a refuge behind Mr. Flynn. Would not our text books be smaller if second-hand authority and deductions were taken out? Practising engineers cannot put up work safely second-hand. Such work is likely to fall down or rise above grade. We are usually admonished to use "judgment," in applying the rules and formulas of our authorities and we generally find it necessary to heed the injunction. How about the use of better judgment in formulating rules for our guidance? Would not this lead to closer harmony between theory and practice?

J. L. Campbell.

Clifton, Arizona, Nov. 21, 1900.

Notes and Queries.

W. H. L., Nashville, Tenn., asks for the addresses of manufacturers of standard equipment for saturating roofing felt and refining coal tar.

Referring to the description of of the Easton suspension bridge described in our issue of Nov. 22, Mr. H. G. Tyrrell writes us that the engineer for the owners was Mr. John McNeal, of Easton, Pa., and that while the design of bridge, including both substructure and superstructure, was made by Mr. Tyrrell for the contractor, and his plan was accepted in a competition, Mr. McNeal had charge of putting in the foundations and of other engineering work for the owners.

In our issue of July 19, 1900, we reprinted a paper read by Mr. Dabney H. Maury, M. Am. Soc. C. E., before the American Water-Works Association, in which Mr. Maury attributed the collapsa of the Peoria Water-Works Co.'s standpipe to the corrosive action of return current from an electric railway. Mr. Albert B. Herrick, in the "Street Railway Journal" for Dec. 1 criticises Mr. Maury's conclusions and claims that electrolytic action due to currents from the railway was, under the conditions, impossible.

A NEW RECORDING AIR PYROMETER.*

By William H. Bristol, M. Am. Soc. M. E.†

The instrument herein described has been designed to meet a demand for a pyrometer to measure temperatures of high ranges, and to give continuous records of changes of such temperatures on a moving chart; also to produce an instrument which would be self-compensating for barometric and thermometric changes of the atmosphere without introducing delicate mechanism which would tend to inaccuracy and to preclude its use for commercial purposes.

The diagram (Fig. 1) shows the arrangement of the parts of the pyrometer, which consist simply of a porcelain bulb connected by a capillary tube to a recording pressure gage. The stem of the porcelain bulb is made of sufficient length to pass through the furnace wall. The capillary connecting tube is made of seamless copper. The recording-pressure gage employed is constructed on the same plan as those previously described. By reference to the description it will be found that each pressure tube or spring is constructed on the Bourdon principle, and consists of a tube of closely flattened cross-section formed into a helix of two complete turns.

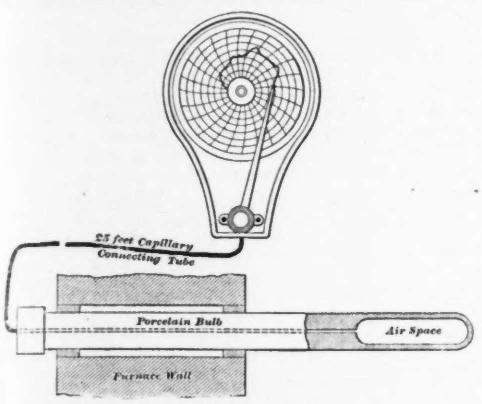

Fig. 1.—Diagram Illustrating Operation of Bristol Recording Air Pyrometer.

Two of these pressure tubes or springs are employed in the recorder—one of these, the indicating tube or spring, being connected to the air bulb by the capillary tube, and adapted to be turned axially by the variations of pressure due to changes of the temperature to be measured; the other, a compensating spring, is mechanically attached to the free end of the indicating tube or spring. The compensating spring is adapted to be turned axially by variations of atmospheric pressure and temperature in a directions opposite to the motion of the first or indicating spring under the same influences. The compensating and pressure tubes are made of equal strength, hence external or internal pressure will produce the same angular movement in each.

The air bulb, capillary connecting tube, and indicating spring are almost exhausted of air, so that when the air bulb is cold, it is subjected on the exterior to nearly atmospheric pressure; but when the bulb is exposed to high temperatures, the remaining inclosed air is expanded so as to practically balance the external pressure, and the bulb is relieved of strains which would, in its weakened condition, tend to injure it.

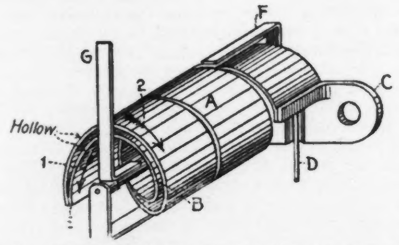

Fig. 2.—Indicating and Compensating Springs of Air Pyrometer.

Fig. 2 shows the indicating and compensating springs of the recorder on an enlarged scale. C is the bracket to which one end of the indicating spring B is secured; D represents a portion of the capillary connecting tube where it enters the stationary end of the indicating spring. The compensating spring A is helically formed in the same direction as the indicating spring, but of a larger diameter, so that it may be placed outside of and concentric with the indicating spring, as shown, and is mechanically attached at E, there being no opening or connection between the interiors of the two springs. At the free end of the compensating spring a bracket F is soldered, making a rigid connection to a shaft through the center of the springs. At the front end of the shaft the recording arm G is rigidly secured.

To illustrate the operation of the compensating spring, assume that the air has been partially exhausted from it, and that the barometer rises under such a condition the indicating spring would turn to the left (Fig. 2) if the compensating spring was not present; that is, in direction of arrow 1; but the compensating spring A being present, and tending to turn to the right, as indicated by arrow 2, through the same angle, the effect of changes in atmospheric pressure is neutralized, and the position of the recording arm is unaffected by the rise of atmospheric pressure. For the same reasons there would be no movement of the recording arm when there is a fall in atmospheric pressure.

If the air is not entirely exhausted from the compensating spring, it will also compensate for thermometric changes in the same manner, the indicating spring tending to turn in the direction of arrow 1 when the temperature falls, and in the direction of arrow 2 when it rises; while the compensating tube will be turned in opposite directions equal amounts under the same influences. By leaving the proper amount of air in the compensating spring the compensation may be made perfect for any change of atmospheric temperature, provided the air bulb is at a given tomperature. The error for small variations from the average temperature to be measured will be so small that it may be neglected. As the tubes are turned in opposite directions by barometric and thermometric changes it is evident that there will be no movement of the recording arm unless due to changes of pressure communicated to the indicating spring through the capillary tube from the air bulb exposed to the temperature to be measured.

The helically formed pressure springs are particularly well adapted for use in this instrument on account of the small internal space, which, together with that of the capillary connecting tube, forms a small volume in comparison with that of the air bulb.

Thus far, special attention has been given to working out the mechanical features of the instrument, and to determine experimentally the most practical form of the porcelain air bulb, and how these bulbs may be applied to continuously record high temperatures. As the volume of air space outside of that exposed to the temperature to be measured is very small, and as there are no corrections or computations necessary for barometric or thermometric changes, it will be a simple matter to calibrate the instrument according to the theory of the air thermometer, which is a recognized standard for measuring temperatures. The instrument here exhibited has been calibrated by comparison with a standard from 32° up to 600° F., and by the melting points of aluminum and copper for the scale up to 2,000° F.

This instrument is the joint invention of E. H. Bristol and the author.

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*A paper presented at the New York meeting of the American Society of Mechanical Engineers.

†Assistant Professor of Mathematics, Stevens Institute, Hoboken, N. J.

* * *

POPULATION OF CITIES OF OVER 25,000 INHABITANTS IN 1900 AND THEIR GROWTH IN A DECADE.

The compilation of the results of the twelfth census show that in June, 1900, there were in the United States 159 cities having a population of 25,000 and over, as compared with 124 such cities in 1890. The aggregate population living in cities of 25,000 population and upwards was 19,694,625 in 1900, and in 1890, 14,855,489, a total gain of 4,839,136, or 32.5%. In the accompanying table will be found the population of each of these 159 cities in 1900 and in 1890, followed by the increase or decrease for the decade and the corresponding percentage.

One thing the table does not always show, and that is the relative importance of the cities as centers of population. Thus, although New York stands first in the list, its pre-eminence as a center of population is far greater than is indicated by the number of people within its political boundaries. To say nothing of the cities and towns of less than 25,000 inhabitants that are really a part of the commerce, industry and life of New York, there are seven cities in this table, with an aggregate population of 777,598, that are really a part of the great metropolis, as follows: Newark, Jersey City, Paterson, Hoboken, Elizabeth, Yonkers, Bayonne and Passaic, with populations ranging from 246,070 to 27,777.

Pittsburg stands eleventh in the list, with 321,616, but if the near-by population in the two great river valleys were added, so as to show the real strength of this great industrial center, Pittsburg would probably stand sixth, following directly after Boston. Allegheny alone has a population of 129,896, making, with Pittsburg, a total of 461,512, besides which there are a host of small towns close at hand.

Boston would be a great gainer if the many populous cities and towns pressing so closely around and even locking in with it were classed as one city, as they so largely are one in interest. Cambridge, Lynn, Somerville, Brockton, Salem, Chelsea, Malden, and Newton, in the order named, are all included in our table, and have an aggregate population of 399,384, making 960,276, when added to Boston's 560,892. If the twenty or more other cities and towns within a few miles of Boston were added, the Boston district would pass way beyond the million mark:

Cities Having 25,000 Population and Over by the U. S. Census of 1900.

Cities.	Population 1900.	Population 1890.	Increase from 1890 to 1900 Number.	Increase from 1890 to 1900 Per cent.
New York, N. Y.	3,437,202	2,492,591	944,611	37.8
Chicago, Ill.	1,698,575	1,099,850	598,725	54.4
Philadelphia, Pa.	1,293,697	1,046,964	246,733	23.5
St. Louis, Mo.	575,238	451,770	123,468	27.3
Boston, Mass.	560,892	448,477	112,415	25.0
Baltimore, Md.	508,957	434,439	74,518	17.1
Cleveland, O.	381,768	261,353	120,415	46.0
Buffalo, N Y.	352,387	255,664	96,723	37.8
San Francisco, Cal.	342,782	298,997	43,785	14.6
Cincinnati, O.	325,902	296,908	28,994	9.7
Pittsburg, Pa.	321,616	238,617	82,999	34.7
Washington, D. C.	287,718	230,392	48,326	20.9
New Orleans, La.	287,104	242,039	45,065	18.6
Detroit, Mich.	285,704	205,876	79,828	38.7
Milwaukee, Wis.	285,315	204,468	80,847	39.5
Newark, N. J.	246,070	181,830	64,240	35.3
Jersey City, N. J.	206,433	163,003	43,430	26.6
Louisville, Ky.	204,731	161,129	43,602	27.0
Minneapolis, Minn.	202,718	164,738	37,980	23.0
Providence, R. I.	175,597	132,146	43,451	32.8
Indianapolis, Ind.	169,164	105,436	63,728	60.4
Kansas City, Mo.	163,752	132,716	31,036	23.3
St. Paul, Minn.	163,065	133,156	29,909	22.4
Rochester, N. Y.	162,608	133,896	28,712	21.4
Denver, Colo.	133,859	106,713	27,146	25.4
Toledo, O.	131,822	81,434	50,388	61.8
Allegheny, Pa.	129,896	105,287	24,609	23.3
Columbus, O.	125,560	88,150	37,410	42.4
Worcester, Mass.	118,421	84,655	33,766	39.8
Syracuse, N. Y.	108,374	88,143	20,231	22.9
New Haven, Conn.	108,027	81,298	26,729	32.8
Paterson, N. J.	105,171	78,347	26,824	34.2
Fall River, Mass.	104,863	74,398	30,465	40.9
St. Joseph, Mo.	102,979	52,324	50,655	96.8
Omaha, Neb.	102,555	140,452	*37,897	*26.9
Los Angeles, Cal.	102,479	50,395	52,084	103.3
Memphis, Tenn.	102,320	64,495	37,825	58.6
Scranton, Pa.	102,026	75,215	26,811	35.6
Lowell, Mass.	94,969	77,696	17,273	22.2
Albany, N. Y.	94,151	94,923	*772	*0.8
Cambridge, Mass.	91,886	70,028	21,858	31.2
Portland, Ore.	90,426	46,385	44,041	94.9
Atlanta, Ga.	89,872	65,533	24,339	37.1
Grand Rapids, Mich.	87,565	60,278	27,287	45.2
Dayton, O.	85,333	61,220	24,113	39.3
Richmond, Va.	85,050	81,388	3,662	4.4
Nashville, Tenn.	80,865	76,168	4,697	6.1
Seattle, Wash.	80,671	42,837	37,834	88.3
Hartford, Conn.	79,850	53,230	26,620	50.0
Reading, Pa.	78,961	58,661	20,300	34.6
Wilmington, Del.	76,508	61,431	15,077	24.5
Camden, N. J.	75,935	58,313	17,622	30.2
Trenton, N. J.	73,307	57,458	15,849	27.5
Bridgeport, Conn.	70,996	48,866	22,130	45.2
Lynn, Mass.	68,513	55,727	12,786	22.9
Oakland, Cal.	66,960	48,682	18,278	37.5
Lawrence, Mass.	62,559	44,654	17,905	40.0
New Bedford, Mass.	62,442	40,733	21,709	53.2
Des Moines, Ia.	62,139	50,093	12,046	24.0
Springfield, Mass.	62,059	44,179	17,880	40.4
Somerville, Mass.	61,643	40,152	21,491	53.5
Troy, N. Y.	60,651	60,956	*305	*0.5
Hoboken, N. J.	59,364	43,648	15,716	36.0
Evansville, Ind.	59,007	50,756	8,251	16.2
Manchester, N. H.	56,987	44,126	12,861	29.1
Utica, N. Y.	56,383	44,007	12,376	28.1
Peoria, Ill.	56,100	41,024	15,076	36.7
Charleston, S. C.	55,807	54,955	852	1.5
Savannah, Ga.	54,244	43,189	11,055	25.5
Salt Lake City, Utah.	53,531	44,843	8,688	19.3
San Antonio, Tex.	53,321	37,673	15,648	41.5
Duluth, Minn.	52,969	33,115	19,854	59.9
Erie, Pa.	52,733	40,634	12,099	29.7
Eilzaheth, N. J.	52,130	37,764	14,366	38.0
Wilkesbarre, Pa.	51,721	37,718	14,003	37.1
Kansas City, Kan.	51,418	38,316	13,102	34.1
Harrisburg, Pa.	50,167	39,385	10,782	27.3
Portland, Me.	50,145	36,425	13,720	37.6
Yonkers, N. Y.	47,931	32,033	15,898	49.6
Norfolk, Va.	46,624	34,871	11,753	33.7
Waterbury, Conn.	45,859	28,646	17,213	60.0
Holyoke, Mass.	45,712	35,637	10,075	28.2
Ft. Wayne, Ind.	45,115	35,393	9,722	27.4
Youngstown, O.	44,885	33,220	11,665	35.1
Houston, Tex.	44,633	27,557	17,076	61.9
Covington, Ky.	42,938	37,371	5,567	14.8
Akron, O.	42,728	27,601	15,127	54.8
Dallas, Tex.	42,638	38,067	4,571	12.0
Saginaw, Mich.	42,345	46,322	*3,977	*8.5
Lancaster, Pa.	41,459	32,011	9,448	29.5
Lincoln, Neb.	40,169	55,154	*14,985	*27.1
Brockton, Mass.	40,063	27,294	12,769	46.7
Binghamton, N. Y.	39,647	35,005	4,642	13.2
Augusta, Ga.	39,441	33,300	6,141	18.4
Pawtucket, R. I.	39,231	27,633	11,598	41.9
Altoona, Pa.	38,975	30,337	8,636	28.4
Wheeling, W. Va.	38,878	34,522	4,356	12.6
Mobile, Ala.	38,469	31,076	7,393	23.7
Birmingbam, Ala.	38,415	26,178	12,237	46.7
Little Rock, Ark.	38,307	25,874	12,433	48.0
Springfield, O.	38,253	31,895	6,358	19.9
Galveston, Tex.	37,789	29,084	8,705	29.9
Tacoma, Wash.	37,714	36,006	1,708	4.7
Haverbill, Mass.	37,175	27,412	9,763	35.6
Spokane, Wash.	36,848	19,922	16,926	84.9
Terre Haute, Ind.	36,673	30,217	6,456	21.3
Dubuque, Ia.	36,297	30,311	5,986	19.7
Quincy, Ill.	36,252	31,494	4,758	15.1
South Bend, Ind.	35,999	21,819	14,180	64.9
Salem, Mass.	35,956	30,801	5,155	16.7
Johnstown, Pa.	35,936	21,805	14,131	64.8
Elmira, N. Y.	35,672	30,893	4,779	15.4

