Appendix No. 1.

THE NEW CONDUIT OF THE ROCHESTER WATER WORKS.

By E. Kuichling.

In response to numerous requests for a detailed description of the new gravity conduit from Hemlock Lake to Mt. Hope Reservoir, which was practically completed in October, 1894, the following account of the work and the circumstances which rendered an additional water supply necessary, is herewith submitted :

THE OLD WATER WORKS.

The question of providing a public water supply for the city had been considered for some years prior to 1860, at which time the population was about 48,000 ; but it never assumed definite form until that year, when a private corporation obtained a franchise for bringing water by gravity from Hemlock Lake, which is situated in a hilly district about 29 miles south of the city. This corporation, however, failed to accomplish its purpose after spending several hundred thousand dollars in the attempt ; and as there was no evidence that the undertaking would ever be properly completed, the city finally resolved to build an entirely independent system of water works.

A Board of Water Commissioners was accordingly created in April, 1872, and on November 15th, of the same year, this Board reported in favor of a dual system of supply, selecting Hemlock Lake as the most expedient and desirable source for obtaining by gravity an abundance of pure, soft water for domestic and general uses, and supplementing the lack of efficiency of the gravity works for fire purposes in the central and manufacturing districts of the city, by a separate direct pressure pumping system supplied with hard and impure water from the Genesee River, which flows northerly through the town.

The final plans for this project contemplated a capacity of about 7,000,000 gallons per day from each of the two systems, to be distributed through about 40 miles of pipe in the city streets; they also provided for the construction of two reservoirs on the line of the gravity conduit, one on the southern boundary of the city for distributing purposes, and the other about nine miles south of the city for storage purposes. The total expenditure for the work was limited to $3,000,000.

The general plan thus outlined was duly approved by the muncipal authorities, and early in 1873 the work was advertised for letting. Meanwhile the necessary details of the undertaking had been elaborated under the direction of the Chief Engineer, Mr. J. Nelson Tubbs, and construction was commenced soon after the contract was awarded. As it was anticipated that the long gravity conduit would require nearly three seasons to finish, the direct pressure system was completed first and put in full operation in February, 1874, with 7.32 miles of distributing mains. The gravity works, with the two reservoirs, a compound conduit consisting of 9.75 miles of 36-inch riveted wrought-iron pipe and 18.50 miles of 24-inch pipe, mainly of cast-iron, and 51.52 miles of distributing pipe, were finished early in 1876.

It may be remarked that when these works were planned, the city had a population of about 70,000, and an area of 4,840 acres with 156 miles of streets and alleys. Few citizens then believed that the population would ever reach 120,000, and those who were bold enough to venture the opinion that this limit would ever be exceeded, were regarded as dreamers. It was pointed out that the proposed capacity of the gravity works would suffice to give 60 gallons of potable water per head per day to 120,000 people, and as not more than four-fifths of the population would probably ever become consumers of the water, the supply was thought to be adequate for a great many years.

These estimates, it must be remembered, were made twenty-three years ago, when the fund of information regarding water supplies and the growth of cities was not only very much smaller than at present, but was also vastly more difficult of access. They were the outcome of many careful inquiries, and are, therefore, entitled to lenient criticism.

Soon after the completion of the works, however, the city boundaries were moved far outwards on all sides. A large suburban population was thus added and the muncipal territory was increased to over 11,000 acres, with about 220 miles of streets. This was followed by a period of rapid development, so that in 1888 Rochester had an estimated population of 125,000, with about 190 miles of water distributing mains, and 21,000 house connections from the Hemlock Lake system.

The capacity of the old conduit from Hemlock Lake to Rush Reservoir had been carefully gauged several times during the spring and summer of 1876, and found to be about 9,000,000 gallons per day, or 25 per cent. more than had originally been estimated. As a consequence of this large delivery, no restrictions in the use of water were enforced by the authorities up to 1885. In the meantime, the poor quality of the subsoil water, and the drainage of many private wells by sewerage works in almost every portion of the town, had caused such a demand for the Hemlock Lake water, that the distributing system was rapidly extended, and soon almost every building in streets where water mains were laid was provided with a water service pipe. The consumption thus became much larger than had been estimated to occur so soon after the works were finished, and as large quantities were lost by defective house fittings and lavish use, it finally became necessary in 1886 to enforce measures for preventing waste, as it was evident that the limit of the conduit's capacity would otherwise soon be reached.

SURVEYS AND PLANS FOR AN ADDITIONAL WATER SUPPLY IN 1888 AND 1889.

With the continued fast growth of the city, however, these restrictive measures could not long be successful, and the climax was at last reached in 1888. In that year the storage in the reservoirs was nearly exhausted, and it was then definitely realized that the demands for the water were greater than the supply. Engineer Tubbs was therefore authorized to make surveys and examinations for procuring an additional supply, and in September of the same year, he presented his report in which, after considering various remedies for the existing conditions and a few sources for the additional supply, he recommended the early construction of a new conduit with a capacity of 15,000,000 gallons per day, from Hemlock and Canadice Lakes.

The plans outlined in this report, however, did not appear to be generally accepted, and the matter was submitted on February 16, 1889, to the well-known engineers, Messrs. A. Fteley, of New York, and J. T. Fanning, of Minneapolis, Minn., for thorough investigation. Several new surveys were made under their direction, and on May 14, 1889, they reported in favor of either Hemlock Lake or Conesus Lake as a proper source, and that the new conduit should have a capacity of 15,000,000 gallons per day. While their plans differed in detail from those of Mr. Tubbs, they agreed with the latter as to source and required quantity.

No definite action upon these reports was taken by the municipal authorities, and the agitation of the subject was briskly continued by the promoters of other plans. Meanwhile it became evident that temporary relief would be needed, even if the construction of a new conduit to Hemlock Lake were authorized, since such an undertaking would require at least two years for its completion.

TEMPORARY ADDITIONAL SUPPLY.

A number of sources for temporary use were thoroughly examined in 1889 and early in 1890, but as they proved to be deficient, either in quantity or quality, the only resource left to prevent the depletion of the reservoirs was to make the consumption in the city equal to the delivery of the conduit, by suitably throttling for a portion of the day a few of the stop-valves in the principal mains at the foot of the hill on which the distributing reservoir is situated. This plan was accordingly adopted in June, 1890, and was retained with some modifications until August, 1894.

It should be remarked that up to June, 1890, it had been taken for granted that no appreciable diminution in the discharging capacity of the old conduit had occurred, and that it was still continuing to deliver about 9,000,000 gallons per day. At that time, however, a close gauging of its flow into Rush Reservoir was made, which revealed the fact that its actual delivery was then only about 6,730,000 gallons per day. The discrepancy between these two discharges could not be accounted for by leakage or abstraction of water from any portion of the conduit, and hence it was evident that its efficiency had become permanently impaired. Meanwhile, Chief Engineer Tubbs became ill and resigned his position at the end of July, 1890. A few weeks later the writer, who had severed his connection with the Water Works Department some years previously, was appointed to take charge of the works.

In this state of affairs, the matter of obtaining a temporary additional supply of potable water was considered of chief importance. Some months previously an old artesian well in the town of Gates, about one mile west of the city, gave promise of furnishing a supply of 1,000,000 gallons per day, and contracts had been made for the rental of this well, and also for the delivery of a suitable pumping engine and the necessary quantity of pipe, for the purpose of forcing this water directly into the nearest city distributing pipe. The machinery had however, not yet arrived, and as some doubts regarding the permanency of the flow from the well had been entertained, preparations were made to test its capacity in a time of drought.

The result of this test was very discouraging, and as the owner of the well refused to allow any new wells to be drilled anywhere on his land, also because the geological characteristics of the region were unfavorable to the assumption that the same vein of water could be tapped by other wells at some distance from the original one, it was deemed prudent to investigate other sources before incurring the large expense involved by the construction of the above-described temporary works, especially as it was very doubtful whether the well would yield even 500,000 gallons per day during dry periods.

To complete our outline of this part of the subject, it may also be mentioned that none of the various propositions for temporary relief, which were advanced after the failure of the Gates well, met with approval until March, 1893, when an agreement was made with a private company whereby a large quantity of water was to be delivered by them at very reasonable rates, into the distributing reservoir from a series of wells which they proposed sinking in the flats about one mile south of said reservoir. This source had been discovered by the company a short time previously, and full control of the land for a considerable distance around their experimental wells had been secured by them.

As no other arrangements for the use of this water could be made, the company accordingly caused six 10-inch wells to be drilled and equipped with suitable pumps, and a 16-inch cast-iron force main about 5,000 feet in length to be laid to the reservoir. The first delivery of water was made on June 12, 1893, at the rate of only about 500,000 gallons per day, and although every effort was made to increase the yield of the wells, no appreciable improvement occurred thereafter. This was a serious disappointment both to the company and to the public, since the volume thus delivered was by no means adequate to enable the Water Works Department to dispense entirely with the obnoxious system of balancing inflow and outflow from the reservoir. As this quantity, however, afforded a little relief, the use of the water was continued until October, 1894.

GENERAL PLANS AND ESTIMATES FOR A NEW CONDUIT, FROM VARIOUS SOURCES.

Early in October, 1890, the writer was requested to investigate the various general plans for a permanent additional water supply which had previously been submitted by the other engineers above mentioned, and to make such further examinations for the same purpose as he might deem necessary. This work was soon undertaken, and on December 16 and 30, 1890, reports and estimates were presented for permanent works from Hemlock Lake, Conesus Lake and Lake Ontario on somewhat different plans from the others. These documents also exhibited a comparison of all the various estimates which had been made up to this time for new works from the same three sources, and it was seen therefrom that the choice lay between Conesus and Hemlock Lakes, both on the score of quality of water and cost of construction.

A brief description of the three sources to which reference has been made in the foregoing may now be given. Hemlock Lake is a beautiful body of water about 6.6 miles long and 0.6 mile wide. It is situated in a hilly region about 29 miles south of Rochester, and lies about 386 feet above the general level of the city. Its area at ordinary low water is 1,828 acres, and its average depth in the middle is 65 feet. Including the water surface, its drainage area is 27,554 acres or 43.05 square miles, a large proportion of which is steep and covered with forest. The only settlement of considerable size on the watershed is the village of Springwater, which is located nearly three miles south of the head of the lake and has a population of about 600. On the rest of the area the resident population is probably about 1,000.

