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RECENT IMPROVEMENTS TO THE WATER WORKS AT PEABODY, MASS., INCLUDING PUMPING PLANT AND DISTRIBUTING RESERVOIR.

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[*Read September 11, 1907.*]

The Peabody water works were originally purchased from the Salem Aqueduct Company, one of the oldest in the country. The history of these works begins in December, 1796, the year the Boston system was introduced, when a meeting of subscribers of the Salem and Danvers Aqueduct Company was held at the Sun Tavern, Salem, Mass. At this meeting a committee of three was appointed to procure an act of incorporation, to make all contracts for logs and boring of same, and to contract for land through which the aqueduct was to pass. The necessary funds for starting the work were procured by issuing one hundred shares of stock at $40 per share. A petition for incorporation was presented to the General Court in January, 1797, and an act of incorporation was signed by Gov. Samuel Adams on March 9 of the same year. Work was immediately begun, the pipe line consisting of logs with a bore of 3-inch diameter, and by August the work was so far completed that the directors were authorized to dispose of the privilege of drawing water from the aqueduct for a term not exceeding one year, under such terms and restrictions as they should judge proper. The rate for a family having one post was $5 annually, to be paid semi-annually.

In 1804, after the company had expended $44 000 on the works, it was found that the supply through the 3-inch log was inadequate, and it was ordered that a new log be laid for the aqueduct with a bore of not less than 5 inches.

The first iron pipe, which was 6 inches in diameter, was laid by the company in 1834. In 1850 a 12-inch iron pipe was laid from the source of supply to Federal Street in Salem. In 1866 this 12-inch pipe was extended to a point opposite the Market House in Salem. This 12-inch iron pipe is to-day the means of supplying a small service district in Peabody. After 1852 all extensions were made with cast-iron or cement-lined iron pipe instead of logs. In 1865 a 16-inch cement-lined pipe was laid from the reservoir to Federal Street, Salem. To-day this pipe is one of the principal distributing mains of the town.

In 1873 the town of Peabody purchased the works and franchise from the Salem Aqueduct Company for $125 000. At the time of the purchase one hydrant, located at the Square and attached to the 12-inch pipe, was the only fire protection afforded to Peabody by the system.

Originally the works were planned to furnish Salem and Peabody with water by gravity from Spring Pond. After their purchase by the town, higher pressure being desirable, a pumping station was constructed at the corner of Foster and Washington streets, the water being drawn from the 16-inch gravity main and, after passing through the pumps, being again returned to this same main. In 1882 a standpipe 60 feet in diameter and 23 feet high was erected on Buxton Hill, with its high-water mark at elevation 180 above mean low tide.

The pumping plant consisted of two Worthington pumps, one pump being a horizontal duplex, compound condensing type, rated at 2 500 000 gallons capacity, the other a horizontal duplex simple type of 2 500 000 gallons capacity. The boilers were two in number, 15 feet long, 6 feet diameter, rated capacity 95 horsepower, and when operating carried about 65 pounds steam pressure.

In 1902 the consumption had increased to a point where the capacity of the pumps was not sufficient to fill the standpipe without running well into the night, and the water stored in this way was so far depleted by the night draft that but little remained at the time of starting the pumps the next morning. It was therefore evident that pumps of greater capacity were needed and, if the pump run was to be limited to a reasonable number of hours per day, that a larger standpipe or a reservoir, capable of holding a supply sufficient for the town during the time the pumps were not in operation, must be provided. It was accordingly recommended that a pump of 5 000 000 gallons daily capacity be installed in a new station, located at the source of supply, thus doing away with the long pipe line between the supply and the old station which, while originally a pressure main, had, under the increased draft, operated of late years as a suction pipe.

It was further decided to construct a circular masonry reservoir on Lookout Hill, of 2 500 000 gallons capacity, with its high-water mark at elevation 220, or 40 feet above that of the old standpipe, and to connect this reservoir with the distribution system by a 20-inch supply main 10 000 feet long, extending to the corner of Foster and Washington streets, the location of the old station.

It is intended in this paper to briefly describe the pumping plant and reservoir which, while involving nothing of particular merit, are perhaps of sufficient interest to justify their being made matters of record. In the experience of the writer it has often appeared that while descriptions of large works can be readily found, smaller plants have been more or less neglected, and it is often difficult to obtain suggestive plans and information of the class of work demanded for a community of ordinary size.