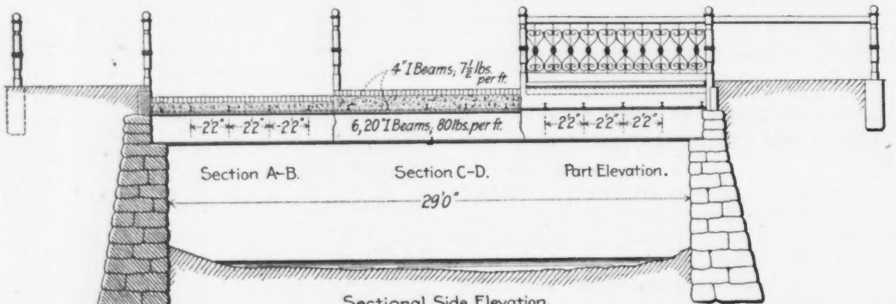
Allentown, Pa.	35,416	25,228	10,188	40.3
Davenport, Ia.	35,254	26,872	8,382	31.1
McKeesport, Pa.	34,227	20,741	13,486	65.0
Springfield, Ill.	34,159	24,963	9,196	36.8
Chelsea, Mass.	34,072	27,909	6,163	22.0
Chester, Pa.	33,988	20,226	13,762	68.0
York, Pa.	33,708	20,793	12,915	62.1
Malden, Mass.	33,664	23,031	10,633	46.1
Topeka, Kan.	33,608	31,007	2,601	8.3
Newton, Mass.	33,587	24,379	9,208	37.7
Sioux City, Ia.	33,111	37,806	*4,695	*12.4
Bayonne, N. J.	32,722	19,033	13,689	71.9
Knoxville, Tenn.	32,637	22,535	10,102	44.8
Chattanooga, Tenn.	32,490	29,100	3,390	11.6
Schenectady, N. Y.	31,682	19,902	11,780	59.1
Fitchburg, Mass.	31,531	22,037	9,494	43.0
Superior, Wis.	31,091	11,983	19,108	159.4
Rockford, Ill.	31,051	23,584	7,467	31.6
Taunton, Mass.	31,036	25,448	5,588	21.9
Canton, O.	30,667	26,189	4,478	17.0
Butte, Mont.	30,470	10,723	19,747	184.1
Montgomery, Ala.	30,346	21,883	8,463	38.6
Auburn, N. Y.	30,345	25,858	4,487	17.3
East St. Louis, Ill.	29,655	15.169	14,486	95.4
Joliet, Ill.	29,353	23,264	6,089	26.1
Sacramento, Cal.	29,282	26,386	2,896	10.9
Racine, Wis.	29,102	21,014	8,088	38.4
La Crosse, Wis.	28,895	25,090	3,805	15.1
Williamsport, Pa.	28,757	27,132	1,625	5.9
Jacksonville, Fla.	28,429	17,201	11,228	65.2
Newcastle, Pa.	28,339	11,600	16,739	144.3
Newport, Ky.	28,301	24,918	3,383	13.5
Oshkosh, Wis.	28,284	22,836	5,448	23.8
Woonsocket, R. I.	28,204	20,830	7,374	35.4
Pueblo, Colo.	28,157	24,558	3,599	14.6
Atlantic City, N. J.	27,838	13,055	14,783	113.2
Passaic, N. J.	27,777	13,028	14,749	113.2
Bay City, Mich.	27,628	27,839	*211	*0.7
Ft. Worth, Tex.	26,688	23,076	3,612	15.6
Lexington, Ky.	26,369	21,567	4,802	22.2
Gloucester, Mass.	26,121	24,651	1,470	5.9
South Omaha, Neb.	26,001	8,062	17,939	222.5
New Britain, Conn.	25,998	16,519	9,479	57.3
Council Bluffs, Ia.	25,802	21,474	4,328	20.1
Cedar Rapids, Ia.	25,656	18,020	7,636	42.3
Easton, Pa.	25,238	14,481	10,757	74.2
Jackson, Mich.	25,180	20,798	4,382	21.0

*Decrease.

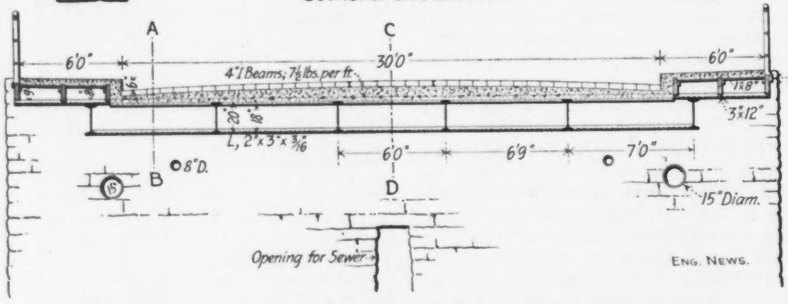
* * *

ECONOMICAL STEEL AND MASONRY HIGHWAY BRIDGE WORK AT RYE, N. Y.

The problem of designing a bridge which shall have the permanent character of steel and masonry construction and which shall yet be low enough in cost to be within the financial ability of rural communities to construct, is one which frequently confronts the engineer. In the accompanying cut we show the method which was adopted to solve this problem in one case. The two bridges which were constructed according to these plans were erected over Blind Brook in the town of Rye, N. Y., and were designed by Mr. Frederick S. Odell, M. Am. Soc. C. E., of Port Chester, N. Y. The work was done by a local contractor, an intelligent stonemason, and notwithstanding the fact that the contracts were let last November, when the cost of iron and steel was about at the highest point, the two bridges were erected for $3,576, including the rebuilding and extension of the old abutments.



Sectional Side Elevation.



Transverse Section.

STEEL GIRDER AND CONCRETE FLOOR BRIDGE OVER BLIND BROOK, AT RYE, N. Y.
Frederick S. Odell, Port Chester, N. Y., Engineer.

The following extract from the specifications in connection with the drawings will perhaps best explain the character and extent of the work:

The bridge is designed and proportioned to support a uniformly distributed load (including its own weight) of 200 lbs. per sq. ft. of surface. The bridge floor will be 32 ft. in length by 42 ft. in width; there will be a carriage way 30 ft. in width and two sidewalks, each 6 ft. wide. This floor will be supported by six steel beams 32 ft. long. The beams shall be of medium steel of standard manufacture, 20 ins. in depth, weighing 80 lbs. per ft. They will be spaced as shown on the plan, and secured in position at their bottoms in the center by a tie rod of angle iron 2 × 3 ins. × 34½ ft., notched to fit the beams and attached to the flanges by hook bolts. The outer beams shall be similarly secured at their top to the beams crossing them.

On the beams and crossing them shall be laid light steel I-beams, weighing 7½ lbs. per ft.; they shall be spaced 2 ft. 2 ins. apart and extend the full width of the bridge. Over and around these shall be placed concrete, composed of one part Portland cement of an approved brand, two parts clean sharp sand, with five to six parts trap rock broken to pass a 1½-in. screen. The sand and cement shall be well mixed dry, then sufficiently wet to make a rather stiff paste, then the broken stone that has been previously wet shall be added in such quantities that the voids shall be completely filled and leave a slight excess of mortar. The concrete shall be deposited and rammed into place and the work of placing it carried on continuously until complete; care shall be exercised in forming the surface to exact shape to receive the brick pavement.

The sidewalks shall be of concrete 4 ins. in thickness, supported by floor timbers of 3 × 12-in. yellow pine. The upper 2 ins. of concrete shall be composed of finely broken stone ranging in size from a grain of buckwheat to a beech nut. The surface shall be properly finished and worked into fine corrugations.

The pavement shall be of Mack or Porter repressed brick, bedded in cement mortar, as specified for concrete. The joints shall be grouted with Portland cement grout, flushed in. When finished, the pavement will be covered with 1 in. of sand, to remain until one week before the bridge is opened for traffic. At each end of the brick pavement shall be placed a header of bluestone curbing 4 ins. thick by 16 ins. deep and in lengths of about 3 ft. They shall be set to conform to the section of pavement, the top of the curbstones being flush with the surface.

The outer edges of the sidewalks will be protected by a substantial ornamental railing of the Germantown pattern, as shown on the plan. It shall be made in panels of 10 ft. lengths, with ornamental posts of cast iron. The posts will be firmly secured to the floor beams of the sidewalk by flanges and lag screws. The railing shall extend one panel of about 10 ft. beyond the ends of bridge to guard the sidewalk approaches. The end posts shall be firmly anchored to stones set 3 ft. in the ground. All exposed metal work shall receive two good coats of paint.

The abutment masonry was of coursed quarry stone laid in a 1 part Portland cement and 2½ parts sand mortar. We are informed by the engineer that the reason for the excessive thickness of concrete used at the crown of the roadway was that it was thought desirable not to complicate the work by crowning the iron work carrying the concrete. The bridges have now been in use several weeks, one of them carrying a trolley car line as well as the ordinary street traffic. For the information from which this description has been prepared we are indebted to the engineer, Mr. F. S. Odell, M. Am. Soc. C. E.

* * *

U. S. FOREST RESERVATIONS, says the annual report of the Secretary of the Interior, now number 38 and cover 46,772,129 acres. The previous report gave 37 reservations with 46,425,529 acres. The new reserve is the Santa Ynez, in California, covering 145,000 acres; but the dimensions of other reserves were changed during the year.

* * *

THE APPROXIMATE COST OF RAILWAYS per mile of track, for the years 1898-1900, inclusive, and for rail weighing from 56 lbs. to 90 lbs. per yd. at prices per ton ranging from $20 to $35 is given in tabular form by Mr. Francis How, public accountant, of 6 Wall St., New York. While the entire table can be obtained by applying to Mr. How, an abstract is here given of the summaries:

Year.	Price of rails per ton.	Weight of rail per yd.	Rail, and fastenings, cost per mile.	Grand total.*
1898.	$20	56 lbs.	$2,023	$4,143
		70 lbs.	2,545	5,545
		90 lbs.	3,199	6,739
1899.	$35	56 lbs.	3,629	6,544
		70 lbs.	4,576	8,566
		90 lbs.	5,729	10,469
1900.	$26	56 lbs.	2,618	5,092
		70 lbs.	3,295	6,795
		90 lbs.	4,144	8,394

*Ties, ballast and tracklaying added; cost per mile.

* * *

THE U. S. POST OFFICE DEPARTMENT, in its annual report for 1900, gives its annual financial operations as follows:

Ordinary postal revenue	$100,899,433.44
Money order business	1,455,579.85
Total receipts from all sources	$102,354,579.29
Total expenditures—1900	107,740,267.99
Excess over receipts	$5,385,688.70

The estimated revenue for 1901 is $110,031,172; with estimated expenditures of $121,276,349. Rural free delivery has been in operation for two years, in parts of the country, and the innovation has proved so advantageous that it is to be extended, and for this purpose $3,500,000 is asked for for the year beginning July 1, 1901.

* * *

ZURICH TRAMWAYS have been reported upon by U. S. Consul A. Lieberknecht, of that city. Most of the street railways in Zurich are owned by the city, and all of them will soon pass under its control. The fare is 2½ cts., or 12.5 centimes, when bought in block-books; but it is expected to lower this rate in a few years to 2 cts. Notwithstanding the cheap operation of the line, soft coal costs the city $6.37 to $7.72 per ton at the power station. The change from horse car to overhead trolley has taken place since 1898, and the total length of track is now 25 miles. The girder rails are 40 ft. long and the electric rail bond comes from a New York firm. The track is laid on concrete foundations, or heavy stone masonry, and the trolley wire is generally fastened to the houses, with a special sound-breaker intervening. Where poles are used, these are tubular steel fastened to concrete bases, and these poles also answer for the attachment of gas or electric lamps. The cars are built in Switzerland, but have American Peckham trucks. The street motors and controllers are all of American make. The Engineer in charge was Mr. J. Sigfrid Edström, a Swedish Engineer educated in the United States, but he has recently accepted a position as director of tramways in Gothenberg, Sweden, to construct its new electric lines.

* * *

BOOK REVIEWS.

MUNICIPAL IMPROVEMENTS.—A Manual of the Methods, Utility and Cost of Public Improvements for the Municipal Officer. By W. F. Goodhue, C.E. Third edition; revised and enlarged. New York: John Wiley & Sons. Cloth; 5 × 7 ins.; pp. 207; 11 illustrations in the text. $1.75.

Seven new chapters have been added to this book, the chapter on street surfaces has been entirely rewritten and more or less revision has been given to the remaining 29 chapters of the original book. Mayors, city councilmen and other officials without engineering training can learn much of value from the book, which appears to be designed for them rather than for engineers.

Some of the chapters consist of only a few notes or suggestions. The contents are not logically arranged. Thus, the book opens with three chapters on sewerage, and nearly a hundred pages further on there is a chapter on "Grades of Sewers."

In the new chapter on "Elevated Traffic vs. Subways," the author favors the former, to be developed in accordance with what he calls a "two-story street." All street cars would be on the upper story of the street, and here no other vehicles would be allowed except fire hose carts, fire engines running on the lower street. Foot passengers would travel on either level, but offices and retail stores, except for heavy goods, would be entered, generally from the upper street level. Stores and shops on the lower level, and presumably the street itself, would require artificial light, and would largely replace the use of basements for other than storage purposes.

The revised book also contains a chapter on "Municipal Ownership," ten pages in length, in which that policy is opposed. The author here makes some unguarded statements, and presents his personal opinions as if they were undisputed facts. For instance, he would have some difficulty in proving his statement that municipal ownership in the larger cities "has not, as a rule, proved successful." And he will find many authorities who will challenge the following:

> It is an indisputable fact that in this country consumers pay less for gas and water when supplied by a company than when furnished by a municipality.

CATALOGUE OF THE LIBRARY; AMERICAN SOCIETY OF CIVIL ENGINEERS.—Prepared by Charles Warren Hunt, Secretary, under the Direction of the Library Committee. Published by the Society, 220 West 57th St., New York, N. Y. Paper; 6 x 9 ins.; pp. 73.

As many of our readers are aware, the American Society of Civil Engineers has had work in progress for two years past on a complete classified catalogue of its library, which now comprises some 16,000 titles, representing 32,000 accessions and about 7,000 bindings. The plan adopted in cataloguing provided for three separate typewritten card indices: (1) A classified index, (2) an authors' index, and (3) a subject index. The purpose and scope of these several indices are explained in the introduction to the printed catalogue just issued, as follows:

> In the classified index the general classes are indicated by capital letters (A to Z); subdivisions of general classes are indicated by lower-case letters (a, b, c, etc.); consecutive numbers (1, 2, 3, etc.) are used for entries under each subdivision. The books in each subdivision are brought together on the shelves. In the card index the arrangement is alphabetical for each subdivision. Books relating to more than one class are cross-indexed, and, owing to the fact that there are many volumes made up of pamphlets on separate subjects, it quite often occurs that a title must be catalogued in one subdivision, and placed on the shelves in another.
>
> The Author Index is arranged alphabetically, and many duplicate entries are made therein. In order to bring together material which otherwise would be separated, the names of railroads, structures, waterways, municipalities and corporations are frequently used as authors. Thus, a report relating to a railroad, water-works, or sewerage matter, is brought out under the name of the author, and also under the name of the particular corporation to which it relates.
>
> The subject index is arranged under headings covering details not specifically brought out in the classified index. Here, for instance, is brought together for ready reference, material on rails, ties, ballast, water tanks, locomotives, etc., to find which would require search through the books classified in the subdivisions of railroads. This index does not pretend to bring out all material under each such heading, but is sufficiently comprehensive to save much time to one who visits the library in search of information on specific details.

The printed catalogue, which has just been published, reproduces the Classified Index, only, it being considered unnecessary to print the "Authors" and "Subject" indices for general circulation. The scheme of the printed index is quite clearly explained in the first paragraphs of the above quotation and it need not be dwelt upon further here except to remark that in adopting the plan of indexing the various works in the library by classes, the society has doubtless chosen the most convenient and logical method of indexing for a general engineering library. We have further commented upon this index in our editorial columns.

NOTES ON PERMANENT-WAY MATERIAL, PLATE-LAYING, AND POINTS AND CROSSING, With a Few Remarks on Signaling and Interlocking.—By W. H. Cole, M. Inst. C. E., Late Deputy Manager, Eastern Bengal and Northwestern State Railways, Public Works Department, India. Third edition. New York, Spon & Chamberlain; London, E. & F. N. Spon. Cloth, 8vo.; pp. 170; illustrated. $3.

This is an excellent book on track and track work in England and India, but can hardly serve as a practical manual to an American engineer or roadmaster, as the character of construction and methods of practice are so entirely different from the construction and practice prevailing in this country, while the technical terms are in many instances very different from those used in this country. On the Indian railways, also, the width of gage (5 ft. 6 ins. standard) and the climatic conditions introduce special requirements. The first chapter deals with the construction of the track, or permanent way, and it appears that English rail sections are in the main defective in having very steep fishing angles of 20° to 30°, instead of 13°, which is practically universal in this country. To this the author attributes much of the trouble from "creeping." Very short splice bars are used, and it appears that the standard joint for 82-lb. rails on one Indian line consists of 22-in. bars with five ⅞-in. bolts, the middle bolt passing through notches in the rail webs. The author considers that with properly made bolts and nuts, no nutlocks should be necessary. As to fastenings, spikes are not in favor, and the Board of Trade (England) requires T-rails to be secured by through bolts at the joints and on some of the intermediate ties.