Canadice Lake lies about two miles east of Hemlock Lake, and is 200 feet higher than the latter. It is about 3.13 miles long, 0.33 mile wide, and its average depth in the middle is 70 feet. At ordinary low water it covers an area of 648 acres, and the total drainage area is 8,883 acres, or 13.88 square miles. The territory is occupied wholly by farms and woods, with a population of not more than 400. The stream which forms the outlet of Canadice

Lake must also be considered in this connection, as it unites with the outlet of Hemlock Lake at a point about one-third of a mile below the foot of the latter lake, and has a drainage area of 3,515 acres, or 5.49 square miles. The character of this territory is similar to the other watersheds, and its population is about 200.

It should also be noted that for nearly one mile below the foot of Hemlock Lake, the ground is nearly level along the course of the outlet, but rises with easy grades to the base of the hills which form the sides of the valley. With such a configuration of the surface, it is obvious that the flow from Canadice Lake and its outlet can readily be diverted into Hemlock Lake, either by means of a new open or closed channel, or by a low movable weir placed across the channel of the Hemlock outlet below its junction with the Canadice outlet. In this manner Hemlock Lake can be made the general reservoir for the yield of the three distinct watersheds already considered, whose aggregate area amounts to 39,952 acres, or 62.43 square miles.

Conesus Lake lies parallel to, and a few miles west of Hemlock Lake. It is about 7.8 miles long, 0.63 mile wide, and has an average depth of 45 feet in the middle. At ordinary low water, its area is 3,184 acres, and its elevation is about 308 feet above the general level of the city, or 78 feet lower than Hemlock Lake. Including the water surface, its drainage area is 39,980 acres, or 62.47 square miles, and is therefore practically the same in extent as that of Hemlock and Canadice Lakes and Canadice outlet combined. The character of the territory, however, differs from that of the latter by having a much larger proportion of open farming land, less abrupt hillsides and a greater average density of population. Several good-sized villages, as well as a few smaller settlements, are on the watershed, and from the recent census statistics it may be estimated that the total number of persons residing thereon permanently is at least 3,500. This lake extends a few miles further north than Hemlock Lake, but from the preliminary surveys it is found that the length of a practicable route for a conduit to Rush Reservoir is only 2.6 miles shorter than one from Hemlock Lake.

Lake Ontario is about seven miles directly north of Rochester, but its average water surface is 266 feet below the general level of the city, and 390 feet below that of Mt. Hope Reservoir. To avoid the influence of the roily and sewage-polluted water of the Genesee River, the intake of a conduit for supplying the city must necessarily be located as far distant from the river as possible. As the prevalent winds are from the west and northwest, and from the peculiar configuration of the lake shore, it is obvious that no suitable location for an intake can be found at any reasonable distance easterly from the mouth of the river, and hence such a location must be sought to the west thereof. For some miles in this direction, however, a series of swampy bays or ponds, connecting with the lake, are encountered, whose waters are entirely unfit for domestic use, both by reason of excessive aquatic vegetation, and from the fact that they are contaminated by the drainage from nearly the whole of the northwestern quarter of Monroe County. This area is relatively thickly populated, and contains a large number of villages and hamlets. In view of all these circumstances, the nearest available location for an intake on the lake shore is at a point about 8.5 miles west of the mouth of the river, and 15 miles in a direct line northwesterly from Mt. Hope Reservoir. By the shortest practical route, without crossing the populous districts of the city, this distance would become about 17 miles.

Briefly summarized, the various reports and estimates showed that the long force main, costly intake works and pumping engines, and the capitalization of the annual expenses for lifting the water to so high an elevation, would render the Lake Ontario project far more expensive than either of the other two ; and that while a conduit from Conesus Lake might cost a little less than one from Hemlock Lake, yet the expense of protecting the water from pollution, by introducing and maintaining adequate sanitary arrangements on the large and relatively populous watershed of Conesus Lake, would probably more than make up the difference. Various other elements also entered into the choice between these sources, but after due consideration, the preference was finally given to Hemlock Lake by all the municipal authorities, on June 16, 1891.

SURVEYS FOR THE NEW CONDUIT FROM HEMLOCK LAKE.

Pending this definite action, a bill was introduced in the Legislature early in 1891, whereby the city would be allowed to take an additional water supply from either Hemlock or Conesus Lake, and to bond itself for the necessary cost in the sum of $1,750,000. For some reason, however, the measure was opposed, and the Legislature adjourned before the bill could be passed. As a large amount of engineering work both in the field and in the office was necessary before the details of any of the general plans could be prepared, and no funds for the purpose being available, the Common Council appropriated an adequate sum on June 26, 1891.

Soon afterward, two surveying parties commenced operations and were kept busy during the remainder of the year examining various routes and preparing topographical maps thereof. From the data thus acquired careful studies and comparative estimates of the most feasible routes were then made, and a definite location of the conduit established. The previous hydrological investigations were also thoroughly revised for the purpose of determining the storage volume needed in the lake during a cycle of years of least observed rainfall, and from this the necessary depth of the upper end of the conduit below the existing ordinary low-water level of the lake was fixed. Nearly a year was occupied in this work and in the preparation of the drawings and specifications.

A new bill similar to the one above mentioned was introduced in the Legislature early in 1892 and succeeded in becoming a law on April 20,

1892. Work on the new conduit plans was therefore continued energetically, and proceedings were at once instituted to obtain the necessary rights of way in those localities where the route had been fixed. Much delay was here encountered, owing to the organized opposition of a number of landowners to grant such rights except at exorbitant rates, and advantage was taken of the time during which these matters were in court to have all the plans and specifications carefully reviewed by Mr. A. Fteley, Chief Engineer of the Croton Aqueduct Commission, who was retained as Consulting Engineer by the Executive Board, while the general provisions of the forms of contract were criticised by Mr. C. D. Kiehel, then City Attorney.

DESCRIPTION OF THE PRELIMINARY PLANS AND ROUTE.

The plans for the new conduit as finally adopted contemplated the construction of a brick conduit, of horse-shoe shaped cross-section, about 6 feet in diameter, on a grade of one in 4,000 from the northeastern corner of Hemlock Lake to a point on the east bank of the creek about 12,000 feet northerly. Of this length, 7,500 feet was in tunnel, worked from several shafts through the clay and shale rock which underlies the region, while the remainder was in open excavation. A large and deep gate and screen house was to be built at the shore, from which a steel intake pipe, 5 feet in diameter and 1,600 feet long, was to be extended into the lake to a point where the water was about 35 feet deep. The pipe was to be laid in a channel dredged to a depth of about 19 feet below the existing ordinary low water level of the lake until this depth of water was reached, after which it would be laid directly on the bottom and terminate in a submerged timber crib resting on the bottom.

At its beginning in the gate house, the invert of the brick conduit was to be about 17 feet below the aforesaid low water level; and at the northerly terminus it was to be a little above the average water surface in the creek in order to provide for natural drainage in case of cleaning or repair. To prevent the masonry of the conduit from being injured by the water pressure which would ensue from improper manipulation of the works, an overflow chamber was to be constructed at the north end, whereby the water surface in the conduit would effectually be prevented from reaching the top of the arch.

From the said overflow chamber onward to the storage and distributing reservoirs, the water was to be conducted in either a 36-inch cast-iron, or a 38-inch steel pipe conduit, laid on a continuous hydraulic grade to its terminus at the latter reservoir. This grade was about one in 570 for the total distance of nearly 140,000 feet, or 26.5 miles.

The route was along the east side of the relatively narrow outlet valley with steep banks for a distance of about 2.0 miles to Richmond Mills; thence northerly about 3.5 miles across the undulating territory west of Honeoye Creek to a point where the valley again becomes narrow with high banks; thence still northerly a similar distance through the said valley, in which the creek meanders from side to side, the pipe crossing and re-crossing the same nine times to avoid tunneling and location on treacherous banks; thence rising on the east side of the valley to the elevated plateau below the village of West Bloomfield, and continuing northerly along this plateau and across the deep depression called Surrine Hollow, for a distance of 5.35 miles; thence northwesterly along a highway and across fields for 3.41 miles in a direct line to Rush Reservoir; thence northerly along the route of the old conduit and through the Henrietta road for 4.81 miles to a point where the prolongation of Pinnacle Avenue intersects said road; thence along said prolongation to and through Pinnacle Avenue for 3.31 miles to a point 439 feet north of Elmwood Avenue; and thence northwesterly across private and park lands for 0.69 mile to the east end of Mt. Hope Reservoir. New gate houses and inlet works were also projected at both reservoirs.

It should be stated that the Pinnacle Avenue route was chosen because it was foreseen that a new and large distributing reservoir would soon be required; and as the most available site for such a structure is on the elevation known as Cobb's Hill, at the southeastern corner of the city, while Pinnacle avenue is nearly midway between this site and Mt. Hope reservoir, it follows that the said location of the pipe conduit would best serve both places.

A few words, also, as to the reason for providing so large a masonry conduit and intake works at Hemlock Lake may be given. The enormous difficulties with quicksand which were encountered in the construction of the old conduit in this locality, and the discovery of extensive deposits of this material by preliminary borings along several contemplated routes for the new conduit, indicated that the costs of construction for the latter would be so great that the addition of 1.5 or 2.0 feet to the diameter needed for a discharge of 15,000,000 gallons per day would not make a serious increase in the amount; and as this additional size would give the conduit a capacity for delivering easily about 32,000,000 gallons per day, which was the computed average yield of the entire watershed of Hemlock and Canadice Lakes, it was deemed prudent to adopt the larger dimensions in order that no further outlay in this locality would arise, if a second additional water supply should ever be required in the future. The same considerations are also applicable with even greater force in the case of tunnel work, owing to the necessity of having room enough for the workmen to perform their labor properly and quickly.

THE LETTING OF THE WORK.

Considerable time was occupied in the work of revising and printing the several voluminous documents constituting the forms of notice of letting, proposal, contract, specifications and bonds. Early in November the matter was finally submitted to the Common Council for adoption, which was formally done on November 15th, and the entire work was then extensively advertised for letting to take place on December 23, 1892. Bids were requested from contractors for the masonry conduit work and the pipe work separately ; the latter in turn embracing bids for both steel and cast-iron pipe, and for two different routes, designated A and B, for a portion of the distance.