Incidental to these improvements in the distribution system, some work was done in bettering the quality of the supply. Around Spring Pond numerous small cottages had been located, and there were evidences that the pollution of the water would rapidly increase unless precautionary measures were taken. Application was accordingly made to the State Board of Health for the establishment of sanitary regulations governing the watershed, and, in addition, land was purchased for a depth of 200 feet from the shore line, thus requiring the removal of all cottages to a considerable distance from the pond. The opportunity to invoke the powers of the Board of Health in the protection of watersheds, by the establishment of definite regulations, is believed to be one of the most valuable provisions in the sanitary laws of the state. While the final results depend on adequate supervision and inspection, these rules focus attention on the necessity for taking particular care in the case of such watersheds as those from which the Peabody supply is drawn.

Before entering upon a description of the pumping plant, it may be well to briefly consider the records of consumption during the past ten years in Peabody. These are most abnormal in the relation of manufacturing and domestic use, and are of interest in indicating how rapid may be the increase in the demand for water in a town depending on one particular industry which is, for the time, enjoying unusual prosperity. Tanneries and glue works constitute the local industry and use large quantities of water. In addition to the amount drawn from the town supply — 879 000 gallons per day — probably as much more is obtained from private sources.

The following table shows the water consumed each year in the pumping district since 1895:

TABLE No. 1.

Year.	Gallons Pumped.
1895	330 050 880
1896	339 682 860
1897	340 535 737
1898	353 418 735
1899	415 644 841
1900	377 248 159
1901	411 283 296
1902	456 849 304
1903	544 332 291
1904	611 195 167
1905	639 508 600
1906	691 527 606

From 1895 to 1906 the water consumption increased two hundred per cent., while the population increased by twenty-five per cent. The manufacturing consumption during this period increased two hundred and fifty per cent. The per capita consumption in 1895 was 87 gallons; in 1906 it was 145 gallons. The manufacturing consumption in 1901 was 32 gallons per capita; in 1906, 67 gallons.

The following table shows the increase in manufacturing consumption, domestic and public consumption and leakage since 1901:

TABLE No. 2.

Year.	Total Average Consumption. Gallons per Day.	Manufacturing Use as Measured by Meters. Gallons per Day.	Domestic and Public Use and Leakage. Gallons per Day.
1901	1 200 000	354 000	846 000
1902	1 315 000	439 000	876 000
1903	1 520 000	620 000	900 000
1904	1 800 000	694 000	1 106 000
1905	1 750 000	736 000	1 014 000
1906	1 895 000	879 000	1 016 000

The increase in the column under domestic and public consumption and leakage in 1904 was due to increased leakage from the effect of the higher pressure from the new system.

The Sunday and week-day consumption in 1906 is estimated as follows:

Sunday.	6 A.M. to 6 P.M. =	565,000	gallons per day
	6 P.M. to 6 A.M. =	425 000	,, ,, ,,
Week day.	6 A.M. to 6 P.M. =	1 510 000	,, ,, ,,
	6 P.M. to 6 A.M. =	530 000	,, ,, ,,

The consumption in 1906 may be divided as follows: For mainfacturing uses, 67 gallons per capita; for domestic and public uses, 35 gallons per capita; and unaccounted for, including leakage, under-registration of meters, etc., 43 gallons per capita.

The consumption between the years 1900 and 1905 increased 41 per cent., and in the latter year it became apparent that no time should be lost in obtaining an additional source of supply. The town had already obtained the right to the waters of Suntaug Lake, and the utilization of this source was accordingly recommended, construction being begun in the summer of 1905. This lake is situated at a higher level than either Spring or Brown's ponds and the addition of its waters to the old source of supply by gravity was, therefore, possible. The pipe line consisted of 20-inch and 24-inch pipe, laid in trench of ordinary depth for a distance of 15 400 feet, up to the point where the ridge surrounding Suntaug Lake was encountered, the surface of which stands some forty feet above the hydraulic grade line of a gravity conduit. Through this ridge it was accordingly necessary to tunnel. This section of the work, 1 600 feet in length, proved most difficult, and the time necessary for its completion considerably greater than estimated, water not being run through the tunnel until July 1, 1906. In the meantime the abnormal increase in consumption had continued, and during the winter of 1905–1906 the condition of the ponds provided a good object lesson that from a given water-shed and storage capacity only so much and no more water can be obtained. The records which have been kept between the years 1903 and 1906 indicated that the Sudbury records were closely applicable to the Peabody conditions.

Below Spring Pond an intake reservoir of 25 000 000 gallons effective capacity extends northerly for a distance of 3 000 feet, and at its lower end the new pumping station was located. This reservoir constitutes the collecting point of all the different sources of supply, and if in the future filtration should be required it will prove a favorable location for the necessary plant, and the pumping station will be in the right position for the handling of purified water.

From the reservoir a 24-inch pipe was laid to a concrete pump well underneath the station. Double screens of standard design, with catch baskets attached to the bottom section, were located in a screen-well also under the station.

The pumping station is a brick structure with concrete foundations and includes coal-shed, boiler-room, machine shop, engine-room, and office. Emphasis was laid on good head room below the engine-room floor in order to make all piping and auxiliaries easily accesssible.