The preservative treatment of wooden ties is disposed of in less than a page, and the author seems to be ill-informed on this important subject. Considerable space, however, is devoted to track construction with steel cross ties and with cast-iron bowls and plates in pairs connected by the rods. Both these systems of construction are very extensively and successfully used in India, but it is pointed out that near the coast or in saline soil steel ties and wrought-iron attachments are liable to rapid corrosion. The latest steel ties are 9 ft. long, weighing 135 lbs., or 139 lbs. with fastenings, while a pair of "pots" with their attachments weighs 230 lbs. complete. These latter are very durable, renewals under favorable conditions being as low as 0.57 to 0.8% per annum. The weight per mile of single track laid with 75-lb. double-headed rails is 350 tons on cast-iron ties or 314 tons with cast-iron chairs on wooden ties; with 75-lb. T-rails, the weight is 253 tons with tie-plates and wooden ties, or 221 tons with steel ties. Details are given of the laying and maintenance work on metal track with coolie labor. In fact the chapter on "Platelaying" (tracklaying) deals very largely with work in India. It appears that 40-ft. rails are used to some extent, and that "a few engineers" prefer broken joints, though the author points out that these make a better track when kept in proper condition.

The chapter on "Points and Crossings" (Switches and Frogs) is mainly mathematical, and spring rail frogs appear to be unknown, for they are not even mentioned. This chapter is supplemented by several pages of tables for turnouts on tracks of different gages. This country is credited with the practically obsolete gage of 3 ft., and it is naively remarked that "the 5 ft. 6 ins. gage has, perhaps, by this time disappeared in Canada, Nova Scotia and the United States." The fourth chapter is composed of rules for setting out curves, finding the number of a frog, lead of turnouts, etc. It is followed by a short chapter on signaling and interlocking, dealing exclusively with the manual system. The night signals are given as red for "danger," green for "clear," white for the back light (visible only when the signal is at "danger") and purple for "danger" on starting and other minor signals.

The book, like many English technical books, is compact and of convenient size, well printed in large clear type and not disfigured by excessively wide margins. If a lighter paper had been used the book could have been thinner, but it is already of very handy size and weight. All illustrations are arranged on about 30 lithographed page plates, and while the lines are rather "woolly," the illustrations and lettering are clear and distinct. They are reduced from larger drawings, and by carelessness the scales "½ in. = 1 ft.," etc., have been left on the plates, where, of course, they are quite meaningless. There is a table of contents, but no index, which is a most serious fault in any technical book.

* * *

ANNUAL MEETING OF THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS.

The 22d Annual Meeting of the American Society of Mechanical Engineers was opened Tuesday evening, Dec. 4, at the Society's House in New York city, with the annual address of the President, Charles H. Morgan, upon "Some Landmarks in the History of the Rolling Mill."

As many of our readers well remember, Mr. Morgan has been one of the most prominent figures in the development of wire and wire-rod manufacture in the United States, and he spoke, therefore, with authority, giving a brief history of rolling-mill practice, but treating especially of the rolling of small bars and wire, and illustrating his remarks by lantern slides. He was listened to by as many members as could crowd into the inadequate auditorium of the Society's House. Over 350 were registered in attendance at the first session.

On Wednesday morning the first business was the report of the tellers of election, giving the result of the letter ballot, in the annual election of officers. The regular nominees were elected as follows:

President, Samuel T. Wellman, of Cleveland, O.; Vice-Presidents, Arthur M. Waitt, of New York city, James M. Dodge, of Philadelphia, and Ambrose Swasey, of Cleveland; Managers, W. F. M. Goss, of Lafayette, Ind., De Courcy May, of Scranton, Pa., and D. S. Jacobus, of Hoboken, N. J.; Treasurer, William H. Wiley, of New York city.

The election of officers was followed by the Annual Report of the Council for the fiscal year 1899-1900. The first matter taken up was the question of the appointment of a committee to consider the subject of the valuation of water-power privileges. The Council was of the opinion that the subject was so much a matter of law rather than engineering that it did not properly come within the scope of the Society and, therefore, a committee had not been appointed.

The place for holding the spring meeting of 1901 is under consideration. A proposition had been received that the society should meet in Buffalo, N. Y., during the Pan-American Exposition. The Council has also taken up the question of enlarging the Society's accommodations at the present site and has decided that it is not desirable to take any action at present. The arrangements for heating and ventilating the present auditorium have been improved by the installation of a forced-draft system.

The report then recounted briefly the incidents of the trip of the society to Europe and the Paris Exposition during the past summer. The announcement was made of the election to honorary membership in the society of the Presidents of the Institution of Mechanical Engineers of Great Britain, the Institution of Civil Engineers of Great Britain and the Society of Civil Engineers of France.

Mr. Gus C. Henning has been appointed to represent the society at a meeting of the council of the International Association for Testing Materials, to be held in Zurich, Switzerland. In response to a request from the management of the proposed Engineering Congress to be held in Glasgow, Scotland, in August, 1901, the council has named the following delegates to represent the society: S. T. Wellman, C. H. Morgan, George W. Melville, Sir Benj. Baker, James Dredge, W. C. Unwin, H. F. Parshall, Philip Dawson, Bryan Donkin, H. F. L. Orcutt, O. H. Baldwin and Alex. Sahlin. The council has received a communication from the Verein Deutscher Ingenieure asking the society to take part in the preparation of a polyglot technical dictionary. This the council has declined to do, further than placing the editor in communication with members of the society who are specialists in the various lines. The council has appointed the chairman of a committee which will consider the matter of co-operating with various other national societies to secure the establishment of a National Standardizing Bureau in connection with the United States Office of Standard Weights and Measures. The society's Committee on Standard Methods of Tests and Testing Materials has been discharged in response to requests from various members of the committee. The Finance Committee reports that the second mortgage of $32,000 upon the society house has been cancelled and only the first mortgage of $33,000 remains outstanding. The total assets of the Mechanical Engineers' Library Association are $80,771, and the total liabilities $62,600.

After the report of the council the Junior Committee submitted a brief report of progress, which had to do mostly with the junior meetings. Mr. Henry H. Suplee then read a brief account of the European trip of the society, at the close of which it was voted that formal thanks be sent to the various foreign societies and firms who extended courtesies to the American engineers during their visit abroad.

The Committee on Engine Tests reported that they had finished their work in so far as it related to steam-engine tests, and that they would probably be prepared to report upon the subject of tests of internal combustion motors at the spring meeting.

COMPARISON OF RULES FOR CALCULATING THE STRENTH OF STEAM BOILERS.

In presenting this paper, the author, Mr. H. DeB. Parsons, said that its object was:

> to attract the attention of engineers to variations in the rules now in use for determining the strength of the different parts which make up a steam boiler, with the hope that it may elicit a full discussion of the question whether or not it is desirable to prepare a set of standard rules for strength.

He then compared the specifications of the United States Board of Supervising Inspectors of Steam Vessels, Lloyd's, the British Board of Trade, the British Corporation and the Bureau Veritas and showed that in many instances the different rules lead to widely discordant results.

The paper elicited considerable discussion, in which the rules of the U. S. Board of Inspectors were severely criticised. It was stated that an unsafe boiler could be built while adhering strictly to these rules. One boiler manufacturer said that if he were building a boiler to meet a certain set of specifications, he followed those specifications, otherwise he tried to follow sound engineering principles deduced from experience. It was finally moved and carried that a committee be appointed to take up the subject of boiler specifications.

The next paper, by Mr. Chas. T. Porter, was entitled "A Record of the Early Period of High-Speed Engineering," and was read by title only, at the request of the author. It was printed in our issue of Dec. 6. In discussion of the paper Prof. R. H. Thurston related many interesting facts pertaining the engineering history of the period covered by Mr. Porter's paper.

THE STEAM ENGINE OF MAXIMUM SIMPLICITY AND OF HIGHEST THERMAL EFFICIENCY.

This was a very long paper by Dr. R. H. Thurston, giving a history of the development of the steam turbine, together with much information concerning its thermodynamics and its prospects. This paper gave rise to a discussion on the efficiency and cost of the steam turbine and its adaptability to the propulsion of steam vessels. It was pointed out that the latter is perhaps its least promising field, as the turbine cannot be reversed and operates at a low efficiency when running below its normal speed. It was stated that at present the cost of steam turbines in this country is prohibitive, being much higher than that of reciprocating engines of the same size and efficiency.

The evening session was opened by a paper entitled

"A Note on Centrifugal Fans for Cupolas and Forges," by Mr. Wm. Sangster. The paper was printed in our last week's issue.

THE POWER PLANT OF THE MASSACHUSETTS GENERAL HOSPITAL.

In this paper Mr. F. W. Dean described the steam heating, power and lighting plant designed by him for the above institution. Vertical boilers were used on account of lack of space and the steam pressure is 140 lbs. The exhaust from the engine is used for heating, to be supplemented in case of necessity by live steam passed through a reducing valve. Lighting is done by a two-wire system working at 220 volts. In the discussion the latter feature was severely criticised on account of the unsatisfactory character of 220-volt lamps. As a substitute it was suggested that a three-wire 110-volt system should have been used, with a motor generator or other equalizing device to obviate the necessity for two large generators.

THE CONSTRUCTION OF CONTRACTS.

In this paper the author, Mr. Reginald P. Bolton, criticised the "Uniform Contract" recommended for general use by the American Institute of Architects and the National Association of Builders. In its place he proposes a simple agreement in which for a certain consideration the parties agree to perform the work as described and further agree to adopt as a portion of their agreement certain particulars set forth in the paper.

In the discussion following, the opinion was quite generally expressed that the "Uniform Contract" was too exacting and gave the architect too much power. Mr. John C. Wait said that the courts as a rule refused to enforce a contract that appeared unreasonable in its terms and that they would award only actual damages and not enforce penalties. The form of contract under discussion, he said, was drawn up primarily for the architect's benefit and did not sufficiently protect the contractor.

AN AMERICAN CENTRAL VALVE ENGINE.—This paper, by Mr. E. P. Adams, was printed in our last issue. The design of the engine was favorably commented upon by a number of members.

The Thursday morning session was held in Havemeyer Hall of Columbia University, in accordance with an invitation from President Low of that institution. The first paper to be read was by Mr. Max H. Wickhorst on

A MECHANICAL INTEGRATOR USED IN CONNECTION WITH A SPRING DYNAMOMETER.

The paper is printed elsewhere in this issue.

The next paper, by Mr. Carleton A. Read, described

AN APPARATUS FOR DYNAMICALLY TESTING STEAM ENGINE INDICATORS.

In the apparatus devised by the author it is sought to simulate as closely as possible the conditions under which an indicator is actually used. Steam is turned on and off for very short periods by a mechanically driven three-way cock and at the same time indicator cards are taken. The distance between the horizontal lines on the card gives the compression of the spring for the steam pressure used, which may be accurately measured by independent means. The discussion was devoted principally to the manner of using the steam engine indicator. It was stated that if the steam pressure is left on too long, the spring becomes heated above 212° F. by the action of superheated escaping steam. The presence of oil from the engine cylinder was said to make the indicator piston work hard and to render the instrument inaccurate.

This paper was followed by one by Prof. W. F. M. Goss, entitled:

TESTS OF THE BOILER OF THE PURDUE LOCOMOTIVE,

giving the results, as far as they related to boiler performance, of a long series of tests made upon the locomotive at Purdue University. The conclusions reached are stated by the author as follows:

> The steam delivered by the boiler, tested under constant conditions of running as shown by a calorimeter attached to the dome, is at all times nearly dry, the entrained moisture rarely equaling 1½% and being generally much less than this. While the relationship cannot be perfectly defined, it appears that the entrained moisture increases slightly as the rate of evaporation is increased.
>
> The maximum power at which the boiler was worked with Brazil block coal was such as gave 30 boiler HP. for each foot of grate, and .427 HP. for each foot of heating surface. Experiments with other fuels indicate that these values may be increased by the use of a better coal by about 15%, giving maximum values, which, in round numbers, are 35 HP. per foot of grate and .5 HP. per foot of heating surface. For the type of boiler experimented upon, and under conditions of constant running, these values may be accepted as near the maximum.
>
> The maximum rate of combustion reached was 182 lbs. of coal per foot of grate per hour, which is equivalent to 2.6 lbs. per foot of heating surface.
>
> The maximum draft for any test was that for which the average value was 7.5 ins. If D is the reduction of pressure in the smoke-box measured in inches of water, and G the pounds of coal burned per foot of grate per hour, then
>
> $$D = .037\ G.$$
>
> Also, if W be the total weight of water evaporated per hour, the draft necessary to produce a given evaporation is represented by the equation,
>
> $$D = \frac{.00214\ W}{10.08 - .000244\ W}.$$
>
> These equations apply to the boiler tested when using Indiana block coal.
>
> Smoke-box temperature ranges from 550° F. to 800° F., values which are lower than those which are often assumed to prevail.
>
> The evaporative efficiency of the boiler as affected by different rates of evaporation is expressed by the equation,
>
> $$E = 10.08 - .296\ H,$$
>
> in which E is the pounds of water evaporated from and at 212° F. per pound of coal, and H the pounds of water evaporated from and at 212° per square foot of heating surface per hour; this for the boiler tested using Indiana block coal, and for values of H of not less than 5 or greater than 15. By different coals the constants will vary, results which are near the minimum being expressed by
>
> $$E_{\text{min.}} = 9.4 - .024\ H,$$
>
> and results near the maximum by
>
> $$E_{\text{max.}} = 12.9 - .041\ H.$$
>
> The evaporative efficiency of the boiler as affected by different rates of combustion is expressed by the equation,
>
> $$E = \frac{10.08}{1 + .00421\ G},$$
>
> in which E, as before, is the pounds of water evaporated from and at 212° per pound of coal, and G the pounds of coal burned per foot of grate per hour; this for the boiler tested using Indiana block coal.
>
> The relation of coal burned to water evaporated is expressed by the equation,
>
> $$C = \frac{W}{10.08 - .000244\ W},$$
>
> in which C is the total pounds of coal burned per hour, and W the total pounds of water evaporated from and at 212° per hour; this for the boiler tested using Indiana block coal.
>
> The condition of running the engines, whether with long or short cut-off, or at high or low speed, does not appear to affect the efficiency of the boiler of a locomotive, except in so far as it affects the average value of the draft.
>
> The efficiency of the boiler of a locomotive, as disclosed by two different tests, for which all conditions or running are the same, may vary considerably, due doubtless to inequalities in the firing.

A NEW RECORDING AIR PYROMETER.

This paper, by Prof. W. H. Bristol, is reprinted in this issue. Prof. Bristol exhibited his apparatus, which excited great interest. He demonstrated how exactly the instrument had been connected for changes in atmospheric pressure and temperature by placing it under a bell-jar and pumping out the air and by immersing the working parts in hot and cold water. He stated that while as yet he had made no experiments with very high temperatures, he expected soon to do so. It was stated by one of the members that the porcelain tube, which is an essential part of the instrument, would withstand a temperature as high as 3,000° C.

After the reading of the papers on the program for the morning, the meeting was addressed by President Low, who cordially welcomed the society to Columbia University. He referred to the growing importance of the mechanical engineering profession as contributing to our national strength and greatness, and said that the further progress of the profession was a matter of national concern. At Columbia they were endeavoring to contribute to this progress by the establishment of a first-class engineering school. After the address President Low received the members in one of the rooms of the library.

The afternoon was devoted to inspecting the buildings, shops, and museums of the University. In the mechanical and electrical laboratories most of the machinery was in operation under the supervision of the students. The compound locomotive, "Columbia," running under full steam, attracted much attention. The members were also entertained during the afternoon by the Locomobile Co. of America, and the De Dion & Bouton Co., who had provided eight or ten steam and gasolene motor carriages, with which short runs were made about the city.

In the evening the annual reception of the members and guests by the President and President-elect was held at Sherry's. The attendance was unusually large and demonstrated that engineers are not such unsociable beings as they are commonly reputed to be. There were many ladies present and dancing was continued until long after midnight.

The closing session of Friday morning was opened by a paper on

TESTS OF CENTRIFUGAL PUMPS

by Mr. W. B. Gregory. The tests described were made on a large and a small pump, the former being one of the pumps used in the drainage of the city of New Orleans and the latter a part of the equipment of the Mechanical Laboratory of Tulane University. As the first pump was designed for a head of 12 to 18 ft. and was tested at a head of only 2 ft., it was impossible to obtain a very high efficiency and much difficulty was experienced in making accurate measurements of heads, velocities and other quantities. It was shown that the loss of head due to friction in a pump is a constant multiplied by the velocity head. The velocity of the water in the discharge pipe was measured by means of a Pitot's tube.