It should be mentioned that Route A for the pipe conduit was located in the alluvial flats through which Honeoye Creek meanders, and involved several difficult crossings of the existing and former channels of said creek; while Route B avoided some of these crossings by following the course of a certain lateral valley for some distance, and then returning to the main valley by means of a masonry conduit and tunnel about 1,000 feet long. These two routes were each about 8,000 feet in length and formed a part of the entire length of 140,000 feet of conduit to be constructed in either case.

The lowest bid for the masonry conduit and tunnel work was made by William H. Jones & Sons, of Rochester, N. Y., its aggregate amount, as computed from the prices and estimated quantities, being $292,518 ; that for the pipe conduit was made by the Moffett, Hodgkins & Clarke Co., of New York, their bids amounting to $903,324.00 with 38-inch steel pipe, by Route A, and to $857,552.50 by Route B ; for the same work with 36 inch cast-iron pipe as an alternative, the only bidders were Whitmore, Rauber & Vicinus, of this city, and a syndicate of cast-iron pipe manufacturers, respectively, their joint bids amounting to $1,173,110.00 by Route A, and $1,177,035.00 by Route B.

From the foregoing bids it was seen that by Route A the cost of the new conduit with 36 inch cast-iron pipe would be about 29.9 per cent. greater than with 38-inch riveted steel pipe, and about 37.3 per cent. greater by Route B. Much surprise was caused by this result, as well as by the entire absence of competition on the part of manufacturers of cast-iron pipe. It may also be remarked that the delivering capacities of the two kinds and sizes of pipe just mentioned were regarded as equal for the reasons given in another part of this paper.

Before the work was definitely awarded, inquiries were made of several manufacturers of large cast-iron pipe whether any lower bids for such material would probably be received in case this part of the work were re-advertised for letting. The replies were all to the effect that no reduction of prices could reasonably be expected which would make the cost of the work with cast-iron pipe nearly as low as that which would result by adopting the steel pipe ; and as it was desirable that no further delays in commencing the work should occur, the decision was reached to construct the pipes of steel plates riveted together, and properly protected from corrosion by an asphaltic coating. This decision was also influenced in a very large degree by many satisfactory reports as to the durability of such pipes in other localities, as well as by the good condition in which the old wrought-iron pipe conduit was found on its recent complete exposure for distances of several hundred feet at the crossings of the Lehigh Valley and Honeoye Valley Railroads.

The contract for the construction of the masonry conduit and its appurtenances, which is designated as Contract No. 1, was duly awarded to William H. Jones & Sons on January 6, 1893; and on January 12th the award of Contract No. 2, for the construction of the 38-inch riveted steel pipe conduit, and all the required appurtenances thereto, was made to the Moffett, Hodgkins & Clarke Co. The proposals of these two firms were accompanied by thoroughly good bonds in the amount of $30,000 and $90,000 respectively, conditioned that they would accept the contracts if the same were awarded to them, and hence there was every reason to anticipate that the documents would be executed promptly. The award was accepted by Jones & Sons, but was declined by the other firm on the ground of an error in their figures.

This action of the Moffett, Hodgkins & Clarke Co. involved the forfeiture of their said bond for $90,000, and to avoid this great loss they quickly obtained from the United States Circuit Court a temporary injunction restraining the Executive Board of this city from declaring them in default and proceeding with the collection of the money. Several attempts have been made by the City Attorney to bring the case to trial, but in every instance a postponement was secured by the opposing counsel. The case is of great importance to the city, and it is hoped that a settlement will soon be reached.

It was evident from the legal procedure referred to that great delay would result before the said company could be compelled by the court either to abide by its bid or submit to the forfeiture of its bond; and as such delay would be prejudicial to the sanitary condition of the city, Contract No. 2 was awarded on January 20, 1893, to the next lowest bidder, which was the firm of Whitmore, Rauber & Vicinus, of this city. The award was made on the basis of using 38-inch steel pipe with Route A, and was promptly accepted. The amount of the proposal, as computed from the prices and estimated quantities, was $1,123,920.

COMMENCEMENT AND DESCRIPTION OF THE WORK.

Early in March, 1893, both contractors for the new conduit commenced active operations on the lines of their respective work, the few preceding weeks having been fully occupied with making the necessary preparations. Arrangements for the speedy manufacture of the steel pipes were then also concluded by Whitmore, Rauber & Vicinus, the work being divided equally between the East Jersey Pipe Works of Paterson, N. J., and the Rochester Bridge and Iron Works of this city. The most improved machinery and appliances for the purpose were placed in both of the establishments, and the manufacture of pipe began as soon as the steel plates arrived from the rolling mills. For the first-named works the plates were made by the Carnegie Steel Co. at Homestead, Pa., and for the second by the Paxton Rolling Mill at Harrisburg, Pa. At each mill every plate was carefully examined by a competent inspector, and frequent tests of the quality of the material were made, as provided in the specifications. A check on this part of the work was also constantly exercised by independent tests made in other laboratories, as well as by the city's inspector at the pipe shops, so that every possible care was taken to secure good and sound plates.

The contracts provided that the steel should be of the class termed "soft," and be made by the open hearth process. Chemical analyses of each melt were required to show that the metal contained not more than 0.60 per cent. of manganese and 0.06 per cent. each of phosphorus and sulphur ; while the physical tests called for a tensile strength of between 55,000 and 65,000 pounds per square inch, with an elastic limit of not less than 30,000 pounds per square inch, and an elongation of 22.5 per cent. in a length of eight inches ; also for various proofs as to cold bending, punching, drifting and forging. Similar requirements were likewise made for the iron and steel rivets. The thickness of every plate was determined by fine micrometer measurements around the edges, and all plates which were less than 95 per cent. of the required thickness at any point were rejected without appeal ; furthermore, at least 90 per cent. of the accepted plates were of full thickness at all points. Every precaution was also taken to prevent the formation of rust upon the metal, and to this end it was constantly kept under cover, from the time of its manufacture at the rolling mill, until the completed pipe was thoroughly coated in the pipe shop with a durable asphaltic varnish. In case of any accidental rusting, the plate was either rejected or the rust was entirely removed by manual labor.

It was contemplated that the pipe conduit should be a continuous riveted tube throughout its whole length, without expansion joints or other mechanical devices for compensating changes in length caused by variations in temperature. By this continuity, such changes are prevented from manifesting themselves, and are replaced by internal stresses in the metal, which are far within its elastic limit for the range of temperature encountered in the work ; but it becomes essential in this case that the strength of the net section of the plate at the circular seams shall be equal to the shearing resistance of the rivets therein. The joints were therefore carefully designed to meet this condition, and at the ends of the conduit motion was prevented by bedding the pipe in large masses of masonry. Similar precautions were also observed in the design of all stop-valves and branches which were inserted in the pipe line. All of these appurtenances were provided with flanges and bodies of considerably greater strength than the pipe, and were connected thereto by numerous heavy bolts.

Great care was taken to make accurate maps and profiles of the route on a large scale. Upon these the pipe was carefully drawn, and every deviation from a straight line clearly indicated, after which they were handed to the manufacturer. As it was required that the pipe should be made so as to bring all the straight seams in the upper quarter of the circumference, close attention to the work on his part was imperative, and a good check on the computations made by the engineering force was thus secured.

In manufacturing the plates into pipe, the utmost care and precision in edging, punching, riveting and calking were used. One-half of the whole number was rolled into truly cylindrical "outside" sections or courses, and the other half into similar "inside" courses, which fitted closely into and alternated with the former. The internal diameter of every inside course was made exactly 38 inches throughout, and the net length of both kinds of courses, estimated from the centers of the rivet holes at the ends, ranged from 6.83 to 6.75 feet, according to the thickness of the plates. Each course or section, moreover, was made of a single sheet, of such width as to form the required cylinder with ample allowance for overlap.

Four classes of pipe, formed of three different thicknesses of plate were manufactured and arranged according to the water pressure to which they would be subjected in the line of the conduit. For pressures due to static heads of 120 feet or less, the pipes were made of plates one-quarter inch thick, with the longitudinal or straight seams single-riveted; for heads ranging from 120 to 153 feet, the same thickness was used, but the straight seams were double-riveted; for heads between 153 and 199 feet, the thickness was 5-16 inch, and for heads between 199 and 263 feet, the thickness was three-eighths inch, with the straight seams double-riveted in both classes.

All of the circular or round seams were single-riveted, except where two different classes of pipe were joined together, in which case these seams in the thinner pipe, including the junction seam, were double-riveted for a distance of about 200 feet. The object of this provision was to make the efficiency of the double-riveted round seams in the thinner pipe approximately equal to that of the single-riveted round seams in the thicker pipe, as it was computed that in the distance mentioned, the friction of the earth against the pipe, after the trench is properly refilled, would be sufficient to balance the resultant of the longitudinal forces produced in the two classes of pipe by the assumed extreme variation of temperature in the finished conduit, which was here taken at 45 degrees F. Each class of pipe is therefore regarded as being firmly anchored in the soil, except for the said distance at the junctions.

The pipe was generally furnished in lengths of about 27⅓ feet, consisting of four courses riveted together in the shop with powerful machines, and having all seams thoroughly calked on both the inside and the outside. Changes of direction, either in alignment or grade, were made by slightly beveling, at one end only, as many courses as were needed to make the required curve or deflection. These beveled pieces were then power-riveted in the shop, either to each other or to square-ended courses, according to whether the curve was of short or long radius. In the former case it was found expedient to rivet only two courses together in the shop, on account of difficulties in the transportation of longer pieces; but for easy curves requiring only one beveled course to three square-ended ones, four courses were riveted together, the same as for straight pipe. To avoid multiplicity of patterns, a standard bevel of 2 degrees and 43¼ minutes, corresponding to an offset of 1.806 inches in the diameter of 38 inches, was adopted and used as far as possible throughout the work. With this deflection it was still practicable to make a good circular seam without "flanging" or hammering over the ends of the courses. If a somewhat smaller angle was needed occasionally, a special pattern therefor was made; and deflections of less than one-third degree were easily accomplished by slightly reaming out the rivet holes on opposite sides in the round seams.