The pumping plant consists of two 100-horse-power Stirling boilers and a 5 000 000-gallon triple-expansion duplex Worthington pump with high-duty attachment.

The boilers are standard Stirling construction with three banks of tubes connecting the steam drums with the mud drum and a Niclausse superheater suspended between the middle and rear banks of tubes. The boilers contain 990 square feet of heating surface and 28 square feet of grate surface and are designed for 160 pounds working pressure.

The superheater is planned to superheat the steam 100 degrees above the temperature due to a pressure of 150 pounds. It is practically the same as a Niclausse boiler element, and is so arranged by dampers operated from outside the setting that the

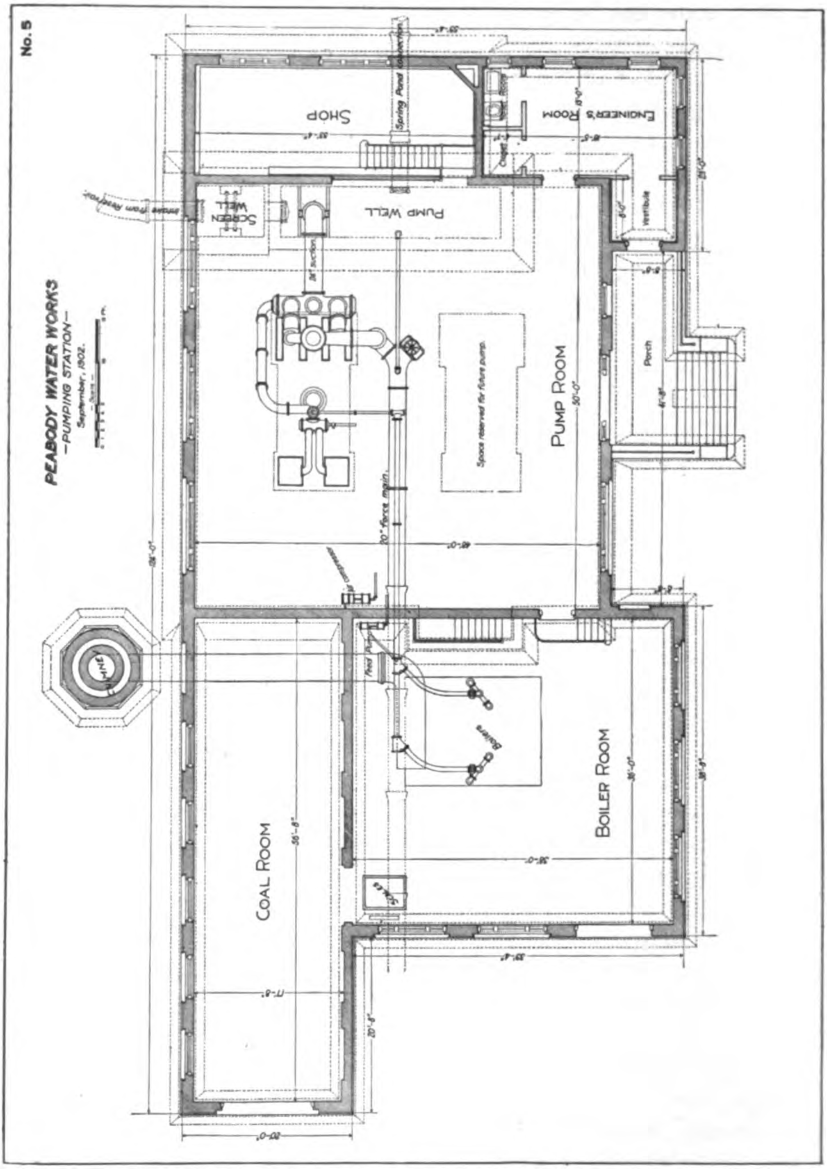

FIG. 1. PLAN OF PUMPING STATION.