The following paper by W. J. Keep, on

HARDNESS OR THE WORKABILITY OF METALS

was read in abstract only. The apparatus described is a vertical drill press, the drill operating on the under side of the work, and being held to it by the action of weights which may be varied. The revolutions of the drill move a paper in one direction, while the penetration of the drill moves a pencil in a direction at right angles thereto. The hardness of the material being drilled is indicated by the angle of inclination of the line traced by the pencil. The variation in hardness of the different parts of the test piece are indicated as the drill passes through it. A special machine has been constructed for uniformly grinding the drill points.

A NEW PRINCIPLE IN GAS ENGINE DESIGN.

This paper, by Mr. C. E. Sargent, is presented in this issue. In the discussion Mr. C. V. Kerr stated that in the engine described the piston rods were lubricated by graphite, which maintained a highly polished surface.

The following paper, by Mr. Kerr, was entitled:

THE HEAT EFFICIENCY OF A GAS ENGINE AS MODIFIED BY THE POINT OF IGNITION.

The principal result reached is that, so far as the heat efficiency of the engine is concerned, ignition should never be later than at the dead point. For a later ignition there is a decided tendency to increase the time of combustion. The concluding paper, by Mr. Forrest R. Jones, entitled "Power and Light for the Machine Shop and Foundry," is reprinted in this issue.

Before disbanding thanks were voted to President Low of Columbia University, the Engineers' Club of New York and the Locomobile and De Dion & Bouton companies for the courtesies extended during the meeting. After adjournment Mr. Arthur Herschman exhibited a steam dray designed by him for the service of the Adams Express Co., and described in Engineering News of May 24, 1900.

This was one of the most successful meetings ever held by the Society, especially in point of attendance, the total registration exceeding 750.

* * *

COMPARATIVE VALUE OF DIFFERENT ARRANGEMENTS OF SUCTION AIR CHAMBERS ON PUMPS.*

By F. Meriam Wheeler,† M. Am. Soc. M. E.

Few appreciate that it is quite as important to provide an air chamber on the suction connection as it is on the discharge side of a pump. By such practice you will not only prevent water hammer and its attendant evils, but it should be remembered that the moving column of water has considerable dynamic energy, and this should be utilized to improve the efficiency of the pump and not to be a detriment to it.

To avoid the noise and serious effect of water hammer, the suction air chamber should not only be used, but it is most important that it should be properly located. I can cite many cases where suction air chambers have been so placed that they were of little or no use.

Experience shows that water or other liquids, passing under or across the opening of an air chamber placed at right angles to the flow, will cause the pump to pound about as much as if no air chamber were used—except at a low rate of speed. Therefore, in arranging suction air chambers I always urge that they be so located that the energy or momentum of the column of water can be expended directly upon the confined air in them.

I recently tested a small "Blake" simplex compound steam pump, not only to demonstrate the advantage of the suction air chamber, but also to show the respective merits of two arrangements of such suction air chambers. As shown in Fig. 1, one arrangement was to have the suction air chamber on the opposite side of the pump to where the supply entered, placed on an elbow. The other arrangement was the location of the suction air chamber in a direct vertical line with the suction pipe, the air chamber being placed on a tee. Gate valves were provided so that either or both suction air chambers could be shut off and opened at will.

At a slow speed, with both chambers out of use, the pump ran quietly enough, but when the number of strokes was increased to a fair rate of speed water hammer was the result.

To give an idea of the serious effect water hammer has on the piping as well as on the pumps themselves, I would call attention to the fact that this pump (intentionally left unbolted to its foundation, with the piping entirely free to move), at 80 double strokes per minute, produced water hammer sufficient to cause the suction pipe to vibrate at each stroke of the pump at least ½-in. horizontally. When either suction chamber was opened, there was no perceptive movement in the piping and the pump ran absolutely quiet. The pump drew its supply from a tank below, the total suction lift being about 5 ft., while the length of horizontal suction pipe was about 20 ft.

The indicator cards taken, and submitted herewith, are quite an interesting study. All the cards were taken while the pump was running at about 80 double strokes per minute, with a water pressure of 75 lbs. per sq. in., the pressure in the steam chest of the high-pressure cylinder being about 60 lbs.

Fig. 2 is an indicator diagram taken when the pump was running with both suction air chambers cut off, while

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*From a paper read at the New York meeting of the American Society of Mechanical Engineers.

†Geo. F. Blake Mfg. Co., 93 Liberty St., New York city.

Fig. 2½ is an indicator taken at the same time from the suction pipe at a point close to the pump. This latter card graphically demonstrates what "water hammer" means. Fig. 3 shows an indicator card taken from the water cylinder of the pump with one suction air chamber in use —the one located on the tee connection. Fig. 4 represents an indicator card taken at the same time from this suction air chamber.

The gate valve on the first-named chamber was then closed, and the valve on the other suction air chamber, placed on the elbow at the opposite side of the pump, was opened. Fig. 5 shows an indicator card taken from the water cylinder with this elbow style of suction chamber; while Fig. 6 shows a card taken at the same time from the suction air chamber itself.

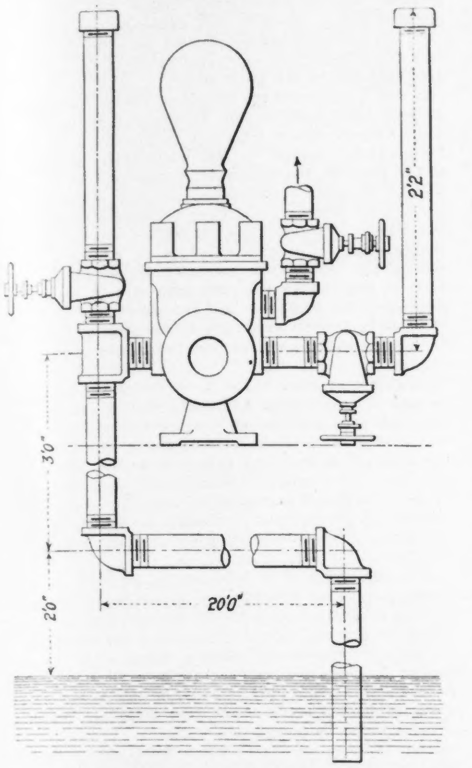


Fig. 1.—Apparatus Designed to Test the Influence of Differently-Located Suction Chambers on the Smooth Working of Pumps.

It will be seen from these indicator cards that the suction air chamber located on the elbow was more efficient than the other (tee style) suction air chamber. The gate valves were wide open when the cards were taken from the suction air chambers, but it was noticed that when the gate valve on the elbow chamber was opened it required only about one turn to stop the water hammer, while in the case of the chamber placed on the tee, it required nearly two turns of the valve to get the same quiet effect. The suction pipe of the pump was a 2-in. size, hence had a cross-section area of 3.14 sq. ins. With the gate valve one turn open it was found, by careful measurement, that the area of the opening was about 0.114 sq. in. With the valve two turns open the actual opening was 0.78 sq. in. Before completing the test the pump was worked up to the extreme of 120 double strokes per minute, and at this speed it continued to run quietly, there being no vibration of the pump or pipes.

Another illustration was the case of the installation of a certain 1,500-HP. compound stationary engine, where the circulating steam pump, which supplied a surface condenser, had nearly 400 ft. of 14-in. suction pipe. I urged the use of a suction air chamber, and understood it would be arranged as shown in Fig. 7. When visiting the place later on I was not surprised at the complaint about the noise made by the pump, as I found they had not properly located the suction air chamber, having placed it at right angles to the horizontal suction pipe, as shown in Fig. 8, explaining that, for certain reasons, they could not approach the pump with the suction pipe on a vertical line, as was originally intended. The trouble was corrected by removing this suction chamber from the position in which they put it, and placing it on the opposite side of the pump with a suitable elbow, as shown in Fig. 9. Thus the impact of the water was received over and across the water barrel of the pump into the suction air chamber. It is hardly necessary to say that after this change was made the pump worked with perfect freedom from water hammer.

In marine practice it is often very difficult to properly locate a suction air chamber, owing to limited space. When not convenient to arrange suction air chambers on either plan as shown in Fig. 1, as, for instance, when the suction approaches the pump horizontally, then the arrangement shown by Fig. 10 is very efficient.

If the manufacturers of pumps would take the trouble to always recommend the use of suction air chambers, and if pipe fitters were made to properly locate such air chambers, there would be less complaint about jar and noise in pumps, to say nothing about the saving of wear and tear.

This remark applies to pumps of all types, whether single or double-acting, vertical or horizontal, and especially to pumps that are liable to run at the higher speeds, such as fire pumps, ash-ejector pumps, wrecking pumps, etc. There are thousands of cases of noisy pumps that could be entirely relieved from the ill effects of water hammer by the use of properly-located suction air chambers.

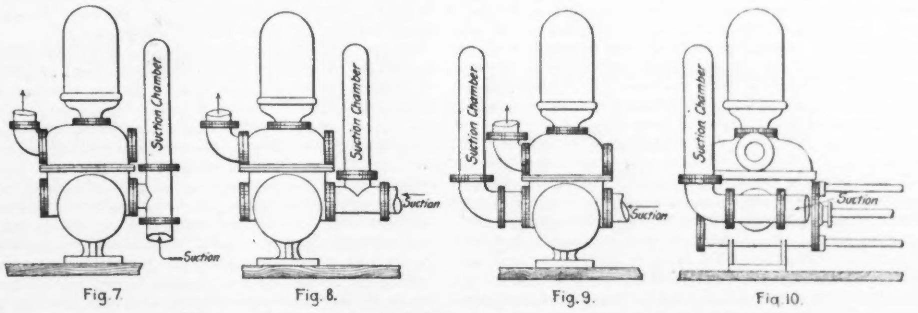


Fig. 7. Fig. 8. Fig. 9. Fig. 10.

FIGS. 7 TO 10.—VARIOUS METHODS OF APPLYING SUCTION CHAMBERS.

SMOKE PREVENTION AT CLEVELAND, O.

Acting under the authority of a legislative act passed April 16, 1900, the city of Cleveland has passed "An Ordinance to Regulate the Emission of Smoke," as follows:

Ordinance No. 27,129—An Ordinance to regulate the emission of smoke.

Section 1—Be it ordained by the Council of the city of Cleveland: That the owner or owners of any boat, locomotive, stationary engine, furnace, boiler or manufactory, or the person or persons employed as engineer or otherwise, in the working or operation of the furnace, engine or engines of said boat, or in the operating of such locomotive, and the proprietor, lessee, agent or occupant of any building within the city of Cleveland, who shall permit, cause, or allow smoke, emitted by the burning of coal, to issue, or to emitted from the smokestack or from any part of any such boat, locomotive, stationery engine, furnace, boiler, manufactory, or from any chimney anywhere within the city of Cleveland of such a nature or in such quantities as to in any way or manner injure the health or property of any such person or of such a nature or in such quantity as to be dangerous, or offensive, or unwholesome, or cause anoyance to any of the people of the city of Cleveland, shall be deemed and held guilty of creating and maintaining a nuisance, and shall for every such offense be fined in a sum not less than $5.00, nor more than $10.00 for the first offense, and for each subsequent offense not less than $15.00, nor more than $20.00.

Section 2.—Smoke emitted from chimneys of private residence houses used and for exclusively private residence purposes other than buildings used as apartment buildings or tenement buildings, which provision is made for residences for more than four families, shall not be deemed within the provisions of this ordinance.

The legislative act on which the ordinance is based applies to cities of the first and second class of the first grade (Cincinnati and Cleveland), and provides for the appointment of "a person of suitable qualifications as supervising engineer" to enforce the provisions of the act, such appointment to be made by the mayor of the city. The supervising engineer for Cleveland is Prof. Chas. H. Benjamin, of the Case School of Applied Sciences, and Mr. H. W. Woodward is first assistant engineer. Prof. Benjamin is beginning his work by combining observations with persuasion. That is, observations of smoke from different chimneys, as seen from some commanding point, are made from time to time and the results, on a decimal scale, are published in the local papers; in addition, interviews are had with manufacturers and suggestions as to the best means of abating smoke are made in a friendly spirit. Another promising method of helping on the work is the making of addresses before public meetings. Thus, in October, 1900, an address was delivered before the Cleveland Chamber of Commerce.

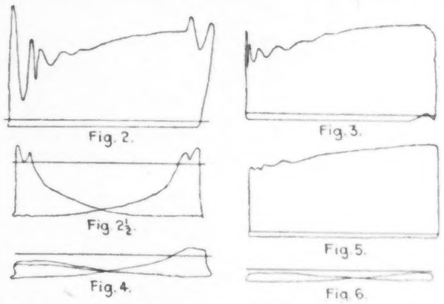
In this address, Prof. Benjamin stated that smoke abatement had been before the Cleveland public for 17 years. Until quite recently the work was in charge of the board of health, whose numerous other duties left it little time for this one.

There are now 350 stokers in Cleveland, besides "numerous other devices having in view the abatement of smoke." Since the office of supervising engineer was created in July, "over sixty stokers and improved furnaces, besides numerous devices which are to some extent smoke abaters" have been put in or contracted for.

Prof. Benjamin closed his address as follows:

We shall also have on hand for consultation by any who wish, a large collection of letters from the principal users of such furnaces in this city, many approving, a few disapproving, but all containing valuable information. We shall be prepared to show any one interested what is being done, and to visit with them, if need be, places where improved furnaces are being used with profit to all concerned.

I would like to have each member of this chamber who hears or who reads this paper, ask himself candidly what this means to him, what building or factory he controls, and whether he is doing what he can to further progress. If not, let him be about it forthwith and not wait for his neighbor, nor wait for a visit from the inspector. It takes a long time for me to get around to all of you, but you can come to me, and ask "what shall I do to be saved?" Cleanliness is next to godliness, and by this standard Cleveland is far from both.



Figs. 2 to 6.—Indicator Diagrams from Pump Shown in Fig. 1 Under Various Conditions.

Let us take up this down-town district, circulate a paper pledging co-operation in the matter of smoke abatement, and if a man refuses to sign we shall know where he stands. I believe few will refuse.

Ten years ago the problem of how to abate smoke was unsolved, but to-day it is not an experiment. Smoke can be easily prevented, and that with profit to the manufacturer. To prevent three-fourths of the smoke in this city would be a greater gain from a business as well as from an aesthetic standpoint, than the accession of all our parks and boulevards, and would take its placo with pure water and clean streets.

And now, gentlemen of the Chamber of Commerce, I ask your support as a body, but more as individuals in this undertaking, for no other body has such powers for good, no other assembly contains as many men who can do what they will with their own.

A NEW PRINCIPLE IN GAS-ENGINE DESIGN.*

By C. E. Sargent, M. Am. Soc. M. E.†

While the gas engine has become such an important prime mover that it is looked upon and is, to-day, a most formidable rival of the steam engine, it has certain disadvantages as a power generator which are not only recognized by its devotees and manufacturers, but are considered inherent and beyond elimination by many of those who have given the internal combustion engine a great amount of study. To overcome these disadvantages, eradicate the defects, improve the efficiency, and design an engine which would meet the requirements of prime movers, and one that would not only be simple and cheap to construct, but one which could be easily manipulated and controlled by the average engineer, has been the object of the author, and the result the subject of this paper.

DISADVANTAGES OF ORDINARY GAS ENGINES.

In order to understand thoroughly the disadvantages of modern gas engines, it is necessary to consider the cycle and operation of the working parts. As it is not in our province to criticise what is recognized as being the best warranted by the state of the art, we will refer only in

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*A paper presented at the New York meeting of the American Society of Mechanical Engineers.

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general to the shortcomings of the modern gas engine of the four-cycle type, by which is meant an engine with one or more cylinders fitted with trunk pistons, working on the Beau de Rochas or Otto cycle, in which the piston acts during the first, or forward, stroke (towards the crank) as a pump, drawing in the charge of air or of a combustible mixture; compressing same on the second, or back, stroke completing the first revolution of the crank shaft; performing work during inflammation, the forward stroke of the second revolution; and exhausting the burnt products during the back stroke of the second revolution. Such is the operation of the modern gas engine, with a few possible exceptions which will not be considered herein. Engines working in this way have been in successful operation twenty years; yet that there is large room for improvement no one denies. On the contrary, authorities on the subject say that the mechanical and thermal results are very inefficient, and anticipate improvements which will improve the mechanical as well as the thermal efficiency.