The above mentioned standard bevel on the end of every fourth course forms a regular polygon which fits closely what railroad engineers designate a 10-degree curve; applied on the end of every second course, it corresponds to a 20-degree 8-minute curve, and on the end of every course, it gives a 41-degree 9¾-minute curve. These three curves may also be defined in terms of their radii, which are 573.7, 286.1 and 142.2 feet, respectively; and all changes in direction and grade of the pipe conduit were made in accordance therewith. It may also be remarked that the work was in general so arranged as to avoid making a change of grade in a curve, although in a few instances such a combination could not be obviated without incurring large additional expense for excavation.

COATING THE STEEL PIPE.

As soon as practicable after the riveting and calking on a pipe were finished, it was thoroughly cleaned, heated in an oven to about 300 degrees F., and then placed in a large tank containing the hot coating mixture, where it was allowed to remain for such time as would suffice for the temperature of the metal to become the same as that of the mixture. The pipe was then removed from the bath and the surplus coating substance allowed to drip off, after which its treatment by the two different manufacturers varied very materially. At the East Jersey Pipe Works, a purely asphaltic coating was used which became hard when cold; and hence after having been dipped the pipes were simply placed on skids outside where the material was left to harden. At the Rochester Bridge & Iron Works, on the other hand, a species of japan coating was used, which required the pipe to be placed vertically in a large brick oven after dipping, and baked therein at a high temperature for about ten hours, on an average.

Much attention was given to the matter of preparing and applying a coating mixture which should be durable, hard, tough and adhesive to the smooth surface of the steel plates at all ordinary temperatures. Numerous experiments with different kinds of asphalt and other substances had been made by the writer, at intervals during several years before the new conduit was projected, in the hope of finding a compound which would meet all of these requirements ; but as they were generally more or less unsatisfactory in fulfilling the last-named condition, it was deemed expedient, after the decision to use steel pipe in the new work was reached, to seek counsel from some chemist who had made the preparation of paints, varnishes and lacquers a special study. In response to various inquiries, the writer was referred to Prof. A. H. Sabin, of the well-known firm of Edward Smith & Co., varnish manufacturers, of New York, and finally succeeded in persuading him to undertake the necessary investigations. Much time, however, was required for the purpose ; and as the East Jersey Pipe Works were soon ready to commence making pipe, the proprietors were directed to use meanwhile the same asphalt coating which had been found to be very successful on numerous conduits in California, as well as on the large steel conduit recently completed for the water supply of Newark, N. J. This material had been highly recommended by several distinguished chemists, and it was generally regarded as superior to any other preparation of asphalt which had yet been devised.

Every effort was made to obtain materials of the best quality for the purpose from California, also to prepare and apply the coating in the most approved manner. The results at first appeared to be very gratifying, but after the pipes had been exposed to the air for several weeks, it was noticed that the high gloss of this coating gradually disappeared, thus leading to the inference that the substance was undergoing a slow change. In water, on the other hand, no alteration was detected, and it was therefore believed that the coating would prove serviceable after the pipes were once filled. It also failed in adhering tightly to the metal, and the contractors were subjected to great expense in painting with costly material large areas from which the coating had scaled off during transportation and handling. Directions were then given to substitute for the California asphalt, a mixture of refined Trinidad asphalt and the best grade of coal-tar, thereby producing the same coating as had been applied to the old conduit and which has proved to be durable at all events. Although this mixture was, on the whole, more satisfactory than the other one, it nevertheless left much to be desired in the way of toughness and adhesion to the steel.

Meanwhile the experiments of Prof. Sabin in the direction of obtaining a better practicable coating had resulted in the evolution of a japanning process which, from both theoretical and practicable considerations, gave promise of conspicuous success. Pieces of small pipe, which he had coated in his laboratory, were subjected to numerous tests for determining the durability of the coating ; and as it withstood all these tests perfectly, and moreover, adhered remarkably well to the metal, its use for the remainder of the conduit was decided upon. At this time, however, the East Jersey Pipe Works had nearly completed their portion of the work, while the

Rochester Bridge and Iron Works was just commencing operations on the pipe. The proprietor of the latter was accordingly requested to investigate the Sabin process thoroughly, and to adopt it if no valid objections could be raised against it by the expert chemists he was to employ for the purpose. As no such objections were forthcoming and nothing better was available, he promptly constructed the necessary expensive plant for carrying out the process under Prof. Sabin's direction, and coated all of his pipe in this manner. So far as can now be determined, this coating is superior to those which were applied to the first half of the conduit, and it is hoped that the crucial test of time will fully confirm this opinion.

TRANSPORTING AND PAINTING THE STEEL PIPES.

Great care was also required in the handling and transportation of the pipes, both by railway and by wagon, to avoid damaging the coating. To this end, all chains and bolsters or saddles which came in contact with the pipe were covered with old rubber hose, canvas or carpeting, and the site where each pipe was deposited, preparatory to excavating the trench, was thoroughly cleared of stones. In spite of these precautions, the abrasion of the coating in spots was unavoidable, not only from the processes of transportation, but also from the subsequent processes of riveting the pipes together. It may also be mentioned that during the latter work, canvas coverings or mats were placed on the top of the pipe outside, and on the bottom inside, wherever the workmen were engaged ; and all who entered the pipe for any reasons were required to use soft felt or rubber overshoes. As it was essential that every defective place in the coating should be repaired as well as possible, the use of a suitable asphaltic paint was necessary, and in the absence of anything better, a preparation called "P. & B. Paint" was selected for the purpose. This material consists of refined asphalt dissolved in bisulphide of carbon ; and as the latter is a very volatile liquid, its rapid evaporation soon leaves a thick coating of hard asphalt on the metal.

The offensive odor of this liquid, however, is a serious objection to its use on the interior of the pipe, as the vapor is both suffocating and inflammable ; hence it was necessary to insure the thorough ventilation of the conduit during its construction. For this purpose, as well as to afford future ingress for examination and repair, manholes with tightly fitting covers were riveted upon the pipe at intervals of about 1,000 feet. The covers of two or three consecutive openings were removed while the interior of the conduit was being examined, and newly driven rivets and abrasions in the coating were being painted, and a strong current of air was forced through these portions of the pipe by means of a suitable fan or blower. In this manner the performance of the necessary inside painting work and its thorough inspection were made endurable.

LAYING, CLEANING AND TESTING THE STEEL PIPE.

After the pipes had been delivered along the route of the conduit, two lengths were riveted together upon the surface of the ground, thus form-ing a section about 54.5 feet in length, and weighing from 7,000 to 10,500 pounds, according to the class. These sections were then rolled in succession by a large number of men upon suitable timbers placed across the trench, where one or two strong derricks raised them clear of the timbers and lowered them safely to the bottom of the excavation. One end of a section was then carefully fitted into the pipe which had previously been laid, and was temporarily fastened thereto with a number of bolts passed through the rivet holes. The exact adjustment of the section to its proper alignment and grade was then done, and after the rivet holes had all been made to coincide, either by reaming or a slight turning of the pipe, the joint was ready for the riveters.

Meanwhile the trench had been excavated truly to line and grade, and wherever the soil permitted, its bottom was shaped to fit the convex exterior of the pipe. All large stones and boulders were carefully removed therefrom, and in rock excavation the trench was made somewhat deeper and then refilled to grade with earth. Where the bottom could not be shaped as aforesaid, wooden saddle blocks were placed at frequent intervals and brought to grade by tamping the soil underneath. At the joints, the trench was enlarged somewhat, so as to admit of inserting the hot rivets from the bottom and sides, the upsetting and hammering of these rivets being done on the inside of the pipe. The remainder of the rivets were passed into the pipe through a small hole cut in its top, and were upset on the outside whilst being held in place with a lever on the inside. On the completion of the riveting, the pass-hole was closed with a brass plug firmly screwed into place. These holes also served to assist in ventilating the pipe, as well as to facilitate the introduction of fresh supplies of paint to the workmen inside.

In refilling the trench, only the finest selected earth material was deposited under and around the pipe, up to a level of six inches above its top, and was thoroughly rammed in thin layers as it was being thrown in, so as to give the pipe a solid bearing for its entire length. Somewhat less care was taken with the filling of the remainder of the trench, although the material was also compacted by ramming where required. For the greater part of the route, it became necessary to partially refill the trench soon after the pipe had been riveted together, in order to prevent the latter from floating in case that the excavation should accidentally be filled with water; but wherever practicable, a space was left open around every field-made joint, in order that any leakage might easily be discovered and remedied on the application of the water-pressure test to the conduit. On the other hand, in places where no appreciable inflow of water could occur, the upper part of the pipe was left entirely exposed until after said test, thereby obtaining an opportunity for observing the quality of the shop-made seams.

Upon the completion of lengths of a mile or more of the conduit, each such section was in its turn thoroughly cleaned out and examined to see that all defects in the coating had been made good with paint, whereupon the ends were tightly closed up, either temporarily with a steel boiler head or permanently with a stop-valve, and the pipe filled with water from a force-pump. The water pressure was gradually raised until it became about 50 per cent. greater than that to which the conduit would afterward be subjected in its normal operation ; and while under this pressure the work was closely examined for leakage. By this means all defects quickly manifested themselves and were thereupon promptly repaired. It may also be mentioned that the force-pump was usually stationed at the beginning of the pipe conduit near the village of Hemlock Lake, and hence most of the sections above Rush reservoir were thus subjected repeatedly to this severe test. For the portion of the conduit from Rush to Mt. Hope reservoir, the force-pump was not needed, as the static head from the said beginning of the work was amply sufficient for testing purposes.

OVERFLOW ON THE CONDUIT NEAR WEST BLOOMFIELD.