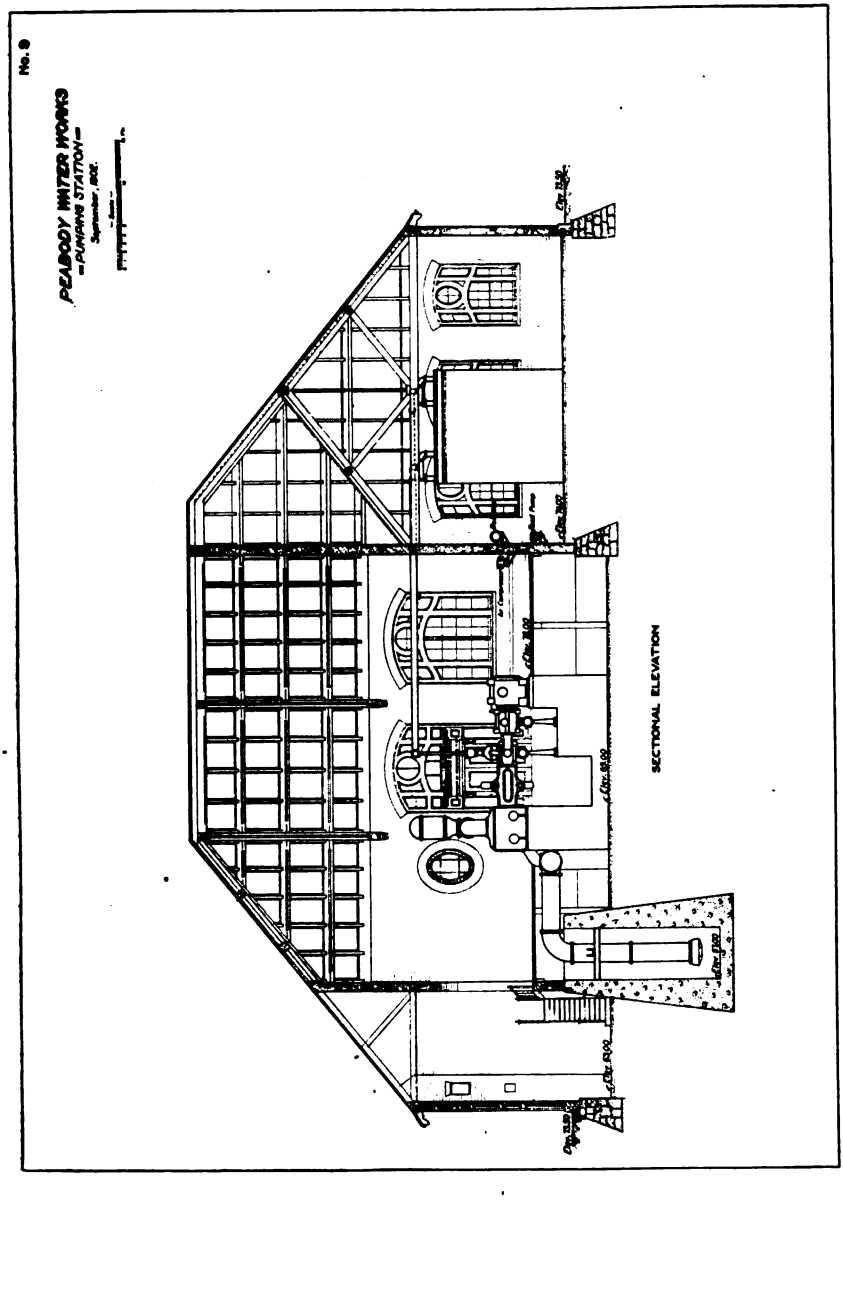

FIG. 2. LONGITUDINAL SECTION OF PUMPING STATION.

gases can be by-passed around the superheater and thus the amount of superheat controlled. Owing to the location of the superheater it is practically indestructible and does not require flooding when steam is not circulating through it.

The engine, as already stated, is a triple-expansion Worthington duplex, with high-duty attachment located between the high-pressure and water cylinders. The diameters of the steam cylinders are 12, 20, and 34 inches, and the nominal stroke 24 inches. The water plungers are 18 inches in diameter, and the average pressure pumped against is 165 feet.

Reheaters are placed between the high and intermediate cylinders and between the intermediate and low-pressure cylinders. The steam cylinders are jacketed with steam at boiler pressure, which also serves to heat the tubes of the reheaters between cylinders. The condensation from this jacket space is collected below in a tank having a ball float which controls the steam supply of a 3 × 2 × 2-inch pump, which takes the water of condensation from the tank and returns it to the boiler.

In the exhaust line between the low-pressure cylinder and the surface condenser is a closed heater having 30 square feet of heating surface. For boiler feed, water is forced through this heater by the delivery line pressure to a 4½ × 2¾ × 4-inch boiler feed pump, at a temperature slightly below the temperature of the main engine exhaust. The feed pump then forces it through a 15-square-foot closed heater which is heated by the exhaust from the feed pump, Westinghouse air compressor, and the jacket pump. The feed is thus put into the boiler at a temperature of approximately 200 degrees.

Located in the suction pipe of the main engine is a surface condenser of 228 square feet surface. A duplex air pump, having 9-inch plungers and 6-inch stroke, driven by the motion of the main engine, takes the water of condensation from the condenser and discharges it to the sewer.

Each cylinder of the engine has four valves operated by the Worthington semi-rotative valve motion, the feature of which is that there are no trips or dash pots, all motion being positive.