In specifying the disadvantages of a single-cylinder gas engine, we find that, on account of but one impulse being obtained for every two revolutions of the crank shaft, the working parts must be as heavy and strong for the three idle strokes as for the impulse stroke; therefore, the engine is practically four times as heavy per horsepower as it would be if the impulse were received every stroke of the piston. No compression is possible on the forward stroke, and, as compression takes place every other revolution only on the back stroke, a heavy frame and foundation are necessary to prevent injurious vibration. In order to absorb the inertia of the reciprocating parts and to improve the regulation, some manufacturers put two, three, or even four cylinders side by side, thus getting as many impulses in the cycle of two revolutions as there are cylinders, and by transmitting the strains through the crank shaft, as many compressions as there are impulses. An engine working under these conditions may run very smoothly, be in running balance, and give excellent results from a mechanical standpoint. With a single-cylinder, single-acting engine, to get regulation equal to an engine getting an impulse every stroke, it is necessary to have a flywheel of four times the capacity.

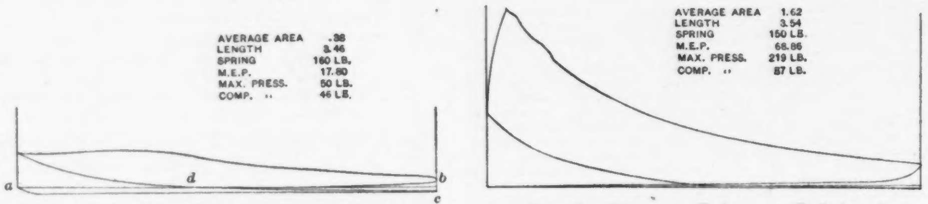

Fig. 1.—Diagram Taken at Quarter Load.

Fig. 2.—Diagram Taken at Full Load.

INDICATOR CARDS FROM 125-HP. WESTINGHOUSE GAS ENGINE.

GOVERNING.—When a single-cylinder engine is governed by missing an explosion, an impulse may be obtained in every fourth or sixth revolution, and, on account of the burnt products having been cleared out, when the engine does take an explosive charge, the first impulse, after skipping a charge, is very severe, giving a much higher initial pressure than the ordinary impulse, which, though it may be conducive to economy of gas, is not conducive to the longevity of the engine. With a "hit and miss" governor, there is greater economy, because the compression is practically uniform; but with this kind of governing the engine is constantly racing, and, though it may be adjusted to vary not over 2% in revolutions between full and no load, its angular velocity is always increasing or decreasing, as a look through a vibrating tachometer at the flywheel of this kind of an engine will impress you. A better method of governing is by varying the mean effective pressure by throttling the fresh charge. A regulation sufficiently close for electric lighting, even with a single-cylinder engine having sufficient flywheel capacity, may be obtained in this way, but at the expense of thermal efficiency. This is best illustrated from an indicator diagram of a light load represented in Fig. 1, and taken from a paper presented to the society one year ago. The engine was rated at 125 HP., and the diagram was taken when the engine had about one-quarter load. Ab is the atmospheric line, aud ac the admission line. The mixture is throttled by the governor, and, as the admission line is about 5 lbs. below atmospheric pressure, there is a loss by wire-drawing represented by the area scda. On account of the throttling of the admission, there is only about half a cylinder volume of combustible mixture; consequently, the compression is only one-half what it should be for economy, and what it is at full load, as shown in the diagram, Fig. 2, taken from the same engine.

The thermal efficiency of the engine when developing the load represented by Fig. 2, is nearly twice that when developing the load shown in Fig. 1; yet the temperature and pressure of release at the end of working stroke of the full load are considerably more than at one-quarter load. As the efficiency should increase as the terminal pressure and temperature are lowered, throttling the admission and lowering the compression and its attendant results must cause a considerable loss. As the load decreases, the quantity of combustible mixture is decreased; but as the clearance remains the same, the mixture is weaker, inflammation is slower, and as ignition takes place at the same point, the piston runs away from the explosion (see Fig. 1), making the highest pressure and temperature where the proportion of cooling surface is greater, which accounts for the rapid falling of efficiency pointed out in previous paragraph.

The high pressure and temperature when the exhaust opens at full load are the sources of greatest loss in an internal combustion engine. In the paper from which the diagrams were taken, it was stated that 57% of the heat units pass into the exhaust, the pressure of which, at the moment of opening, is 40 to 50 lbs. absolute, and the temperature from 1,100° to 1,200° F. This terminal pressure is so great that in large engines it often requires a lifting force of more than a ton to open the exhaust valve, and though the actual horse-power used is small, the strain on the gears and shafting is worth eliminating.

With a termiual pressure of 40 to 50 lbs. mufflers to deaden the "bark" are absolutely necessary, and with a release at 1,200° F., and an initial temperature of probably 2,700° F., the average temperature of a cylinder must be near the critical point where with high compression, back firing and premature ignition are liable to take place, the cooling effect of the jacket water to the contrary notwithstanding. This is one of the most aggravating things in an internal combustion engine, and any change in design which would overcome this trouble would be of inestimable value.

STARTING.—As all gas engines which are sufficiently economical for practical purposes must compress the combustible charge before ignition and, consequently, before any work is given out or stored in the flywheels, the starting of the internal combustion engine has been one of the greatest troubles to overcome. It is accomplished in small sizes by man-power storing up energy in the flywheels, or by compressing the entire charge with a windlass; while in larger sizes, compressed air, with its necessary reservoirs, pipes, and pumps is used. Many start the engine with a charge of gunpowder or combustible mixture of gas and air, giving from a standing position such a shot that the inertia stored up will compress the next charge and keep the engine going. Nearly every manufacturer has a perfect starter, yet, where compression must take place before ignition, the difficulties encountered in always getting an engine to go, are evident. Such are some of the thermal and mechanical disadvantages of the modern gas engine.

THEORY OF THE IDEAL GAS ENGINE.—In accounting for the heat in the internal combustion engine, we have: (1) Heat converted into work. (2) Heat imparted to water jacket. (3) Heat released in exhaust.

As the sum of the three quantities is a constant, it is necessary, in order to make the first as large as possible, to reduce the second and third. As the cylinder walls must be sufficiently cool for proper lubrication, we cannot expect to reduce the second loss materially, yet by improving the conditions, the best possible efficiency may be obtained. The transmission of heat from the burning charge to the cylinder walls depends, for one thing, on the ratio of surface exposed to the unit of volume. The reason that compression is necessary for high efficiency, and that the efficiency increases with compression is, that while the volume remains constant, the cooling surface for radiation diminishes. It is impossible to get any more heat out of the gas than there is in it, and with complete combustion there is just as much heat released in a non-compression engine of the Lenoir type as in the Diesel motor, and the only reason why the latter shows such excellent efficiency, is because the compression is so high that the surface of radiation during inflammation is comparatively small.

Time is another factor in the transmission of heat from the burning charge. If the engine is put on center, so that it cannot be moved, and no heat can be turned into work, and the charge exploded in the compression chamber, the pressure should fall to the same pressure it had before ignition took place, in about 1½ seconds, which shows that high-piston speed is essential in a gas engine, as well as in the steam engine, for economy. The quicker we can expand the burning gas, the less heat will go into the jacket and more into work.

The transmissiou of heat from the burning charge to the water jacket depends also upon the difference between the mean temperature of the gases during the working stroke and that of the cylinder walls, so that the lower the terminal temperature, other things being equal, the lower the mean temperature and less heat will be lost. We see, then, that the loss of heat to the water jacket depends on the ratio of the volume of explosive mixture to the surface which confines it, to the piston speed, and to the average temperature of the burning gases, none of which have been neglected in the designs presented.

The prime object in bringing out a new design of gas engines was to get a more complete expansion of the gases during the working stroke. It is evident that if a cylinder full of combustible mixture is compressed, ignited, and allowed to expand to its original volume (a cylinder full) and then released, the terminal pressure and temperature will be considerably higher than when compression began, while if this expansion could continue until the pressure and temperature were the same as before compression, the only loss would be the amount of heat absorbed by the water jacket.

In Fig. 3, ehicbfe is the theoretical perfect diagram of an internal combustion engine igniting the charge at constant volume (taken from the latest edition of Clerk's "Gas and Oil Engine," p. 50), which shows an expansion of the gases to the atmospheric pressure. Mr. Clerk, as well as all other authorities on internal combustion engines, says, however, that such a complete expansion has never been obtained. The desirability of attaining such results, however, is emphasized by all writers when discussing the possibilities necessary for an increased efficiency, and though the realization of such results in a single-cylinder engine is not considered, the probability of securing a better expansion of the gases by compounding is suggested, and has been tried with more or less success.

Looking once more to Fig. 3, we see that if the original volume of combustible mixture, including the clearance, were taken as a unity, an expansion to 2 7-10 volumes would bring the pressure to atmospheric. While the writer has obtained as great an expansion as that indicated in Fig. 3, the work produced is so small during the last part of the stroke, and an engine so large for the power developed, no attempt has been made in practice to get, at full load, a lower terminal pressure than 18 to 20 lbs. absolute.

Referring to Fig. 3, if lb represents the length of piston stroke, then fehbf would be the theoretical power diagram such as is obtained from the modern gas engine, wherein expansion beyond original volume does not take place. If instead of releasing the burning charge at h, we could expand to twice the volume of piston displacement and release at l, there would be added to our power diagram area, hikbh, and much of the heat ordinarily lost in the exhaust would be turned into work.

Now, to build an engine which would give a diagram, feikf, all that is necessary is to cut off the fresh charge at b, allow it to rarefy and return to atmospheric pressure at b, as the piston returns, compress to f, ignite and expand from e to i, the end of the forward stroke where exhaust opens and the products are driven out as the piston travels from k to l, the end of the back stroke, when the operation is completed.

Figs. 4 and 5 are diagrams taken from an engine hereafter described, working in this way, which approach very closely the ideal card, and Fig 6 is a diagram taken at the same time with a light spring fitted with a stop.

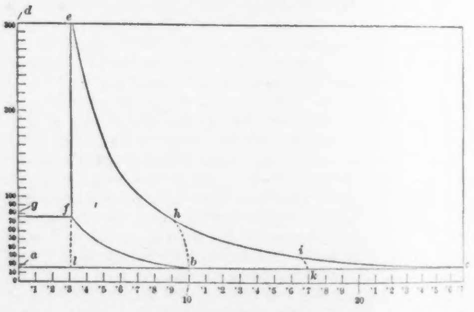

Fig. 3.—Theoretical Indicator Diagram of Perfect Gas Engine.

Referring to Fig. 6, ab is the atmospheric line and length of stroke; when the piston travels from a to b, the charge is admitted to e; when the admission is cut off, the pressure drops to c, the end of the stroke, and returns to e, as the piston returns where compression above atmosphere begins and continues to d (Fig. 4) when ignition and expansion take place, and the exhaust opens at the end of the stroke b, slightly above the pressure of the atmosphere. There is no loss in rarefying the fresh charge from e to c, as the work is given back to the piston as it returns to c, and the compression above atmosphere takes place during the last half of the compression stroke. If the full power of the engine is obtained, say, at one-half cut-off, and it is so designed that the highest compression permissible takes place when giving its full rated power, then by making the governor cut off the admission and ignite earlier as the speed increases, we ought to obtain a much higher efficiency for light loads than is usually obtained by throttling the charge, as there is no loss by wire-drawing or by late ignition, as heretofore pointed out.

Fig. 10 is a diagram taken from both ends of one cylinder while developing a constant load. Fig. 7 is a diagram taken with a 120-lb. spring from the engine during a change of load of about five seconds' duration, and Fig. 8 is a diagram during four working strokes, which shows the action of the governor in cutting off the admission earlier, and thereby varying the mean effective pressure; yet, by the simultaneous advance of the igniter, the initial pressure is always greatest at the beginning of the stroke. No loss from wire-drawing is perceptible, and the terminal pressure approaches very closely to the atmospheric line. The only possible chance for a drop, in thermal efficiency with a light load, is that loss caused by a lower compression, which is probably balanced by the lower pressure and temperature of release, for the efficiency depends on the difference between the initial and final temperature, and, as the construction of the engine is such that the compression falls only one-half as fast as the cut-off recedes, the thermal efficiency should be nearly constant throughout a considerable range of load.

With such a cycle, let us see what is gained. With a full load, a diagram shows from 20% to 25% more area than is usually obtained from modern gas engines; consequently, 20% to 25% more heat is turned into work for the same amount of fuel. A noiseless exhaust doing away with mufflers, is possible. The average temperature of the cylinder is reduced several hundred degrees, avoiding the probability of premature ignition. The pressure on the exhaust valve is removed, taking a great strain from the side shaft, and on account of lowering the average temperature, makes possible the use of a piston rod, and a double-acting tandem engine; therefore, an impulse can be obtained at every stroke, as well as a compression for every impulse to absorb the inertia of the moving parts without transmitting any strain through the crank shaft. One crank pin may do four times the work of the crank pin in the ordinary gas engine.

The desirability of using two tandem cylinders and getting an impulse at every stroke, has long been recognized, and tried with more or less success. With a temperature of 1,000° F. or more for the release, it is no wonder that hollow piston rods, with the water running through them, must be used. The catalogue of one prominent manufacturer of gas engines says:

> Single-acting cylinders and trunk pistons are used, because they are absolutely necessary in a gas engine, for the reason that stuffing boxes and piston rods deteriorate too rapidly in such a temperature.

This would, no doubt, be true of the engine described in this catalogue, as the temperature of release is from 1,000° to 1,200° F., maintaining, necessarily, a red-hot exhaust pipe. But, with the comparatively low temperature secured by more complete expansion, a piston rod running through water-jacketed stuffing boxes has worked satisfactorily.

With a variable load, no loss by wire-drawing of the incoming charge is possible; the mean effective pressure drops much faster than the compression, and the highest pressure and temperature take place where the radiating surface is the least. A regulation equal to the best steam engine is possible, and, with a practically uniform compression, smooth running is the result.

While a more complete expansion of the gases is the essential feature of this paper, the adoption of such a cycle not only permits the construction of an engine having an impulse every stroke, but suggests a method of starting an internal combustion engine which has more than fulfilled our anticipations.

Referring to Fig. 6, if the valve mechanism were so arranged that ignition took place at the point of admission closure or cut-off (e), and the exhaust would open at the end of the stroke and remain open during the back stroke of the piston, and repeat the same cycle each crank-shaft revolution, we would get an impulse every stroke, and with but one double-acting cylinder, would get two impulses every revolution of the crank shaft.

By the simple moving of a lever (hereafter described), the engine may be changed from the ordinary four-cycle to this non-compression cycle, and Fig. 9 is a diagram taken from the engine after starting same by turning the flywheel one-quarter of a revolution. The operation is as follows: The charge is drawn in by turning the engine by hand; as soon as the piston which starts at a reaches e, cut-off takes place, and ignition fires the charge, while the pressure goes up to d and expands to the end of the stroke b, where exhaust opens; the other end of the cylinder performing the same operation produces the diagram be'd'ab. As soon as the engine is up to speed, the ordinary cycle is thrown into operation.

The cycle of this engine when starting will be recognized, by those familiar with the history of internal combination engines, as that of the first successful gas engine invented by Lenoir.

Such are some of the advantages of the engine which will now be described, and though the details may have to be modified as long-continued operation will develop the defects, the author feels that the principles evolved are a great advance in internal combustion engine design, and that the method of accomplishing the results obtained will be of interest to the society.