A comparatively novel feature of the pipe conduit is the provision of a device, midway in the long stretch of 17.5 miles from its commencement to Rush reservoir, whereby the pressures in the upper half will, under ordinary conditions of operating the works, always be limited to those due to the hydraulic gradient ; while the maximum pressures in the lower half, which will result if the inlet valve to said reservoir be closed, will be about 26 pounds per square inch less than those due to the entire available head. The device consists simply of a short stand-pipe, rising from the conduit on the top of a hill up to the hydraulic grade line for Rush reservoir, and communicating with an adjacent pipe which is continued down the hillside to the creek. With the flow properly regulated by the gates at the lake, and free discharge into said reservoir, the water will not rise in the stand-pipe quite up to the level of the overflow, and hence no waste will ensue ; but if the discharge at Rush is stopped in some emergency, the overflow will at once come into action and carry the entire flow safely into the creek, thereby preventing the head on the upper half of the line from acting on the lower half. The resulting loss of water from the lake will be trifling, as word can soon be sent to the latter place to stop the supply. On the other hand, the benefit derived from the device is the ability to use thinner plates for the pipe over a long distance, and thereby materially diminish the cost of the work.

AIR-VALVES AND BLOW-OFFS.

At every summit in the conduit line, an air-valve of peculiar construction has been placed. The function of these appurtenances is both to afford a facility for letting out the air which may be confined in the pipe before it is filled with water, and to allow air in abundance to enter automatically in case that water is drawn out from blow-offs, or escapes from a rupture in the pipe. The investigations for determining the proper size of such a fixture at any particular summit are extremely interesting, but lack of space prevents their introduction here. It will therefore suffice to say that three different sizes, affording clear openings of 3, 4 and 6 inches in diameter, were used in the work. The devices consist, respectively, of one, two and four similar bronze valves, suspended from springs and attached to a suitable cast-iron chamber, which is bolted to a horizontal stop-valve, and the latter to a flanged casting riveted upon the pipe. The stop-valve is left wide open, but if the air-valve gets out of order, the former may be closed and the repair made without shutting off the conduit. As it is necessary to keep these fixtures free from frost, earth and mischief, each is enclosed in an iron case deeply covered with earth, and from which a capacious stand-pipe projects about three feet above the surface of the ground. The top of this stand pipe is covered with an iron hood in which there is a small opening, also covered with a locked flap, to receive the key whereby one of the cluster of air-valves may be pressed down and opened. For the admission of air, the valves are all opened automatically by the pressure of the atmosphere as soon as the water pressure is removed, since the tension of the springs is only sufficient to balance the weight of the metal.

Corresponding to the air-valves, a blow-off for emptying the pipe, in case of cleaning or repairs, was provided in every depression. One of these was made 8 inches in diameter and all the others were 6 inches. They consisted of two stop-valves bolted together, and to a flanged casting riveted on the lower quarter of the pipe, the valve nearest the latter being kept open and regarded as a reserve in case of injury to the other one, which is ordinarily kept closed. An iron pipe leading to the natural water course or drainage ditch in the depression, serves to carry the discharge, when the valve is opened, to some distance from the conduit. At each blow-off, both the main pipe and the pair of stop-valves are supported upon a bed of concrete, so as to reduce the danger of any breakage in the connection from unequal settlement.

STOP-VALVES AND CONNECTIONS WITH OLD CONDUIT.

Ten large and heavy 36-inch stop-valves are placed in the line of the conduit from its beginning to Rush reservoir, and six such valves are set between Rush and Mt. Hope reservoirs. Of the former, five are placed in such positions that if a parallel conduit about 2.56 miles in length is ever required through that portion of the valley where the new conduit crosses nine times under Honeoye Creek, three connections can be made between the two, so as to divide this somewhat hazardous part of the route into two sections, either of which can be cut out by means of these valves without greatly impairing the efficiency of either of the two lines. Provision has also been made for connecting with the old conduit at two points, the first at Richmond Mills, where the old pipe may be made to partially supply the new line, and the second near North Bloomfield, where the relative elevations first become such as to enable the new line to feed the old one. There is, however, no immediate necessity for making any of these connections, and facilities therefor have been provided only because it is probable that they will become desirable at some future time.

The old and new conduits are also connected indirectly in the new gate house at Rush Reservoir, where a complexity of valves is found necessary for the purpose of avoiding grave annoyances in the future, when another conduit from Hemlock Lake is built. The pipes and valves have here been arranged so as to allow any of the conduits coming to said reservoir to feed any of the pipes leaving the same for Mt. Hope Reservoir. A similar provision has also been made at the point in Pinnacle avenue, about 400 feet north of Elmwood avenue, where the present new pipe deflects abruptly to Mt. Hope Reservoir, the intention here being to treat the deflected line as a branch to said reservoir, while the conduit itself is continued to a new distributing basin, as previously mentioned.

Another large group of valves occurs in the new gate house at Mt. Hope Reservoir, where the new conduit is directly connected with two new 36-inch distributing mains. These latter pipes are also designed to take water from the reservoir ; but as it may become desirable at times to obtain a somewhat higher pressure in the city than is afforded from said reservoir, it has been planned to equip each of these pipes with a check-valve, which will close automatically when they are fed from Rush Reservoir, and will re-open when the connecting valves are shut.

CONNECTION WITH RESERVOIRS.

A few words with respect to the connections of the new conduit with the two reservoirs may also be of interest. For the present, only temporary connections have been made by means of a short line of 16-inch pipe laid over the bank at each locality ; but as the available pressure is large enough to deliver through both lines a sufficient quantity for present needs, and as the funds for the additional water supply were exhausted, the construction of the permanent connections has hitherto been delayed. In the performance of this work, it will be necessary to empty both reservoirs and keep the water out for some time, in order to cut through the banks, lay the various large inlet and outlet pipes, construct the masonry screening wells, and finally refill the excavations ; and while it was expedient to have full assurance from long continued good service, that the new conduit would not require shutting off for repairs during this period, the work should now be postponed no longer.

PRELIMINARY GRADING AND CREEK AND RAILROAD CROSSINGS.

Much more might be added to the foregoing by describing the extensive preliminary grading work which was done in several portions of the route before the pipes could be delivered, as well as the difficulties attending the completion of the crossings under Honeoye Creek and the several lines of railway; but as space therefor is not now available, and nothing has yet been said of the construction of the masonry conduit and the intake pipe, these portions of the work will next be considered.

THE MASONRY CONDUIT AND TUNNEL.

The reasons for adopting a diameter of six feet and a grade of one in 4,000 for the masonry conduit, from Hemlock Lake to a point about 12,000 feet northerly, have already been indicated, and we may therefore pass to the description of the work itself. From numerous test borings it was found that the firmest subsoil, at the contemplated depth below the existing ordinary low water level, occurred over a comparatively small area at the northeastern corner of the lake. This place was accordingly selected for the site of the gate house, and the route of the conduit in earth excavation was governed by similar considerations. It was also aimed to secure the utmost stability for the work by reaching tunnel work in rock as quickly as was consistent with the shortest expedient length of line, since there was little difference in the cost of the finished conduit, whether tunneling was done in earth or in rock. From the contract prices, it was found that when the depth of an open trench in earth reached a limit of 30 feet, the cost per lineal foot of the completed structure would be the same as if the work were done in tunnel, and hence this depth of 30 feet became the dividing line between the two classes of excavations.

An examination of the profile of the route shows that at the beginning of the conduit proper, which is about 100 feet from the shore, the ground is some four feet above the ordinary low water level, and hence that the excavation would here be about 22 feet deep. From this point northerly the ground gradually rises, until at a distance of 395 feet, the depth of cutting becomes 30 feet. Continuing along the route, the surface rises rapidly to Shaft No. 1, which is 68.3 feet deep, and it does not again reach to within 30 feet of the required bottom grade of the conduit for a distance of 7,350 feet. In the remaining length of 4,184 feet to the end of the work, the depths of excavation are all less than 30 feet, the average being 13.3 feet. The contractors were accordingly directed to tunnel the said distance of 7,350 feet and to make an open trench for the remainder of the way, but as they preferred to continue the tunneling for some distance beyond the limits at the same prices as for the work in open excavation, no objection was made.

To expedite the tunnel work, six shafts were sunk at nearly equi-distant and favorably situated points along the route, thus affording, with the two end points, fourteen places at which the excavation could be prosecuted simultaneously. The depths of these shafts ranged from 54.7 to 78.0 feet, the average being 67.2 feet, of which 9.7 feet was in earth and 57.5 feet in dense, shale rock. The power for operating the rock drills was compressed air, which was transmitted through a long line of 4-inch wrought-iron pipe from a centrally located station to each of the shafts, and afterward also to the north portal. Work was first commenced on March 2, 1893, at Shaft

No. 3, and soon afterward at the other five. As this shaft was the shortest, its excavation was finished on April 14, when tunneling was first begun in both directions. On May 5, the last of the other shafts was finished, and tunneling could then proceed from twelve points of attack. At one of the portals the material was clay, while at the other portal soft and friable rock occurred ; hence, the excavation at these points was delayed by the contractors until the principal rock work was well under way.

The tunnel work was prosecuted continuously throughout the twenty-four hours of each day, except Sunday, at a maximum rate of 8.33 feet, and an average rate of 5.71 feet per day, at each of the twelve headings. On August 8, the headings met between Shafts No. 2 and No. 3, and within a few weeks the other headings met, so that on September 1, 1893, a continuous passage was formed between Shafts No. 1 and No. 6, a distance of 5,875 feet. Work at the two ends or portals was begun on August 15 and 24, respectively, timbered shafts 30 feet deep to grade being sunk at these points. From the south portal, the excavation was in clay southerly to the gate house, also northerly for 210 feet, after which it passed into and through soft, shale rock for a length of 130 feet to hard and dense rock ; from the north portal southerly, a similar soft rock was encountered for 224 feet, also for 50 feet northerly, when the excavation passed wholly into clay. The work in this soft rock and clay was somewhat dangerous, and both the roof and sides of the tunnel here required heavy timbering and sheathing. In the firm rock, on the other hand, the roof needed no support and but little trouble from the falling of material was experienced. Progress from the portals was, therefore, somewhat slower than from the shafts, the average rate being about 5.0 feet per day ; yet on October 16, 1893, the excavation of the entire distance of 7,350 feet between the portals was completed.