An early cut-off is made possible by the use of the high-duty attachment. This well-known Westinghouse device consists of

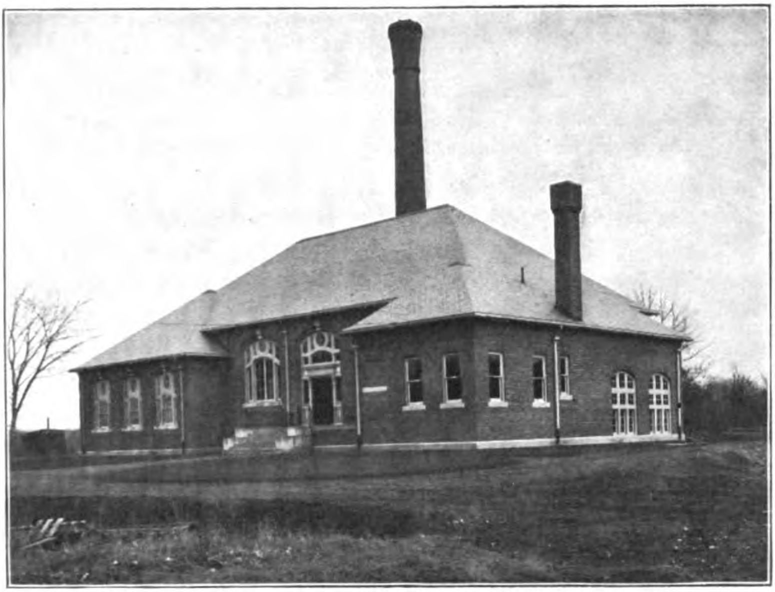

FIG. 1. FRONT VIEW, PUMPING STATION.

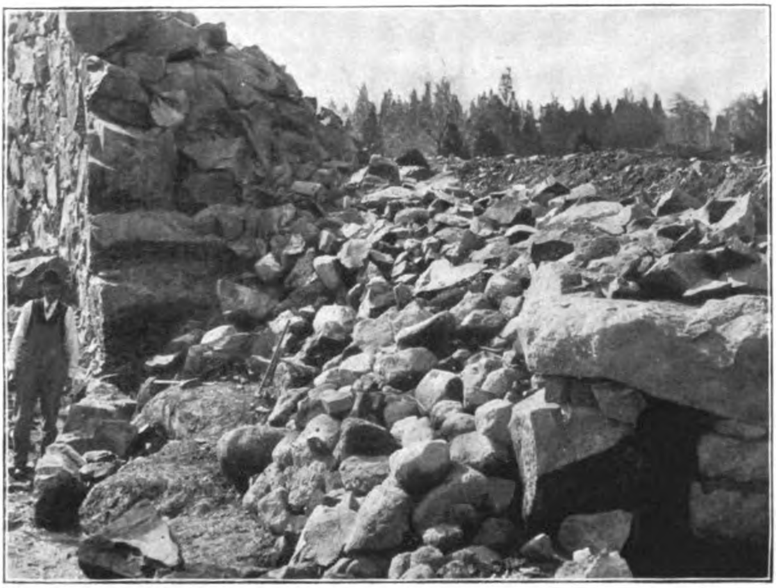

FIG. 2. DRY MASONRY OUTSIDE WALL AND DRAIN.

compensating cylinders and an accumulator, by means of which the surplus energy available at the beginning of the stroke is stored up and liberated at the latter end during the expansion of the steam. The accumulator has an air cylinder 17¾ inches in diameter and a water plunger 4¼ inches in diameter, both of 30-inch stroke. The compensating cylinders have plungers 4⅜ inches in diameter, and the system is supplied by duplex pump having ¾-inch plungers and 4-inch stroke, driven by the motion of the main engine. These pumps receive water from the delivery main or tank that is supplied with clean water from the air pump delivery. A 9½-inch Westinghouse air compressor supplies the air for this system.

No attempt was made to determine the efficiency of the boilers, the contract requiring a duty per 100 pounds of dry Georges Creek or equally good coal burned without allowance for ash, the work being done determined by the water pumped into the reservoir, and the pressure obtained by the reading of a gage on a force main plus the distance from the center of this gage to water in pump well. Under these conditions the contractor guaranteed a duty of 130 000 000 foot-pounds.

The following table gives the principal results of test:

PRINCIPAL RESULTS OF TEST OF PEABODY PUMPING PLANT.