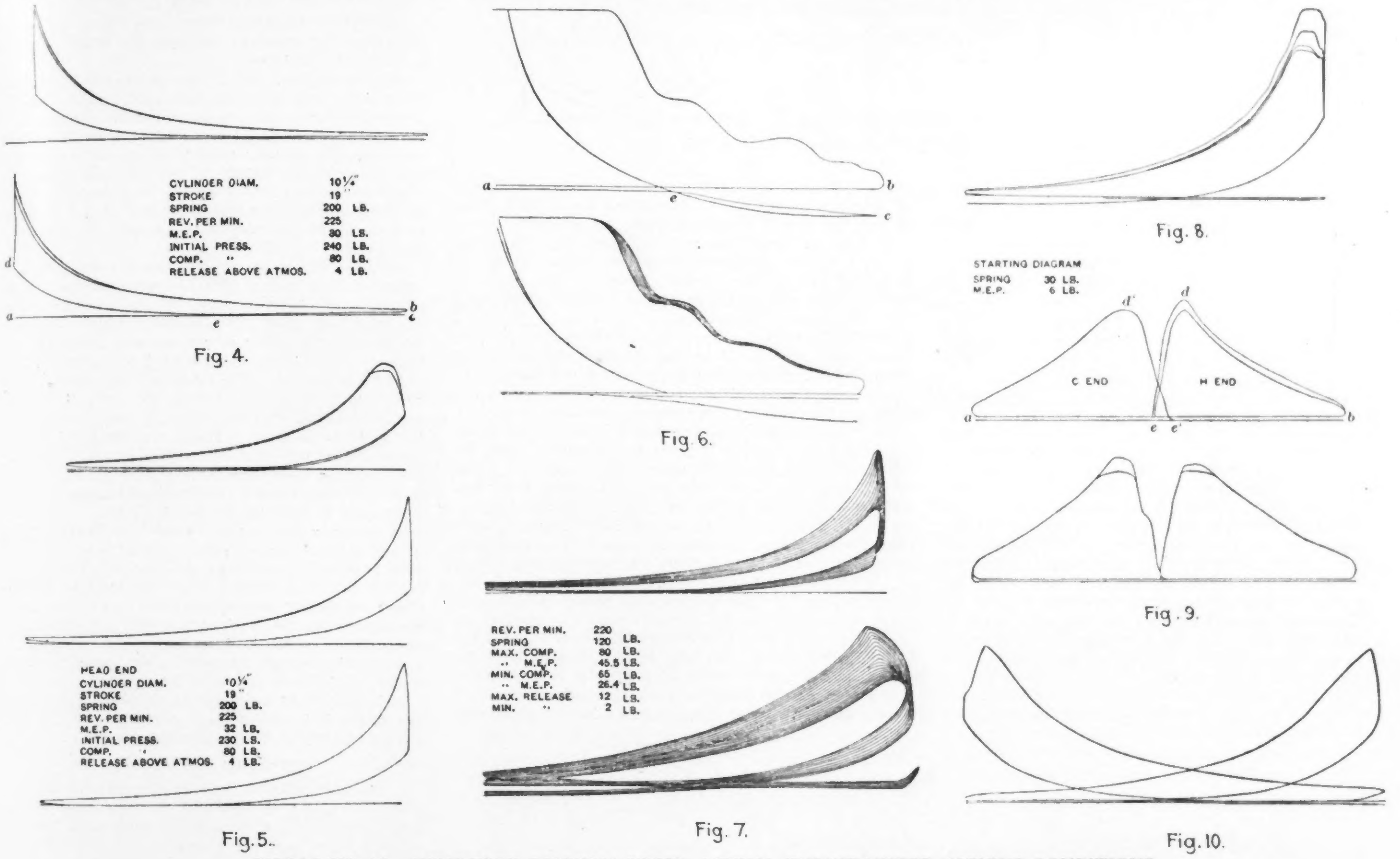

Fig. 4. Fig. 5. Fig. 6. Fig. 7. Fig. 8. Fig. 9. Fig. 10.

FIGS. 4 TO 10.—INDICATOR DIAGRAM FROM ACTUAL ENGINE UNDER VARIOUS CONDITIONS.

DESCRIPTION OF ENGINE.

Fig. 11 is a side elevation of the engine, showing the governor, side shaft, starting lever, valve cams, and igniters. Fig. 12 shows a vertical section lengthwise through the center of a 75-HP. engine, and Fig. 13, a vertical cross section through the crank-end valve of the head-end cylinder of the same engine, looking towards the crank shaft, and Fig. 14 a vertical cross section through the crank shaft, looking towards the cylinder.

In general it is a horizontal center-crank, self-contained engine, the main frame of which rests on a sub-base (which could be replaced by masonry if desired), sufficiently high so that the wheels clear the floor line. The frame is of the self-oiling enclosed type, keeping the oil in and the dust out, with bored guides and side doors giving access to cross head and stuffing box. The cylinders are made with one head cast in and a valve chest on the bottom of each end. The crank-end cylinder is centered in and bolted to the frame. To the head of this cylinder is bolted the distance piece which makes a cylinder head, and to which is centered and bolted the head-end cylinder. A pedestal under the distance head to the sub-base, or foundation, prevents the cylinders from sagging, yet allows linear expansion so necessary in a heat engine. The air for each cylinder is taken from outside of the engine room or from the perforated extension of the sub-base, which deadens the noise of suction, while the exhausts from the cylinders are connected together, and run where desired. No muffler or exhaust head is used. Each cylinder is water jacketed, and the water surrounds each piston-rod stuffing box, and valve chest. Water enters at the bottom center of each cylinder and passes out the center and top through the same opening in outer shell as the cylinder oil passes in, as shown in Fig. 12. Each combustion chamber (clearance space) has one port in the bottom, both for admission and exhaust (Fig. 12), and one vertical poppet check valve, which is held to its seat during compression and inflammation by the internal pressure. There is also a vertical piston valve, R, in each valve chest (Figs. 12 and 13), which opens and closes the exhaust ports and air and gas ports at the proper time.

The side shaft H is driven by worm gears of the same diameter at one-half the speed of crank shaft, as in ordinary four-cycle engines. The valve cams and igniters, one for each explosion chamber, are keyed to this shaft 90° apart, so that one end of one cylinder is always giving an impulse stroke, while the three other ends are exhausting, compressing, or drawing in a fresh charge respectively.

OPERATION OF THE VALVES.—As all valve chests and connections are duplicates, a description of the operation of one will suffice. In Fig. 13, X is a lever, one end of which is forked around collar nuts screwed to the stem of the piston valve R, by which this valve is controlled; Y the roller, carried by the other end of lever, which is held against the cam MK by the spiral spring Z. As the piston in the cylinder makes four strokes every time the cam MK makes one rotation, this cam must perform all operations while going once around. That part of the cam NIKL being a circle, causes no action of the piston valve and is called the normal part of the cam. When the point I is in contact with the roller Y, the piston is at the end of the suction stroke, or at b (Figs. 4 and 6). When the part IK passes the roller Y, one-quarter of the cam shaft rotation, the piston has moved through one stroke and is at a (Fig. 4), while the compression has gone up to d. When K is at the roller Y, the cam G has just passed under the igniter rod B, causing a contact and break between the electrodes at A, igniting the charge, and, by the time L reaches the roller, the piston has made the working stroke, and here that part of the cam LM pushes the roller end of the lever down while the other end goes up, carrying the piston and poppet valve, until it is in the position shown at Ex (Fig. 12) for one stroke, during which exhaust takes place. When the piston is at the end of the exhaust stroke, and M is at Y, the cam has allowed the roller to return to its normal position, as shown in Fig 13, and at Co, where compression is taking place, and Wo, the working stroke (Fig. 12), closing the exhaust port and allowing the poppet to seat; but as the depressed part of the cam MN passes the roller, the spring Z drives the roller up into the depression, while the piston valve goes down until the air and gas ports register as at In (Fig. 12,)when gas and air, in the right proportion, are drawn in. To the lower end of the poppet-valve stem which passes through the piston-valve steam, is attached a small piston W, working in the cylinder V of a dash-pot piston C, which moves with the piston valve. Now, as the piston valve descends by the action of the spring Z from the position of exhaust shown at Ex (Fig. 12) to the position of induction, In, the air in U, being compressed by the downward movement of the dash-pot C, forces up W, raising the poppet valvo P again, which is seated for an instant when the piston valve passes its normal position, passing from exhaust to admission, thus holding open the poppet valve as shown at In, while air and gas are admitted to the cylinder. When the piston has made one-half a stroke, or arrived at e (Fig. 4), the part of the cam N reaches the roller, depresses it, and raises the piston valve to its normal position, as shown in Fig. 13, cutting off both gas and air, and allowing rarefaction to take place from e to c (Fig. 4), when the cycle is repeated.

After cut-off takes place, the poppet may remain open until the return stroke begins, to allow the mixture in the valve chest and cylinder to have equal tension; but from cut-off to exhaust opening, one and one-quarter rotations of the crank shaft, the piston valve remains in its normal position, closing both inlet and exhaust ports. The gas port D, and air port E (Fig. 13), are separated by a web (see also Fig. 15, which is a horizontal section through air and gas ports), so that when the piston valve is in its normal position, and these ports through the bushing are covered, gas is shut off from the air. When induction takes place, the port F in the piston valve registers with the air port E (se position of valves at cylinder port In (Fig. 12) and the gas port D, shown only in Fig. 13. The port F does not run entirely around the piston valve, but is left solid at S (Figs. 13 and 15), which is just the right width to cover the entire gas port, if desired, when the port F registers with the air and gas ports, E and D. By moving the lever O from the crank shaft, this piston valve is rotated, and the part S uncovers the gas port and covers the air port, so that any possible proportion of gas and air may be obtained without, in any way, reducing the area of the inlet ports.

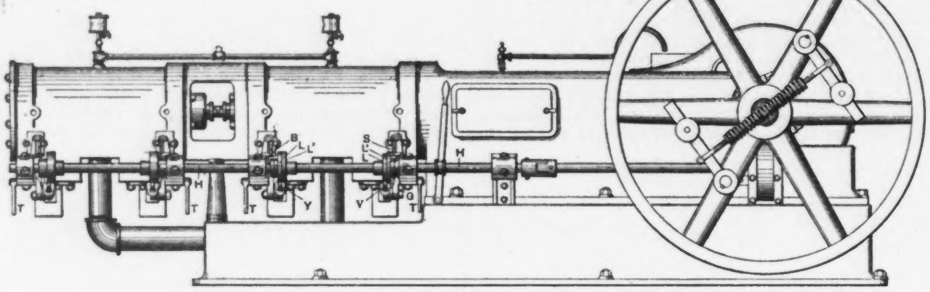

FIG. 11.—SIDE ELEVATION OF 50-HP. GAS ENGINE.

The guide carrying the lever O is graduated, so that the operator can always tell what proportion of gas and air is being used. With blast furnace or producer gas, the gas port might have to be as large as the air port, which is easily accomplished. The electric igniter (see Fig. 13) is so placed in the cylinder that a mixture free from exhaust always surrounds it, insuring proper ignition of the fresh charge, even at atmospheric pressure (see Fig. 9).

As each end of each cylinder is a complete engine of itself, having a separate air, exhaust pipe, and igniter, any one or all of the explosion chambers may be used for producing the power required. By cutting off the gas from any explosive chamber, it ceases doing work; yet compression may take place therein, storing up the energy of the reciprocating parts. By moving the lever T (Figs. 11 and 13) to a horizontal position, its exhaust valve is held open and the cylinder may be examined or the igniter removed without stopping the engine. These levers are also used to hold the exhaust valve of the head-end cylinder open when starting with the crank-end cylinder, thus removing all compression.

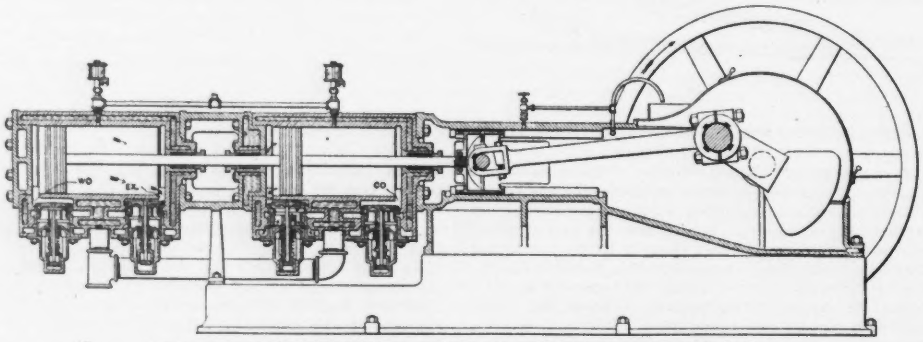

FIG. 12.—LONGITUDINAL SECTION OF 75-HP. GAS ENGINE.

LUBRICATION.—As the ports and valves are on the bottom, any surplus oil in the cylinder will be carried down and will lubricate the piston valves and stems. The crank shaft, cross-head pin, crank pin, guides, and worm gears are lubricated in the following manner:

The worm gears are arranged to run in a tight-fitting case, one-half of which is made in the engine frame by babbiting around the blank before teeth are cut (Fig. 14). The oil from the basin under the crank shaft flows into the gear case and is carried up by the spaces between the teeth, but prevented from passing around by the teeth from the other gear, is forced through a system of pipes to the different sight feed oilers, as shown in Figs. 11 to 14. What oil is not used by the sight feed oilers is by-passed through the goose neck high enough to give the oilers sufficient head, and flows through thé strainer on crank-case hood back into crank-case basin. The crank pin and cross-head pin are oiled by the overflow from the main bearings and the upper slipper in the usual manner. The design of the frame is such that all oil flows by gravity back to the settling chamber in the crank-case basin; yet the crank and counterweights do not dip into the oil, so the working parts are as clean as if they were not enclosed.

The cylinder oilers are of a special design that feed only when the engine is running, stop when the engine stops, yet the feed is always in sight; the quantity in the glass reservoir may always be seen, no pressure or smoke enter the bulls-eye or the reservoir, and the latter may be filled any time without shutting off the needle valve, thus changing the adjustment. From six to fifteen small drops per minute are found to be sufficient for a cylinder and its valves.

GOVERNING.—The governor (Fig. 11) consists of two weighted inertia levers held towards the center of governor pulley by one helical spring on a diametrical line with a right and left nut in each end, so that the tension may be adjusted by turning the spring. The governor arms are keyed to shafts, which extend through a bushed boss on diametrically opposite spokes (Fig. 11), and these shafts have radial arms, the ends of which connect by links to the driving gear, which is otherwise loose on the crank shaft. When the speed goes beyond normal the weighted arms separate and the driving gear, as well as the driven gear, advance in time ahead of the crank shaft. This makes the cut-off earlier, and less gas and air are admitted to the cylinder; consequently, the speed is controlled. If the time of the side shaft advances ahead of the crank shaft, not only will the cut-off be earlier, but the time of every other operation controlled by the cams on this shaft will be advanced. The exhaust will open before the end of the stroke and will close before it, but as the poppet cannot open until the pressure within the cylinder is reduced to atmosphere, the admission begins later and cuts off earlier when engine is cutting off, so that should the governor advance the side shaft 45°, or until the cut-off was at one-quarter of the stroke, then the exhaust would close at three-quarters of the stroke, and no fresh charge would be admitted to the cylinder; and the lowest possible compression, should the admission be entirely cut off, is one-half of the maximum at full load. As the fresh charge becomes more diluted with the exhaust product it becomes a slower-burning mixture, and the time of ignition should be earlier, for which the advance of the cam shaft provides.

STARTING MECHANISM.—If the size of the engine is such that the attendant can turn the flywheels by hand, it is stated as follows:

The vertical lever just in front of the crank-end cylinder (Fig. 11) contains a pin and roller which run in the grooved collar on the cam shaft, and by moving this lever from the crank shaft the cam shaft H is moved longitudinally when the starting cams L' of the crank-end cylinder engage with the rollers Y, and a double igniter cam comes under each igniter rod B. This double igniter cam produces two ignitions at each end of the cylinder for each revolution of cam shaft immediately after cut-offs take place.

Fig. 16 is an end view of the cam L', which admits and exhausts twice during each revolution of the cam shaft, producing the diagrams (Fig. 9). As soon as the engine has sufficient speed to compress a regular charge, the vertical lever is either moved towards the crank, throwing the regular igniters and cams L into operation, or one end of the other cylinder is started, by throwing from a horizontal to a vertical position the lever T. When the cams L' engage with the rollers Y, the crank-end cylinder could be used for a steam or compressed air motor, having a fixed cut-off at half stroke, so if it were not found practicable in very large engines to start by turning the flywheels, compressed air could be used to get up sufficient momentum to start the head-end cylinder.

As the mean effective pressure of the starting diagrams is only about 6 lbs., the engine should start without load with from 8 lbs. to 10 lbs. air pressure, which is about one-fifteenth the pressure used for starting engines in which the regular compression must be overcome. Should circumstances arise in which it would be desirable to start the engine with full load, as in locomotive practice, then compressed air could be used in both cylinders with any predetermined pressure until the maximum speed is obtained, when, by simply moving the lever and opening the gas valve, it is immediately converted into an internal combustion engine with a noiseless exhaust.

GENERAL CONCLUSIONS.

As the mean effective pressure of an engine utilizing only about one-half a cylinder full of combustible mixture is about 60% of that of the ordinary gas engine, the cylinder capacity of an engine maintaining a higher efficiency by greater expansion must be nearly twice the capacity of the ordinary gas-engine cylinder for the same power developed; yet the same could be said of a steam engine utilizing the expansion of the steam compared to one without cut-off. However, as but one crank and lighter flywheels and double-acting cylinders can be used, it is probable that an engine of this type would not weigh more for the same output than the ordinary single-acting engines now on the market.

One of the disadvantages of the modern internal combustion engine advanced when comparing this type of motor with the steam engine is that it cannot be overloaded, and that its range of economy is greatly restricted. If a motor is giving out its full power and more is added, the motor will stop, as there can be no reserve when each induction stroke takes a cylinder full of explosive mixture. On the other hand, the engine must not run below its rated capacity, or the efficiency will be greatly impaired. In other words, the economical range of the modern gas engine is at full load, for reasons heretofore pointed out.

But if, instead of taking a cylinder full of combustible mixture as our unit of fresh charge, we design the engine so that two-fifths or thereabouts of a cylinder full of combustible mixture is sufficient for the average load, with the principle of utilizing the charge and governing pointed out, we will have a much greater range in which the engine may be worked without an appreciable loss in efficiency.