Meanwhile, work on that portion of the conduit which was to be built in open trench, was also in full progress, it having been commenced on July 17, 1893, near the northern terminus of the route. The excavation was mostly through plastic clay, although two deep cuttings through rock were also necessary. In the former material, considerable bracing and sheathing of the sides of the trench was required, so as to allow the construction of the conduit to proceed without danger. For this purpose, the bottom of the trench was neatly shaped to the prescribed concave form and grade, and upon it was deposited a layer of concrete, six inches in thickness, with its upper surface carefully adjusted to the shape of the brick-work. After the concrete had hardened sufficiently, the invert or bottom of the conduit was formed by a single course of brick. The curved brick side walls, eight inches thick, were next built true to line from wooden forms, up to the level of the center of the semi-circular arched roof ; and while this work was going on, the intervening space of about twelve inches, between the exterior of the brick walls and the sides of the excavation, was compactly filled with concrete. Wooden centers were then put in place, over which the brick arch was turned in two courses, each of four inches thickness, and covered with a thick coating of mortar, after which the concrete backing was carried up for 17 inches and sloped off evenly towards the top of the arch.

All of the brick-work was laid in Portland cement mortar, whereas the concrete was formed with natural cement. The roof was allowed to remain exposed until the concrete had become hard; whereupon the trench was refilled and the original surface of the ground restored, except in a few places where the excavation was very shallow, and an embankment was necessary to protect the masonry from frost. In such cases the embankment was carried to a height of 3.5 feet above the top of the arch, and the filling was also extended back to the hillside in order to avoid the formation of pools. Some delays occurred in the supply of materials for the conduit during the fall; and as it was desirable that the open work should be completed before severe cold weather set in, the contractors devoted most of their energy to the accomplishment of this end. The work was therefore pushed with the utmost diligence, and was finally completed, along with the overflow chamber at the northern terminus, early in January, 1894.

Up to this time, little progress had been made in constructing the brick lining of the tunnel, except where the excavation was through soft ground, and the timbering had commenced to settle; but after the aforesaid operations outside were finished, work in the tunnel was actively resumed. The masonry was begun midway between each of the shafts, and was thence carried along in both directions to the latter. Where the rock was hard and sound, the side walls and arch were made of two rings of brick, or eight inches in thickness; and, as in the case of the conduit in open excavation, the entire space between the exterior of the brick work and the rock sides was filled with concrete to near the top of the arch, above which the space was filled with fragments of stone from the excavation, all tightly packed or rammed into place. It should also be stated that on removing the debris and exposing the sound rock on the bottom of the tunnel, its surface was found to be very irregular, owing to the action of the explosives; and it was therefore determined to make this bottom smooth and uniform in grade throughout by filling up all depressions with concrete, the lower portions of this filling, up to four inches below grade, being made with natural cement mortar, while the top layer was made with Portland cement mortar. The bottom of the tunnel is accordingly as smooth and true to grade as a good cement sidewalk, and some advantage will result therefrom in the future, by enabling the tunnel to be easily cleaned by a suitable sweeping machine.

In soft rock excavation, the bottom of the tunnel was lined with one course, four inches thick, of brick; but in earth excavation two courses, in addition to the concrete, were used to form the floor. In other respects the construction was similar to that already described, except in places where the rock roof was very thin and loose. At these localities, the side walls and arch were formed of three courses of brick ; and at the shafts, where great strength was required, the brick lining masonry was made four courses, or 16 inches thick. The aggregate length of the 12-inch brick lining is 434 feet, and that of the 16-inch lining, 132 feet. In each shaft, a brick manhole was built after the tunnel masonry had been finished, which was provided with a vertical iron ladder, resting platforms about 25 feet apart, and a strong iron coping at the surface of the ground. The resting platforms were designed to be capable of being folded back against the brick work, so as to afford an unobstructed passage for large buckets from top to bottom, in case of future repairs or cleaning operations in the tunnel ; and the top casting was furnished with a tight-fitting locked cover, and a 6-inch ventilating pipe, terminating in a suitable hood.

It may also be remarked that a six-inch ventilating hole was drilled at some convenient point between each pair of shafts, as it was anticipated from the preliminary borings that some natural gas might be encountered. Most of these holes have been retained for use hereafter, and the tops of the iron casing pipes are now provided with hoods, as at the shafts. Three relatively short manholes were furthermore built over the conduit in open excavation, so that in addition to the ends, access to the work can be gained at nine different points along the route.

The tunnel masonry was completed on July 6, 1894, but before it could be used for conveying water to the pipe conduit, the interior of the whole work had to be scraped, washed and thoroughly cleaned, as considerable quantities of waste mortar, sand, mud and soot had gradually accumulated therein. After having been carefully cleansed, the surface of the brick work was given a thick coating of neat Portland cement, which was applied as a wash with large brushes, and rendered the whole conduit as clean as the most fastidious could wish.

THE NEW GATE HOUSE.

Some reference to the work of constructing the large gate house on the shore of the lake, at the south end of the conduit, should also be made. Excavation was begun on August 23, 1893, and a timber foundation on a bed of clay was obtained on October 26. From the insufficiency of the bracing, however, the sides slipped in, and caused a serious disturbance of the material on the bottom. After clearing the site several times, about one hundred piles were driven in December at relatively close intervals over the whole surface, into a hard stratum below, and a secure foundation was thus obtained. The piles were capped with heavy timbers, over which another course of similar timbers was laid transversely, and concrete was then rammed into the rectangular spaces of the grillage, up to the top of the upper course of timber. Another layer of fine concrete was then deposited over this surface, both as a precaution against leakage, and to form the footing course of the walls. As no suitable stone could be found anywhere in the locality, the thick walls were built entirely of brick work, laid in Portland cement mortar. This remark is also applicable to the case of the overflow chamber at the north end of the conduit. The masonry of the gate house was begun on January 11, 1894, and was completed up to the level of the contemplated flooring on April 24, 1894, the work also including the laying in concrete of the first length of 38.6 feet of the five-foot steel intake pipe. During the winter, the excavation was covered with a temporary wooden roof, and the enclosure was kept warm enough to prevent the masonry from becoming injured by frost.

The gate house is arranged with two sets of passages to the conduit, both to secure ample area of screen surface, and to allow one set of sluice valves to be repaired without interrupting the water supply to the conduit. For the latter purpose, the openings through the partition walls are provided with strong iron guides for stop planks or shutters, so that any compartment may be isolated. A subterranean chamber was also formed at the mouth of the conduit, in which a weir has been placed for accurately measuring the supply taken to the city; and by removing this weir, room is afforded for launching a boat, either for making an examination of the tunnel at any time, or attaching a sweeper. It may be mentioned, in this connection, that while the conduit is six feet high and wide inside, the maximum depth of water therein will not exceed four feet, unless it is desired to waste it at the overflow chamber.

LAYING THE INTAKE PIPE.

From the character of the work connected with the laying of the large intake pipe, little could be done in this direction until the gate house was finished. An agreement for its performance was made on April 14, 1894, with Chambers & Casey, of this city, but active operations were not commenced until May 16, as the intervening time was needed to obtain materials for building scows for the dredge, the pile-driver and the pipe, also for constructing the various temporary supports and procuring the necessary machinery and appliances. The five-foot steel pipes, with their ball and socket joints, had been delivered and riveted together in lengths of about 100 feet during the preceding fall and winter, and arranged in proper order upon a platform in a convenient field. Their weight ranged from fourteen to eighteen tons, according to the thickness of the plates, and the number of stiffening rings. To transport these heavy tubes safely, a narrow-gauge railway track was laid between the two rows of pipes and down the gently sloping bank to and over a pile pier, at the end of which a powerful hoisting apparatus or winch was placed on a framework overhead. A pipe was then rolled upon two small trucks and conveyed to the end of the pier, where one-half its weight was transferred from the foremost truck to a pontoon or scow, which was then pushed out a certain distance and held in place; the pipe was then lifted from the rear truck and lowered upon a second scow, which had been slipped underneath, so that it now rested on two floating supports; whereupon it was easily towed to its required position between two-well braced clusters of piles, which had meanwhile been driven in the line of the work and which were provided with winches on their tops. The pipe was then lifted from the two scows and held in place by strong chains at each end.

This method of transportation was adopted for all the pipe, except the first long one, which was moved to the gate house by rolling on timber ways carefully bedded in the surface of the ground. Other work, however, was necessary before any pipes were moved. A steam dredge had to cut a channel, giving about 20 feet depth of water and sufficient width on bottom to allow it to operate advantageously, from a point in the lake about 800 feet from the shore towards the latter to meet the open excavation for the first pipe, which was done mainly under the protection of a low dam built in the shallow water near the shore. This plan was pursued both to expedite the work and to avoid the necessity of a diver in coupling together the ball and socket joint at the junction of the first long pipe and the short one which had previously been laid along with the foundation of the gate house. Borings had shown that, to this extent at least, an open excavation, with side slopes of one and one-half to one, could readily be made in the plastic clay; and this was proved by subsequent easy performance of the work. After the earth was removed, the first long pipe was rolled down the side slope of the pit by means of check ropes, and placed approximately in line on the bottom.

Several thick piles 65 feet in length, which was sufficient to span the top of the excavation, were then rolled along from the south bank so as to form a bridge or platform over the end of the pipe. A few supports from below enabled this platform to carry a light pile-driver, the engine of which was left on the bank, whereupon a cluster of six piles was driven on each side of the pipe and thoroughly braced. The tops of these piles projected 10.5 feet above the water surface of the lake and were capped transversely with heavy timbers, the caps being in turn tied together by similar longitudinal timbers. The space of about 14 feet between the two groups of piles was then bridged over with other timbers, upon which a winch was placed, whereby the south end of the pipe could subsequently be lifted above the water surface. At its north end the pipe was raised slightly to its required height with jack-screws, and then slid along until the ball of the joint was properly fitted into the socket of the pipe projecting southerly from the gate house, whereupon the coupling collar of the ball was securely bolted to said socket, thus completing the first joint or flexible union of the two pipes.