Date of test	June 20, 1904
Duration of test	10 hours
Grate surface	28 square feet
Boiler heating surface	990 square feet
Diameter of chimney	39 inches
Height of chimney	100 feet
Steam pressure in boiler	156 pounds
Draft	0.242 inches
Temperature of fire room	73.4 degrees
Temperature of steam at boiler	423 degrees
Temperature of flue gases	422 degrees
Temperature of feed water	192 degrees
Fuel burned	2 380 pounds
Moisture (per cent.)	0.0094 per cent.
Dry coal consumed	2 357.6 pounds
Steam pressure at throttle	152.9 pounds
Steam temperature at throttle	404 degrees
Superheat	44.33 degrees

Average length of stroke	24.62 inches
Total number of revolutions	22 031
Displacement per revolution	14.303 cubic feet
Total head	163.99 feet
Slip of pump	1.51 per cent.
Rate of pumping per twenty-four hours	5 671 965 gallons
Duty per 100 pounds dry coal	134 607 000 foot-pounds

This relatively high duty for such type of pump working under the above-outlined conditions may be largely attributed to the superheating of the steam.

The test was started and stopped without drawing the fire from under the boilers. Whether ten hours is long enough to nullify the personal equation in the different observations, and particularly in judging the depth of coal on the grate at start and stop, is here, as in all such tests, worthy of consideration. In the writer's opinion, moreover, tests of municipal plants should be made on as practicable a basis as possible and as nearly in accordance with the actual running conditions as may be arranged. One of the elements not covered by a ten-hour test is the coal used in banking. Recently, in a plant where gas producers are now being installed, the writer called for bids from builders of both steam and gas engines, requiring, on an equal basis, a guarantee of duty determined by a three-days' test, the engine to run 8 hours and fires to be banked 16 hours each day, and the plant being charged with all coal used in banking and all standby losses. Such a test, it is believed, will eliminate to a considerable extent the results of expert firing and the relation of personal error in observation. It also expresses the relative expense of banking in the different types of apparatus.

The station records of the Peabody plant are of interest. The duty, allowing 2 per cent. slip, on basis of total coal burned in 1905, was 77 900 000 foot pounds, and in 1906, 81 500 000 foot-pounds. These figures are relatively 58 and 61 per cent. of the test duty. It is interesting to note that at Attleboro, with a compound crank and fly-wheel engine and a test duty of 119 000 000, the station duty, including banking, is 61.5 per cent. of the test duty, and the experience of the writer is that the working duty will average about 60 per cent. of the duty obtained in ten-hour tests. The duty at Peabody, without taking into account the coal used in banking, or on the same basis as test, is about 82 per cent. of the test duty. In Attleboro the equivalent figure is 85 per cent. The coal used in banking at Peabody, with the engine running ten hours, is about 28 per cent. of the total coal. At Attleboro, with a seven-hour run of the pumps, exactly the same percentage of the total coal is used in maintaining the fires during the time when the engine is not running.

Few repairs have been necessary, and the engine is a smooth, quiet running piece of mechanism. Such a type of pump, however, requires more attendance, particularly in starting, than a crank and fly-wheel machine, and this is also true of the water tube boilers as compared with horizontal tubular, except where the former are operated in an extensive battery. The limited heat storage in a single water tube boiler demands more constant attention, which is not justified by the quicker steaming capacity in a station where the load is constant. Therefore, while both the test and station duties obtained are good, the labor account is higher than would be necessary in a plant with horizontal tubular boilers and a crank and fly-wheel pump.

Lookout Hill, chosen for the site of the reservoir, is one of the historic spots in the Revolutionary history, of which many are found in the neighborhood of Salem. From its prominence as a vantage point it early gained its name. When, in 1692, John Proctor and his wife, accused and found guilty of witchcraft, were hanged on the neighboring hill to the east, a group of interested spectators probably pushed and crowded for seats on the boulder which is now the special care of one of the historical societies, and to preserve which the reservoir had to be thrown as far to the south as possible. Again, tradition has it that when the *Chesapeake* and *Shannon* met in their historic fight a party of patriots gathered on this eminence and anxiously watched the course of events.

This hill, which was the only one available with the elevation required for a reservoir, in formation was, roughly, an inverted cone of ledge covered with a slight depth of earth. The steep approach rendered the transportation of supplies difficult and expensive and made it necessary to utilize, as far as possible, the materials encountered in the excavation in the construction of the reservoir.