As the compression changes only one-half as fast as the cut-off with a change of load, we can have a reserve of power even if we do release considerably above atmospheric pressure, so long as compression does not go sufficiently high to cause premature ignition. Of course, loading such an engine beyond its normal capacity may even lower the efficiency, as in a steam engine, but sometimes the ability of carry an overload for a short time far outweighs the necessary loss.

The method of retaining the products of combustion to reduce the clearance and thereby raise the compression during light loads may be considered inadvisable by some authorities; yet others show by experiments that the inert gas has no injurious effect on the incoming charge, except possibly to make it a slower burning mixture, which, on account of our method of ignition, has no deleterious effect. With a fixed point of ignition and a slower inflammation as the load decreases, a limit to the piston speed is reached, and is given by some authors as 600 ft. per minute. Yet it is evident that the quicker we can expand the gases the more heat will be turned into work, and the less will be transmitted to the cylinder walls; therefore, if we can advance the time of ignition, so that the maximum pressure takes effect at the beginning of the stroke, the piston speed may be materially increased and the jacket losses minimized.

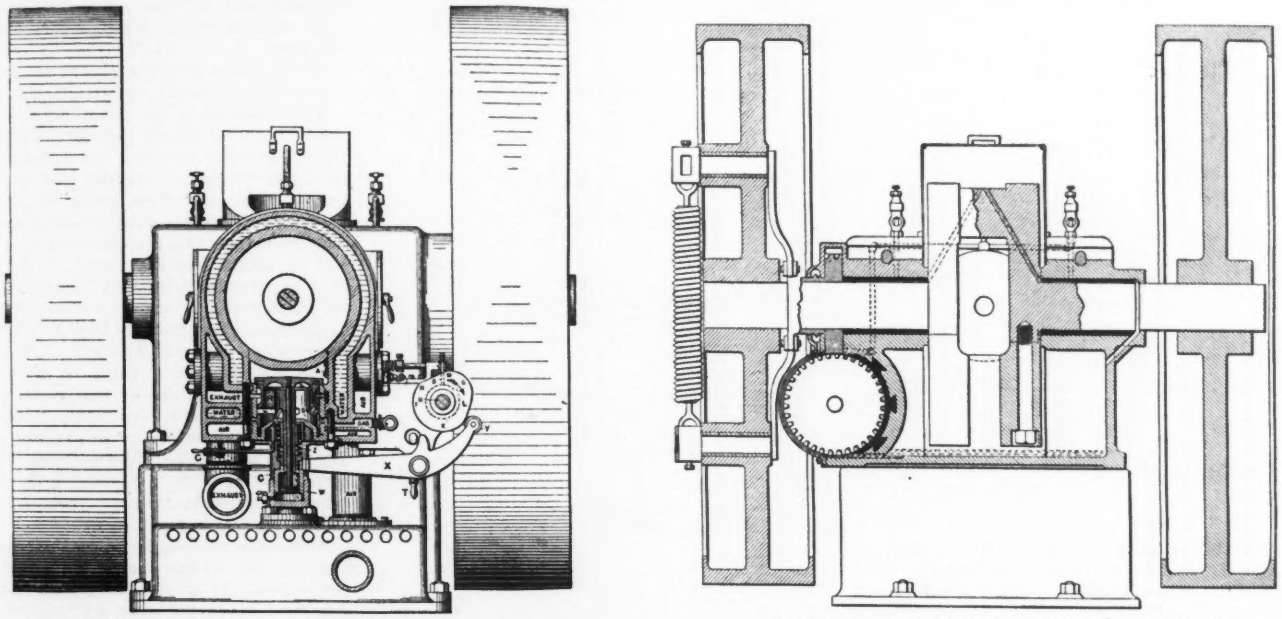

FIG. 13.—SECTION THROUGH CRANK-END VALVE.

FIG. 14.—SECTION THROUGH CRANK-SHAFT.

FIGS. 13, 14.—CROSS-SECTIONS OF 75-HP. GAS ENGINE.

While no exhaustive tests have been made to determine the actual thermal efficiency of the engine under different conditions and loads, a comparison of the amount of gas used per brake horse-power with that of the ordinary gas engine, shows a considerably higher efficiency, and the author hopes the results of an actual test may be presented to the society at its next meeting.

From a mechanical standpoint, very little improvement could be desired. The 10¼ × 19-in. engine which developed 50 HP. with illuminating gas, running at a piston speed of 700 ft. per minute, either light or loaded, produced no perceptible vibration, though it was not anchored to the foundation, but merely rested on the wooden wedges used for leveling up the engine. As the cams and rollers are always in contact, no noise arises from the cams striking the rollers, and though the poppet valves are inclined to rattle when seating, a proper adjustment of the air pressure by the pet cock in dash-pot guide will almost entirely overcome the noise. The worm gears necessary for driving the cam shaft must run in oil to be efficient, and in doing so are noiseless, and make an ideal pump for circulating the oil to the engine bearings.

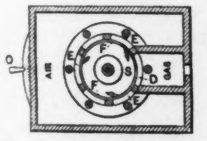

Fig. 15.—Horizontal Section Through Air and Gas Ports.

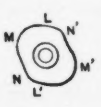

Fig. 16.—Starting Cam.

While the length of the engine is considerable, it is no more than that of tandem compound steam engines of the same stroke, and the height is such that no ladders or galleries are necessary for indicating or making accessible the working parts. The engine from which the half-tone illustrations were taken is fitted with a permanent reducing motion of such a design that pressing a spring starts the indicator drum, and pulling a string stops it.

While the author may have dwelt too long on some points and neglected others, it is hoped that the ideas presented, the advantages gained by their fulfilment, and the means adopted for carrying them out, may be of interest to the society.

RAPID EARTHWORK CALCULATION.

By H. P. Gillette.*

The estimation of yardage forms a large part of the necessary labor of an engineer; and as no class of work is more tedious than the calculation of earth volumes it has been the endeavor of mathematicians to facilitate the work by the use of tables, diagrams and approximate formulas, none of which have met with general favor. Certain college professors have with some reason argued that a good engineer should be satisfied with nothing less than absolute accuracy; some having gone so far as to say that anyone using an excavation formula other than the prismoid formula does so from pure laziness or inability. Professor Johnson, on page 437 of his "Surveying," asserts that there are only two methods that have any claim to accuracy, and gives the preference to the prismoid formula. Practicing engineers, on the contrary, persist in the use of approximate methods, among which the most popular is the one known as the "mean end areas formula," which Johnson condemns. It is well known that this formula receives the sanction of law in New York and other States.

In behalf of the prismoid formula, its extreme accuracy is urged, while in behalf of the mean ends formula its simplicity and rapidity in use are undeniable. In arguing pro and con it is human nature to go to extremes, with the result that the absurdity of the extreme position taken often acts as a boomerang. The practical man takes cross-sections in rough country so close together that gross errors cannot occur even though using the mean ends formula; and he naturally "pooh-poohs" the theoretical advocate of the prismoid formula who always gives hypothetical illustrations which show a great difference in results between the prismoid and the mean ends formula, simply because they are extreme and hypothetical.

Believing that a compromise might be effected between the advocates of the rough and ready means ends formula and the advocates of the elegant but complex prismoid formula, the writer undertook an investigation, the results of which follow.

For ease of reference the formulas to be considered will be designated by name and number, thus:

The prismoid formula,

$$V' = \frac{A + 4M + a}{6} \times \frac{L}{27}. \tag{1}$$

The mean ends formula,

$$V = \frac{A + a}{2} \times \frac{L}{27}. \tag{2}$$

The writer's correction formula,

$$V'' = V - D\,(B - b)\,L. \tag{3}$$

V' = exact number cubic yards, according to prismoid formula;
V = approximate number cubic yards, according to mean ends formula;
V'' = practically exact number cubic yards, according to writer's formula;
A = area in square feet of the larger end cross-section;
a = area in square feet of the smaller end cross-section;
M = area in square feet of the mid-section obtained by averaging dimensions of end cross-sections;
L = distance in feet between end sections;
D = the correction factor to be taken from the writer's Table I.;
B = the larger end area in square feet of a truncated pyramid;
b = the smaller end area in square feet of a truncated pyramid.

It is a fact capable of easy demonstration that the prismoid formula (1), and the mean ends formula (2) give identical results if applied to any five or six-faced figure, provided two of those faces (one of which may be a straight line or edge) are parallel, while the third face is a parallelogram. In other words, these formulas give equal results when applied to wedges, truncated wedges, warped wedges, prisms, and warped prisms; while the results differ only when applied to pyramids or truncated pyramids.

It follows, therefore, that the mean ends formula (2) can be applied to any prismoid, and by afterwards applying a minus correction for the pyramids and truncated pyramids, forming elements of that prismoid, we can obtain results agreeing exactly with the prismoid formula (1).

Having reached this conclusion, the next and most difficult step is to deduce a simple correction to be applied to the mean ends formula (2). Tables have been published based upon the mean ends formula and correction columns given in the tables; but the following formula and table the writer believes to be original, and if not, it is undeniably so simple that its merits should be generally known. The reader is cautioned against being dismayed by the apparent complexity of the process used by the writer in deducing the final formula; and any one who does not care to wade through the algebraic processes that follow may without fear of losing the general trend of the deduction, skip the next few lines down to eq. (14).

Deduction of Writer's Correction Formula:

The approximate value in cubic yards of a truncated pyramid, if determined by the mean ends formula, is,

$$V = \frac{B + b}{2} \times \frac{L}{27}. \tag{4}$$

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The exact volume, however, as given in Book VII., Prop. 28, Davies' Legendre, is,

$$V' = \frac{1}{3}\,(B + b + \sqrt{B\,b})\,\frac{L}{27}. \qquad (5)$$

The difference between V and V′ as given by these two equations is, therefore,

$$V - V' = \frac{B+b}{2} \times \frac{L}{27} - \frac{1}{3}\,(B+b+\sqrt{B\,b})\,\frac{L}{27}. \qquad (6)$$

$$V - V' = \left[\frac{B+b}{6\times 27} - \frac{1}{27}\,\frac{\sqrt{B\,b}}{3}\right] L. \qquad (7)$$

Having reached this point in his search, the writer began to fear that a simple solution was impossible until it occurred to him to multiply equation (7) by $\frac{B - b}{B - b}$, when he obtained the following result:

$$V - V' = \left[\frac{B + b}{6\times 27\ (B - b)} - \frac{1}{27} \times \frac{\sqrt{B\,b}}{3\,(B - b)}\right](B - b)\ L. \qquad (8)$$

$$V - V' = \left\{\frac{1}{6\times 27}\left[1 + \frac{2\,b}{B - b}\right] - \frac{1}{27} \times \frac{\sqrt{B\,b}}{3\,(B - b)}\right\}(B - b)\ L. \qquad (9)$$

$$V - V' = \left[\frac{1}{162} - \frac{1}{27} \times \frac{\sqrt{B\,b} - b}{3\,(B - b)}\right](B - b)\ L. \qquad (10)$$

$$V - V' = \left[0.0061728 - \frac{\frac{1}{27}\left[\sqrt{\frac{B}{b}} - 1\right]}{3\left[\frac{B}{b} - 1\right]}\right](B - b)\ L. \qquad (11)$$

Let,

$$D = 0.0061728 - \frac{\frac{1}{27}\left[\sqrt{\frac{B}{b}} - 1\right]}{3\left[\frac{B}{b} - 1\right]}. \qquad (12)$$

Then,

$$V - V' = D\ (B - b)\ L. \qquad (13)$$

Whence,

$$V' = V - D\ (B - b)\ L. \qquad (14)$$

Equation (14) is the writer's correction formula.

In Table I. values for D, as determined by equation (12), are given corresponding to different ratios of $\frac{B}{b}$. It will be observed that it requires an increasingly great value of $\frac{B}{b}$ to produce an appreciable variation of D, and it is this fact that makes the writer's correction formula one of great simplicity, since a small table (Table I.) suffices to secure great accuracy, while it is at the same time necessary to obtain only an approximate value of $\frac{B}{b}$, which can be done merely by inspection, ordinarily without even using pencil and paper.

We shall now proceed to illustrate the use of Table I. and the writer's correction formula.

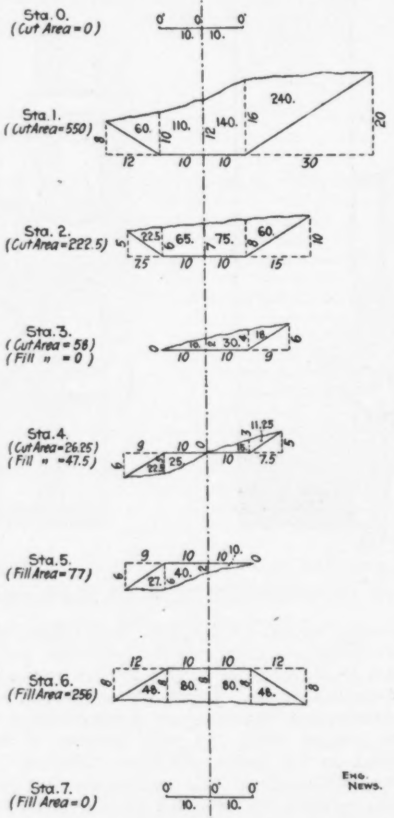
The cross-sections in the accompanying cut are from "The Engineer's Fieldbook," by Cross; and, as the adjacent cross-sections differ far more from one another than is usual in practice, we shall have a severe test of the relative accuracy of the different formulas. The area in square feet of each quadrilateral and triangle is written for convenience on a horizontal line within the individual quadrilateral and triangle; and the volumes as computed by the different formulas are given in Table II.

Beginning with the prismoid between Sta. 0 and Sta. 1, which are 100 ft. apart, we see that it is composed of two pyramids whose bases have an area of 240 and 60 sq. ft., respectively, and of two warped wedges with base areas of 140 and 110 sq. ft., respectively. As above stated, the mean ends formula applies with perfect accuracy to these warped wedges, so that we need apply our correction formula to the pyramids only. The yardage given by the mean ends formula between Sta. 0 and Sta. 1 is V = 1,018.5 cu. yds. (Table II.), from which, according to the writer's correction formula, must be deducted D (B — b) L.

In Table I., for $\frac{B}{b} = \infty$ (a pyramid), D = .0062; therefore, since L = 100 ft., D (B — b) L = .0062 (240 — 0) 100 which is to be deducted for the pyramid on the right side, and .0062 × (60 — 0) 100 for the pyramid on the left side, making a total deduction of .0062 (240 + 60) × 100 = 186.0 cu. yds.; therefore, V″ = V′ — D (B — b) L = 1,018.5 — 186.0 = 832.5 cu. yds.

By the prismoid formula the corresponding volume V′ = 833.3 (Table II.), a difference of only 0.8 cu. yds, or $^1/_{10}$%.

The difference would have been 0 had we used the exact value of D = .0061728, but the additional labor involved in multiplying by so large a fraction is not warranted by so slight an increase in accuracy.



Between Sta. 1 and Sta. 2 there are two warped truncated wedges, to which no correction need be applied, and two truncated pyramids with triangular bases to which the correction formula must be applied, as follows: On the right side $\frac{B}{b} = \frac{240}{60}$ = 4, corresponding to which, in Table I., D = .0021; therefore D (B — b) L = .0021 (240 — 60) × 100 = 37.8 cu. yds., which is the minus correction on the right side; while on the left side $\frac{B}{b} = \frac{60}{22.5}$ = 3 approximately.

For $\frac{B}{b}$ = 3 we have from Table I., D = .0017; therefore, D (B — b) L = .0017 (60 — 22.5) 100 = 6.8 cu. yds. Adding the two minus corrections, 37.8 + 6.8 = 44.6 cu. yds., which is the total correction to be subtracted from the yardage, as given by the mean ends formula, or V″ = 1,430.6 — 44.6 = 1,386.0 cu. yds. In like manner the remaining volumes were calculated and tabulated, and it will be seen in Table II. that the results obtained by using the prismoid formula and the writer's correction formula are practically identical, while the error from using the mean ends formula is 9 to 10%.

It must be admitted that even the prismoid formula is not absolutely accurate, being in certain instances extremely erroneous (see Henck's Field-book, page 110), therefore no one can reasonably assert that the writer's correction formula and table give results less near the truth than does the prismoid formula.

The advantages of the writer's correction formula and Table I. are these:

1. A saving of time and paper in plotting mid-areas.

2. A saving of time in calculating volumes; for while a study of the foregoing deduction may leave an impression that the process is complex, actual test by use of the table and formula will demonstrate that the time of plotting and calculation required with the writer's method is 30% to 50% less than with the prismoid formula.

3. The mean ends formula may be used for preliminary and monthly estimates, and the corrections applied during leisure hours before the final estimate.