As the above mentioned short pipe was firmly held in place both by the thick wall of the gate house and the large mass of concrete in which it was enclosed, also by the clay backfilling over the latter, the south end of the first long pipe could now be moved about freely, and it was therefore raised up and held in place with a chain sling until the dredge had completed the aforesaid channel, and formed a communication with the open pit. A second cluster of piles, like the first, was then driven in the channel at the proper distance from the second ball joint, and provided with a winch, whereupon the second long pipe was brought into position, raised from the scows and coupled to the first one above the water surface. It will be noticed that only one winch was placed on each of the cluster of piles, the one at the open or south end of the second pipe being soon relieved from duty by a chain sling, whereby it became available, with a little shifting, to lift the north end of the third pipe. The sling at the south end of the first pipe could now be released by throwing the entire weight at the second ball joint upon the first winch, whereupon the joint could be lowered down to place on the bottom of the channel; but before doing this a strong timber and plank platform was attached to the joint in order to prevent undue sinking into the soft clay at the bottom. As soon as the platform and joint rested on the bottom, the winch was free to be moved to the third cluster of piles. By repeating these operations, all of the fifteen pipes were finally sunk in place.

The end of the last pipe was provided with a wide, flaring mouth-piece, which was enclosed in a strong, timber crib, 16 feet square and ten feet high. Two sides of this structure were divided into compartments; and when it was ready for sinking, these were loaded with stone distributed in such manner as to produce a nearly uniform pressure upon the lake bottom. As the connection of the crib and mouth-piece did not admit of much motion, it was necessary to lower the last pipe and the crib simultaneously, and in a horizontal position, which was easily done with the winches and guide ropes. It should also be stated that after the pipes had been laid in the aforesaid deep channel, the latter was partially refilled by the dredge with material taken from the adjacent sides, in order that no subsequent sloughing or caving might cause a displacement of the pipe; the large excavation at the shore was likewise refilled. All piles were pulled out as soon as they had served their purpose in any locality, and, if practicable, were again used elsewhere in the work. The same course was also pursued with the other materials.

The crib, which completed the new intake work at the lake, was sunk on October 6, 1894, the first long pipe having been put in place on August 14. Dredging was begun on June 25, and on August 21 connection was made with the open excavation at the shore, although only a portion of the channel was at that time finished. As the clusters of piles at the pipe joints could not be driven until the dredge had cut the required channel, progress with the pipe laying was somewhat slow, but after leaving this channel, the floating pile-driver was kept at work constantly, and the pipes were laid as fast as the pile clusters were completed. The work of launching, transporting, connecting and laying each pipe occupied only a few hours, and had the dredging and pile work all been done in advance, the pipe work alone could have been completed in ten days.

THE TEMPORARY INTAKE PIPE.

Early in the season of 1894, it was realized that the above described permanent intake work could not be finished before an ample supply of clean water from the lake would be needed for washing out both the tunnel and conduit masonry and the steel pipe conduit, which latter was expected to reach Rush reservoir in June. To avoid delays anywhere in the work between the lake and said reservoir, and in order that the earliest advantage could be taken of the considerably greater discharging capacity of the portion of the old conduit between Mt. Hope and Rush reservoirs, over that of the portion between Rush and the lake, a temporary intake was formed early in July, 1894, with a line of 16-inch pipe, about 720 feet long, which was laid as a siphon from a small plank basin on the shore of the lake, and directly communicating therewith, to the bottom of the gate house. This line of pipe was provided with a stop-valve at each end, and by closing the same, the siphon could readily be charged in a short time by filling it with water from a small steam pump. By closing the orifice for filling on top, and then opening the two stop-valves mentioned, the siphon was at once set in operation, and was able to deliver clean water from the lake at the rate of about 8,000,000 gallons per day.

This rate was amply sufficient for every purpose, and the pipe remained in service until the permanent works were completed on October, 6, 1894. It was taken up soon afterward and returned to the city for future use in the distributing system, while the plank and boards of the suction basin now form part of the temporary roof over the gate house. It may also be mentioned that water from the siphon was first admitted into the tunnel for cleaning purposes on July 16, 1894, and that this operation occupied a full month, during which time the masonry was subjected to repeated scrubbings and flushings. On August 17 the water was first admitted into the steel pipe, which was also thoroughly flushed a number of times before the temporary inlet pipe to Rush reservoir was opened, and the remainder was treated in a similar manner ; and it is fair to state that when the inlet valves at the two reservoirs were first opened, the water issued as clear and clean, so far as the senses could detect, as when it left Hemlock Lake, 26 feet below its surface.

GENERAL STATISTICS RELATING TO THE WORK.

Some further statistics relating to the work will doubtless be of interest.

The material excavated in the performance of Contract No. 1, was about 47,400 cubic yards, of which 30,900 were in open trenches, and 16,500 in the shafts and tunnel. The volume of masonry built was 12,870 cubic yards, of which 2,030 was stone work of various classes, 3,980 concrete, 1,085 brick-work in the gate house and overflow chamber, and 5,775 in the conduit, tunnel and shafts. The brick-work represents about 3,700,000 brick. Over 54 tons of iron-work was put in place, and the number of men employed daily ranged from 100 to 400 during a period of sixteen months.

The work performed under Contract No. 2, embraced approximately 62,000 cubic yards of preliminary grading for roadways and reducing depth of backfilling, of which 2,200 were in rock; 207,300 cubic yards of excavation in trenches for the pipe, of which 1,250 were in rock; 4,650 cubic yards masonry of various classes; 250,000 feet B. M. timber and plank in foundations and bridges; 6,500 lin. feet of piles driven for bridges and pipe foundations; 53,361 lin. feet ¼-inch plate pipe with single-riveted straight seams; 24,729 lin. feet ¼-inch plate pipe with double-riveted straight seams; 34,815 lin. feet 5-16-inch plate pipe, and 24,043 lin. feet ⅜-inch plate pipe, both with double-riveted straight seams; 1,350 lin. feet 36-inch cast-iron pipe, special castings and stop-valves; the total length of pipe conduit thus being 138,298 lin. feet, or 26.19 miles. The first shipment of steel pipe from the East Jersey Pipe Works arrived on April 26, 1893, but laying was deferred until June 8, as a large amount of heavy grading along she first two miles of the route had to be finished before any pipe could be delivered or the trench opened.

On December 21, 1893, the pipe conduit was completed to Rochester Junction, on the Lehigh Valley Railroad, a distance of about 13.6 miles from its beginning near Hemlock Lake, and further operations were suspended for the winter. During the preceding period, the average rate of progress in pipe laying was 500 feet per day. Work was resumed on April 6, 1894, and as the weather continued favorable very rapid progress was made, Rush reservoir being reached on May 14, and Mt. Hope reservoir on July 26. The maximum rate of progress in pipe laying was 1,860 feet in one day, and the average for the entire work was 598 feet per day. Much work, however, remained to be done in testing, recalking, attaching air-valves and blow-offs, setting main stop-valves, painting and cleaning the pipe, and making temporary inlets at the two reservoirs; and it was not until August 24, 1894, that the water was first let into Rush reservoir, and October 9, 1894, into Mt. Hope reservoir. The number of men employed daily on the line of work ranged from 300 to 600.

RIGHTS OF WAY.

An important element in the problem was the acquisition of the necessary rights of way for performing the work over a route 27.8 miles in length, where the ground was not already owned by the city. Of this distance, 20.6 miles was through private lands, and 7.02 miles in highways. The title to the area occupied by these roads was, however, vested in the adjoining landowners, and hence it became necessary to negotiate with the latter for the right to lay the pipe, precisely as if the line were located in private grounds. Much diplomacy was needed to obtain these rights without causing delay to the contractors, especially as no limit was placed on the number of conduits which the city might lay in the territory sought, also because it was stipulated that no damages to crops grown thereon in the future should ever be paid. Out of a total of 140 landowners along the route, it was found necessary to apply for legal condemnation proceedings and arbitrations in only thirteen cases. The total costs of these permanent rights of way, and temporary land damages, including all legal expenses involved thereby, was about $61,600, or about $2,215 per mile on the average.

COST OF THE WORK.

The total cost of the work up to Jan. 1, 1896, has been $1,776,911.86, the details thereof being given in Appendix No. 3 ; but as it may be of interest to mention the principal components of this sum, the following general summary is herewith submitted : For the intake works at Hemlock Lake, $51,825.25 ; for the masonry conduit, tunnel, gate house and overflow chamber, $268,624.30 ; for the steel pipe conduit and appurtenances named in the general contract, $1,197,005.83 ; for stop-valves, air-valves, valve boxes and buildings not included in said contract. $29,868.88 ; for prospective damages to mill-privileges on the outlets of Hemlock and Canadice Lakes and Honeoye Creek, $67,250.00 ; for permanent rights of way, temporary land damages and legal expenses, $61,572.30 ; and for preliminary surveys, examinations, borings, engineering, inspection, printing and miscellaneous expenses, $100,765.30 ; total, $1,776,911.86. It should also be remarked that in order to complete the new conduit, an additional expenditure of about $60,000 is necessary for the permanent connections at the two reservoirs and for suitable buildings over the several gate chambers at Hemlock Lake and Mt. Hope reservoir ; and it may furthermore be mentioned that if the aforesaid prospective damages to the mill-privileges had not been charged to the construction account, the work might have been finished within the appropriation. This statement is permissible in view of the fact that the original estimates distinctly excluded any provision for such damages, it having been assumed that these claims would be adjusted after the conduit had been put into operation, and the consumption of water in the city had reached the limit of draft for which payment had previously been made.

ADMINISTRATION.

As the description of a large piece of public work is usually accompanied with the names of those who have been engaged in its performance, and since allusion has already been made to the contractors, it now becomes proper to mention the municipal authorities and employees under whose direction the new conduit was built. The responsibility for the entire work was vested primarily in the Executive Board of the city, acting as a Board of Water Commissioners ; and during the three fiscal years occupied in the design and construction of the conduit, the members and principal subordinate officers of this Board, for the Water Works Department, were as follows :—

Executive Board.

1892–3.	1893–4.	1894–5.
GEORGE W. ALDRIDGE,	JOHN U. SCHROTH,	RICHARD CURRAN,
WILLIAM W. BARNARD,	GEORGE W. ALDRIDGE,	WILLIAM W. BARNARD,
JOHN U. SCHROTH,	WILLIAM W. BARNARD,	JOHN U. SCHROTH.

THOMAS J. NEVILLE, Clerk.

E. KUICHLING, Chief Engineer.

The corps of engineers, assistants and inspectors engaged at various times on the work was as follows, the names of those who were employed intermittently during the period of service indicated having an asterisk (*) prefixed :—

I—ON PRELIMINARY SURVEYS.