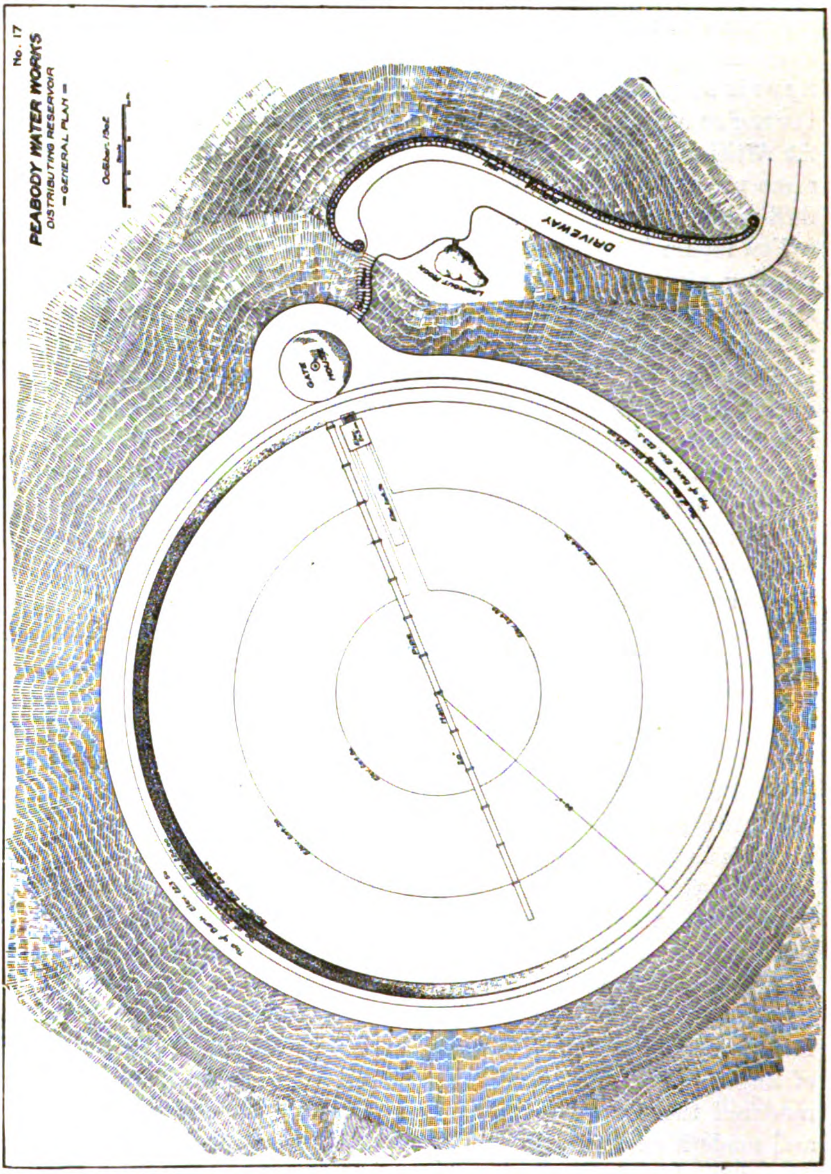

FIG. 3. GENERAL PLAN OF COMPLETED RESERVOIR.

FIG. 1. EXCAVATION OF LEDGE, AND CONSTRUCTION OF OUTER AND INNER WALLS.

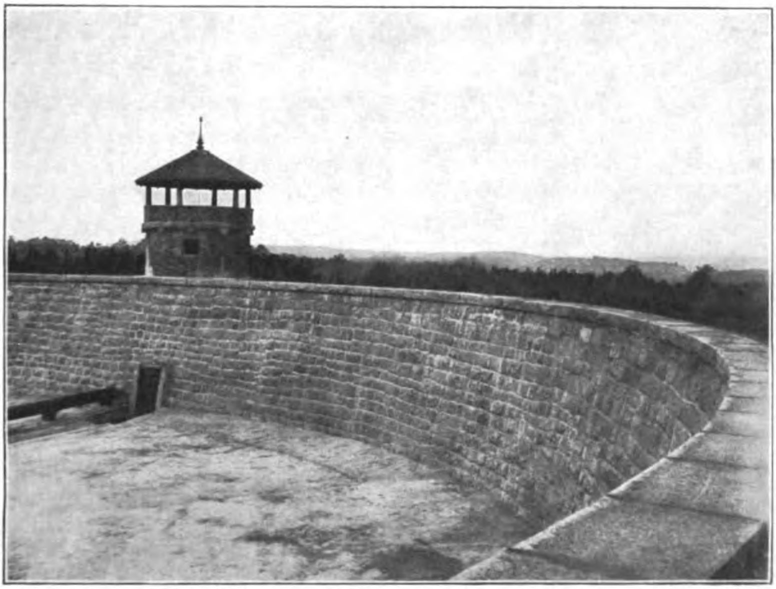

FIG. 2. FINISHED WALL, INLET PIPE, AND OUTLET SCREEN.

The leveling of the cone required the removal of about 5 000 cubic yards of earth and 6 000 cubic yards of rock. The additional earth necessary to back up a masonry lining in the ordinary way could not be economically obtained. At the same time the desirability of leaving the hill in as sightly a condition as possible made it necessary to dispose of the rock excavation without obtrusive spoil banks.