4. Ordinarily no correction at all need be applied where the ground is approximately level.

Notwithstanding the simplicity and accuracy of the writer's correction formula, it is probable that the mean ends formula will continue to be used by many engineers, especially in states where its use is legalized. This being so, the writer has sought to find some simple rule to guide the engineer in so spacing his cross-sections that results will be within 1 or 2 per cent. of the truth. That such accuracy is ordinarily obtained is undeniable, for no engineer of experience would take sections as far apart as those in Fig. 1, where the variations in the cuts and fills are so great.

The last column of Table II. gives the yardage obtained by the use of the mean ends formula after sections have been interpolated midway between all stations, except in the first and last prismoids, where three cross-sections have been interpolated at +25, +50, and +75. Observe the great reduction in the error from 9% in the fourth column to 1% in the last column.

While it is impossible to mathematically deduce a simple and at the same time invariable rule for the spacing of cross-sections, so that errors exceeding a given per cent. will not occur using the mean ends formula, still it is possible to offer a rule that will in practice give great accuracy, usually within 1 per cent. of the truth on any section of a railway survey 500 ft. or more in length.

Not the least of the advantages of the mean ends formula is that tables already exist greatly facilitating the estimation of quantities in three-level section work, and using the following rule the engineer may feel assured that his results will be as close to the truth as can reasonably be required.

RULE.—Take cross-sections so close together that no cut or fill shall exceed by more than 50% the corresponding cut or fill in the previous cross-section; except that where the previous fill is 0 the next cut or fill must be 2 ft. or less.

TABLE I.

$\frac{B}{b}$ =	1	1.2	1.6	2	3	4	6	8	10
D =	.0000	.0003	.0007	.0011	.0017	.0021	.0026	.0029	.0032
$\frac{B}{b}$ =	15	20	30	60	100	500	1,000	10,000	∞
D =	.0034	.0039	.0043	.0048	.0051	.0056	.0058	.0061	.0062

TABLE II.

	Cu. yds. cut according to formula			
Station.	Prismoid (1).	Correction (3).	Mean ends (2).	Mean ends modified.
0 to 1	833.3	832.5	1,018.5	845.0
1 " 2	1,388.0	1,386.4	1,430.6	1,399.6
2 " 3	498.1	498.3	519.4	503.6
3 " 4	149.4	149.3	156.0	151.0
4 " 5	32.4	32.3	48.6	36.5
Total.......	2,898.5	2,898.8	3,173.1	2,935.7
Error.........	0.0%	0.0%	+ 9%	+ 1%

	Cu. yds. fill according to formula			
Station.	Prismoid (1).	Correction (3).	Mean ends (2).	Mean ends (2) mod.
3 to 4	58.7	58.7	88.2	67.8
4 " 5	223.3	224.0	230.4	225.5
5 " 6	585.2	586.4	616.7	593.0
6 " 7	415.0	414.5	474.0	420.4
Total.......	1,283.2	1,283.6	1,409.3	1,306.7
Error.........	0.0%	0.0%	+ 10%	+ 1.8%

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,173.1 | 2,935.7
+ 9% | + 1%

ng to formula
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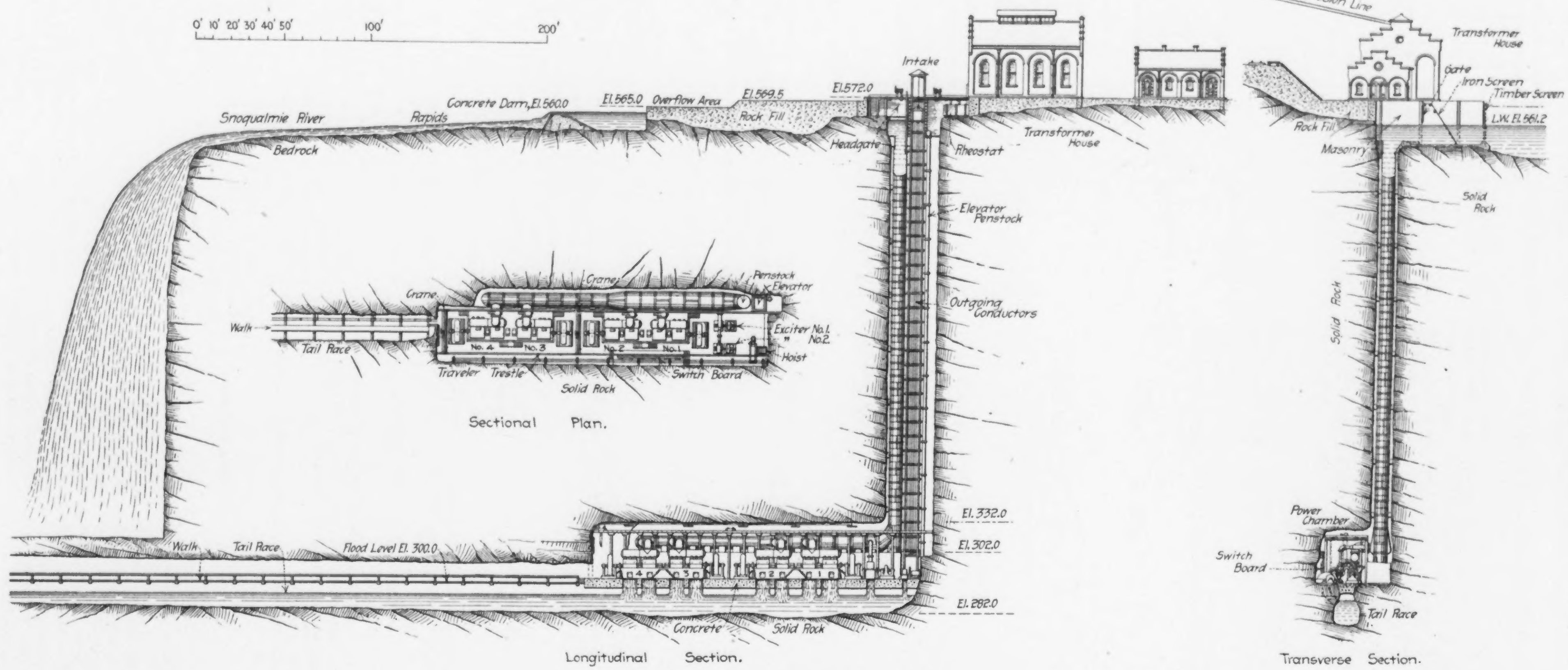
88.2 | 67.8
230.4 | 225.5
616.7 | 593.0
474.0 | 420.4
,409.3 | 1,306.7
+ 10% | + 1.8%

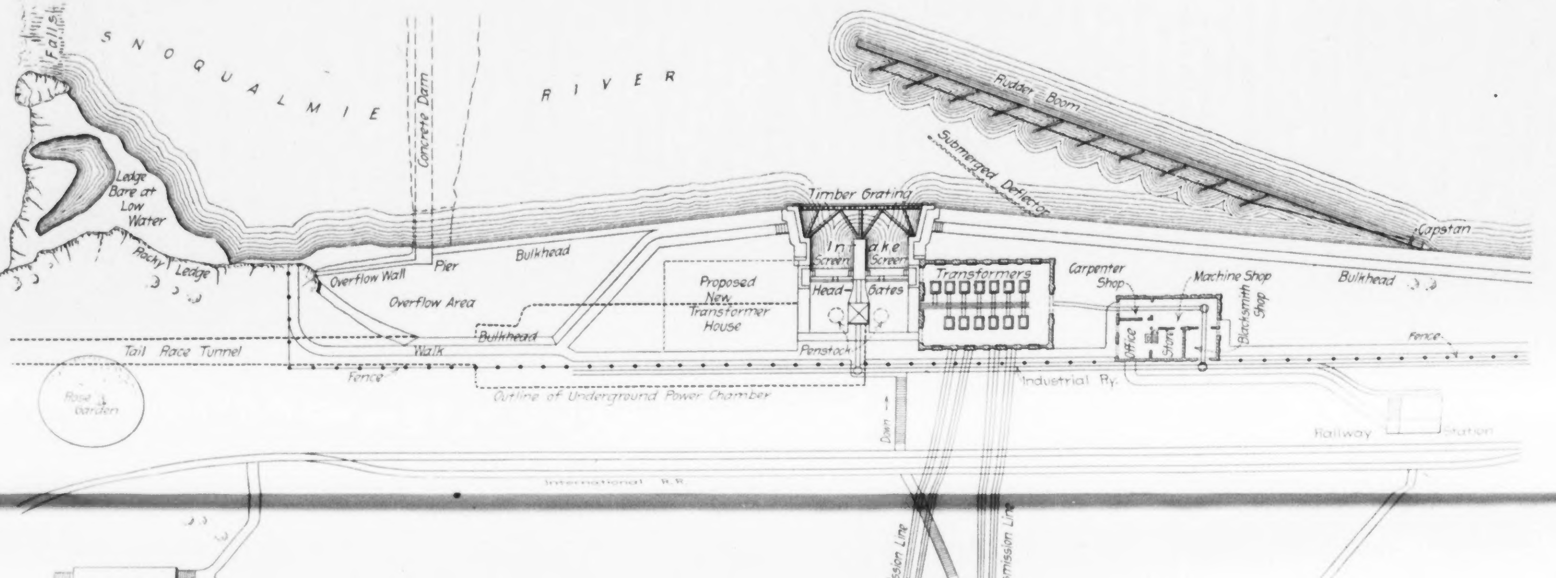


Sectional Plan.

Longitudinal Section.

Transverse Section.

FIG. 5.—SECTIONAL ELEVATIONS OF PLANT.



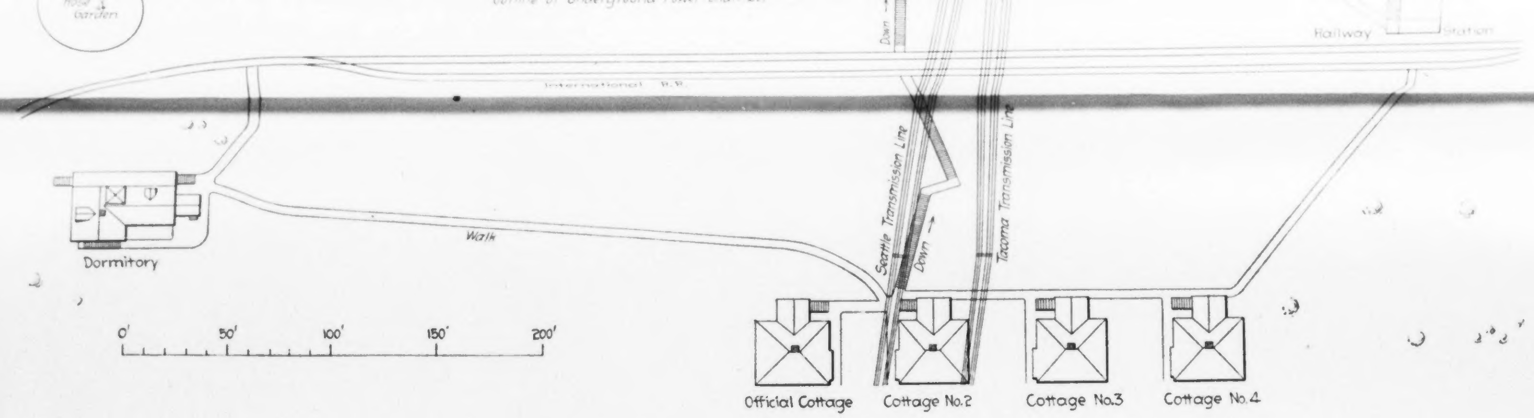


FIG. 3.—PLAN OF HEAD-WORKS.

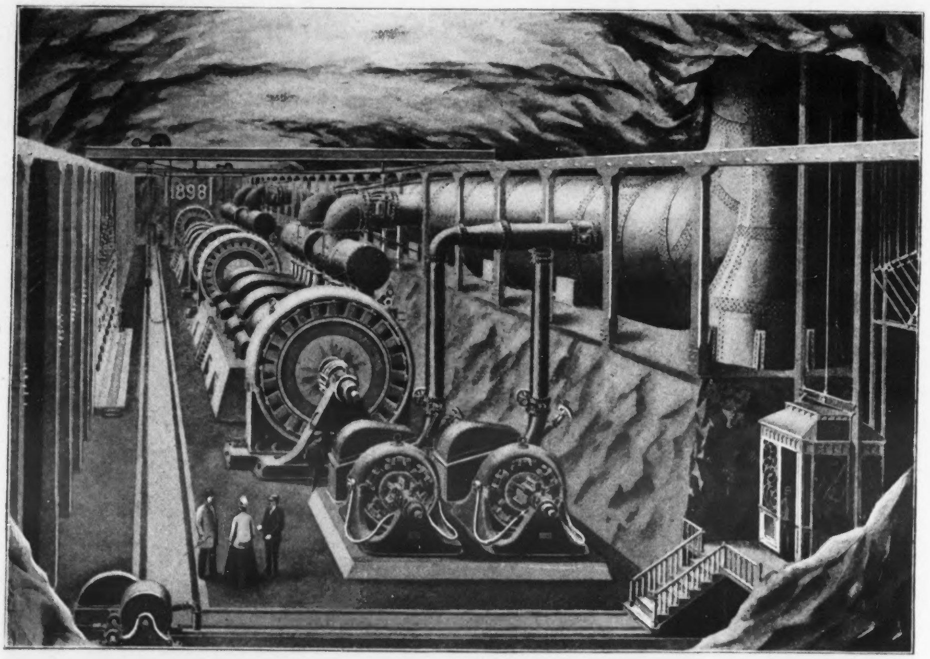


FIG. 11.—VIEW OF INTERIOR OF POWER CHAMBER.

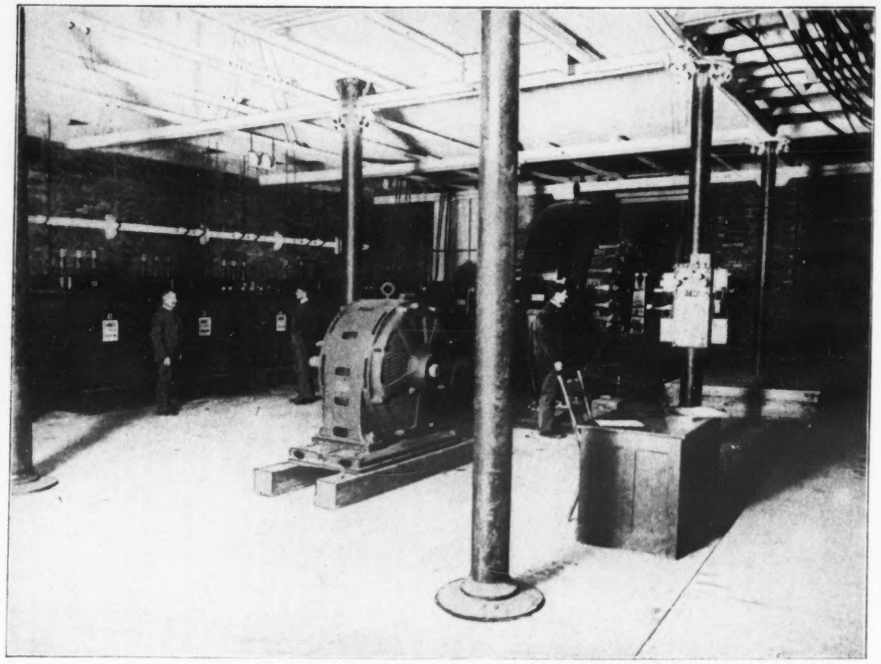
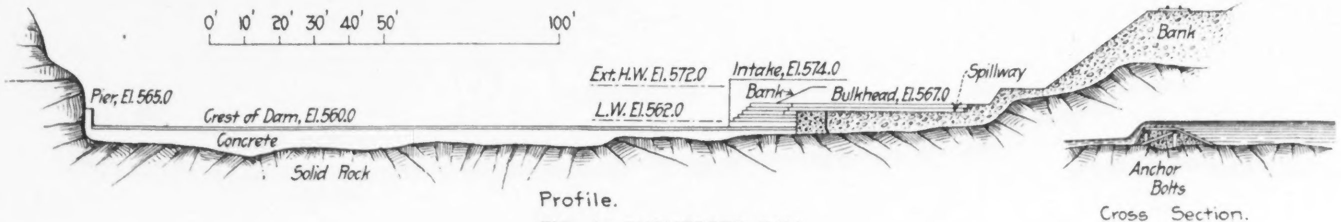


FIG. 13.—INTERIOR OF SUB-STATION AT SEATTLE.



Profile.

Cross Section.

FIG. 4.—SUBMERGED DAM.

WATER POWER PLANT AT SNOQUALMIE FALLS, WASHINGTON.

Snoqualmie Falls Power Co.