LeGrand Brown	Transitman,	July 20, 1891, to Dec. 11, 1891
Cyrus Beardsley	"	July 20, 1891, to Oct. 24, 1891
John F. Skinner	Leveler	July 24, 1891, to Feb. 9, 1892
Beekman C. Little	"	July 20, 1891, to Feb. 9, 1892
Elon H. Hooker	"	July 15, 1891, to Feb. 9, 1892
Spencer J. Steward	"	Aug. 23, 1891, to Sept. 30, 1891
Spencer J. Steward	Rodman	July 20, 1891, to Aug. 23, 1891
*Edward P. Webster.	"	July 20, 1891, to Nov. 28, 1891
*Wm. F. Thompson	"	July 20, 1891, to Oct. 16, 1891
*Wm. Crennell, Jr	"	July 20, 1891, to Nov. 28, 1891
Alex. C. Watson	Chainman, etc	July 20, 1891, to Oct. 3, 1891
Charles H. Blackwood	"	July 20, 1891, to Aug. 17, 1891
E. M. Hague	"	July 20, 1891, to Sept. 8, 1891
William R. Barr	"	July 20, 1891, to Oct. 10, 1891
Richard Buckley	"	Aug. 24, 1891, to Sept. 30, 1891
*John Lawton	"	July 20, 1891, to Nov. 28, 1891
*William J. Kane	"	July 22, 1891, to Nov. 28, 1891
*Leonard R. Clow	"	Aug. 18, 1891, to Sept. 14, 1891
*William S. Westfall	Making Borings	July 22, 1891, to Nov. 28, 1891

II—ON FINAL SURVEYS AND LOCATION.

Walter H. Sears	Assistant Engineer	May 1, 1892, to Jan. 1, 1893
*Edwin A. Fisher	" "	May 1, 1892, to Oct. 1, 1892
LeGrand Brown	Transitman	Feb. 9, 1892, to Jan. 1, 1893
John F. Skinner	Leveler	Feb. 9, 1892, to Jan. 1, 1893
Beekman C. Little	"	Feb. 9, 1892, to Jan. 1, 1893
Elon H. Hooker	"	Feb. 9, 1892, to Sept. 21, 1892
*Spencer J. Steward	"	May 2, 1892, to June 3, 1892
*Wm. Crennell, Jr	Rodman	Feb. 9, 1892, to Jan. 1, 1893
*John C. Dillman	Chainman, etc	May 4, 1892, to June 1, 1892
*John Lawton	"	Feb. 10, 1892, to Oct. 27, 1892
*Leonard R. Clow	"	Feb. 10, 1892, to Oct. 28, 1892
*William J. Kane	"	May 2, 1892, to June 24, 1892
Nath. F. Foote,	"	Aug. 9, 1892, to Aug. 31, 1892
Benj. R. Briggs	"	Aug. 9, 1892, to Sept. 3, 1892
*Caspar Scholz.	Draftsman	May 27, 1892, to Dec. 11, 1892
*William S. Westfall	Making Borings	May 1, 1892, to June 22, 1892
*Charles H. Hoppough	" "	Oct. 25, 1892, to Dec. 21, 1893

III. ON CONSTRUCTION.

Alphonse Fteley	Consulting Engineer	July 1, 1892, to Jan. 1, 1895
Walter H. Sears	Prin. Ass't Engineer	Jan. 1, 1893, to Feb. 1, 1893
Edwin A. Fisher	" " "	Feb. 1, 1893, to Jan. 1, 1896
Gaylord Thompson	1st " "	Feb. 9, 1893, to May 4, 1895
LeGrand Brown	2nd " "	Jan. 1, 1893, to Feb. 20, 1895
J. E. Shields	Transitman	Mar. 15, 1893, to Apr. 8, 1893
Stuart E. Sill	"	Jan. 30, 1893, to Mar. 30, 1895
Caspar Scholz	"	Apr. 1, 1893, to Sept. 11, 1894
Max Kronauer	Topographer and Draftsman	Jan. 30, 1893, to Apr. 11, 1895
John F. Skinner	Leveler and Draftsman	Jan. 1, 1893, to Jan. 1, 1896
*Elon H. Hooker	" " "	June 17, 1893, to Sept. 14, 1893
*Festus A. Steward	" " "	June 7, 1893, to Apr. 17, 1894
Beekman C. Little	Leveler	Jan. 1, 1893, to Feb. 1, 1895
George E. Greene	"	May 6, 1893, to Apr. 29, 1895
Irving E. Mathews	"	Aug. 1, 1893, to Oct. 24, 1894
Wm. Crennell, Jr	Rodman	Jan. 1, 1893, to May 9, 1895
Willard D. Lockwood	"	Feb. 14, 1893, to Aug. 24, 1893
Paul Gregory	"	Apr. 1, 1893, to Dec. 19, 1894
Horace J. McKelvey	"	Aug. 8, 1893, to Feb. 17, 1894
John C. Dillman	"	Apr. 27, 1893, to Feb. 20, 1895
Warner W. Gilbert	"	June 19, 1894, to Aug. 2, 1894
*John C. Dillman	Chainman, etc	Jan. 30, 1893, to Apr. 27, 1893
*Leonard R. Clow	" "	Feb. 1, 1893, to May 13, 1893
Warner W. Gilbert	" "	June 28, 1893, to Sept. 9, 1893
*Chas. H. Sharpe	" "	Mar. 14, 1893, to Jan. 1, 1894
George A. Reed	" "	Feb. 23, 1893, to Dec. 16, 1893
Albert P. Ward	" "	Mar. 22, 1893, to May 11, 1893
Woodworth Campbell	" "	Apr. 14, 1893, to May 13, 1893
*Emil Landsberg	" "	June 26, 1893, to Aug. 2, 1894
Bertram E. Frost	" "	July 4, 1893, to Sept. 30, 1893
Louis Cartwright	" "	June 21, 1893, to July 31, 1893
*Donald J. Hutton	" "	Oct. 2, 1893, to Jan. 1, 1895
Joseph H. Oberlies	" "	Oct. 3, 1893, to Jan. 26, 1894
Frank C. Stelzelberger	" "	Nov. 8, 1893, to Sept. 12, 1894
*L. A. Lewis	" "	May 9, 1894, to Jan. 1, 1895
Emma M. Petty,	Stenographer	Mar. 28, 1893, to Jan. 1, 1896
George M. Page	Draftsman	May 5, 1894, to Jan. 1, 1896
Wm. Williams	Pipe Inspector at shops	Apr. 12, 1893, to July 27, 1894
*Rob't Bryson	" " on line	May 29, 1893, to Oct. 6, 1894
Willard D. Lockwood	" " " "	Aug. 24, 1893, to Feb. 20, 1895
Nicholas U. Long	Masonry Inspector, Sec. 1	Aug. 8, 1893, to May 10, 1894
*Albert Wagner	" " "	Oct. 14, 1893, to Oct. 19, 1894
Martin Stunz	" " "	Oct. 21, 1893, to Aug. 4, 1894
William Carroll	" " "	Sept. 25, 1893, to Oct. 14, 1893
Reimond Stief	" " "	Oct. 30, 1893, to Aug. 4, 1894
George W. Dayton	" " "	Nov. 13, 1893, to Aug. 4, 1894
John B. Gleichauf.	" " "	Nov. 16, 1893, to Aug. 4, 1894
*Samuel Forbes	" " "	Jan. 31, 1894, to Jan. 19, 1895
*E. M. Blakeslee	" " Sec. 2	Sept. 6, 1893, to Nov. 24, 1894
Booth, Garrett & Blair	Inspectors of steel plates at Homestead, Pa	1893
Pittsburgh Testing Laboratory	" " " " " " "	1894
G. W. G. Ferris & Co	" " " " " Harrisburg, "	1893–4
Robt. W. Hunt & Co	" " " "	1893-4
A. H. Sabin	Consulting Chemist on pipe coatings	1893

It is also proper to state that during construction, the work was divided into two sections, the first one embracing the masonry conduit and tunnel, with the overflow chamber, gate house and intake works, while the second embraced the long steel pipe conduit, with its creek crossings, overflow tower and reservoir connections. The former was under the immediate supervison of Mr. Gaylord Thompson, with Messrs. Scholz, Mathews, Hooker, Gregory, Crennell, Gilbert, Long, Wagner and others as assistants; and the latter section was in direct charge of Mr. Edwin A. Fisher, assisted by Messrs. Brown, Sill, Kronauer, Skinner, Greene, Little, Steward, Page, Crennell, Dillman, Lockwood Bryson, Williams, and others. From the foregoing list it will be noticed that a number of persons were employed only for short periods of time or intermittently; but it must not be inferred that such temporary employment was in any case the result of dissatisfaction with their service. On account of the necessity for economy, many of the employees were engaged only for a brief time, while others voluntarily resigned, either to accept more permanent positions elsewhere or to continue their studies.

CONCLUSION.

Before concluding, the writer desires to make proper acknowledgment of the work done by others in the successful accomplishment of the result. To the Executive Board, who participated largely in the many anxieties and worries incident to this important undertaking, he is indebted for generous support, unfailing sympathy and substantial co-operation; to the consulting engineer, Mr. Alphonse Fteley, of New York, he tenders his cordial recognition of much valuable professional advice and counsel; and to his various assistants and inspectors named above, he cheerfully accords unstinted praise for conspicuous ability, interest and diligence in the performance of their duties. He also takes pleasure in bearing witness to the efficiency of the City Attorney and Mr. Jerome Keyes, in respectively transacting the legal business and obtaining the necessary rights of way; and finally in giving due credit for the successful performance of the work itself to the several contractors, Messrs. Whitmore, Rauber & Vicinus, Wm. H. Jones & Sons, and Chambers & Casey, together with the Rochester Bridge & Iron Works, the Genesee Foundry Co., of Rochester, N. Y., the East Jersey Pipe Works, of Paterson, N. J., the Carroll-Porter Boiler & Tank Co., of Pittsburgh, Pa., the Central Bridge & Engineering Co., of Peterborough, Ont., and the Rensselaer Manufacturing Co., of Troy, N. Y