It was accordingly decided to build a dry wall with the excavated rock, laid with interior vertical face on a circle, constructing this wall by merely moving the rock from the place of its excavation by derricks and placing it with only sufficient care to prevent subsequent settlement. Inside of this dry masonry wall it was proposed to build a wall laid with Portland cement mortar, using the stone excavated in the construction of the reservoir, but, with the idea that the stone might not come out in such shape as to permit its use in this way provision was made in the specifications for an alternate plan of lining the dry masonry wall with a wall of Portland cement concrete. In this work, as in all recent work of the writer's, the cement has been furnished by the contractor but paid for separately by the barrel. It was soon found that the nature of the rock, which was a trap and which broke in all manner of shapes and sizes, made impossible the construction of a suitable wall of it, and by arrangement with the contractor it was finally decided to build a thin face wall of rough granite ashlar, obtaining the stone by splitting boulders, which were found in large quantities on the hill near the reservoir, and placing between this granite facing and the dry wall a concrete composed of natural cement and aggregate in the proportion of 1 part cement, 2½ parts sand, and 5 parts crushed stone. The use of the granite facing obtained a structure more pleasing in appearance than would be possible with concrete, did away with the necessity for all form work, and by using natural cement in the backing of concrete, which effected a saving of $1.00 per cubic yard, did not involve much increased cost.

The dry wall, which was placed on the outside to a rough slope, was covered with the earth obtained in the excavation of the reservoir to a depth sufficient to utilize the material available. Thus in this reservoir the construction includes an inner lining, and back of this, for stability, a loose rock filling covered by a coating of earth.

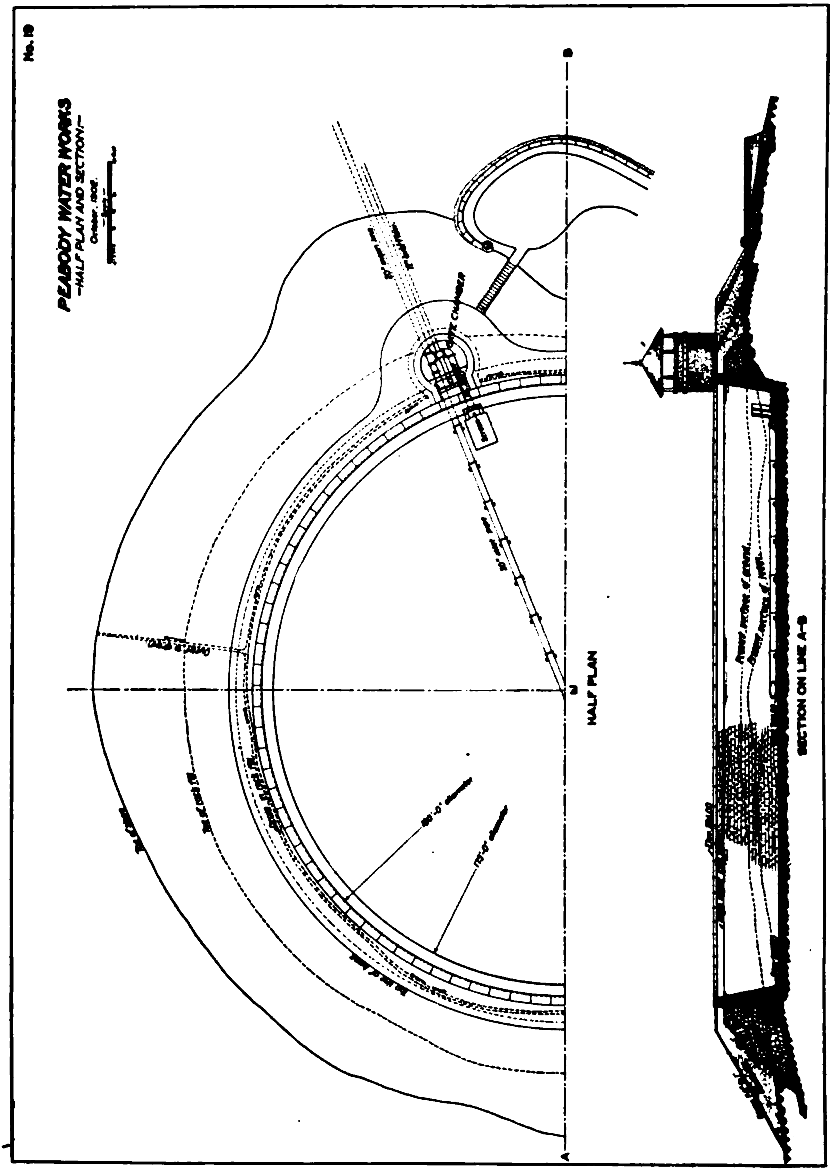

FIG. 4. HALF PLAN AND SECTION OF RESERVOIR.

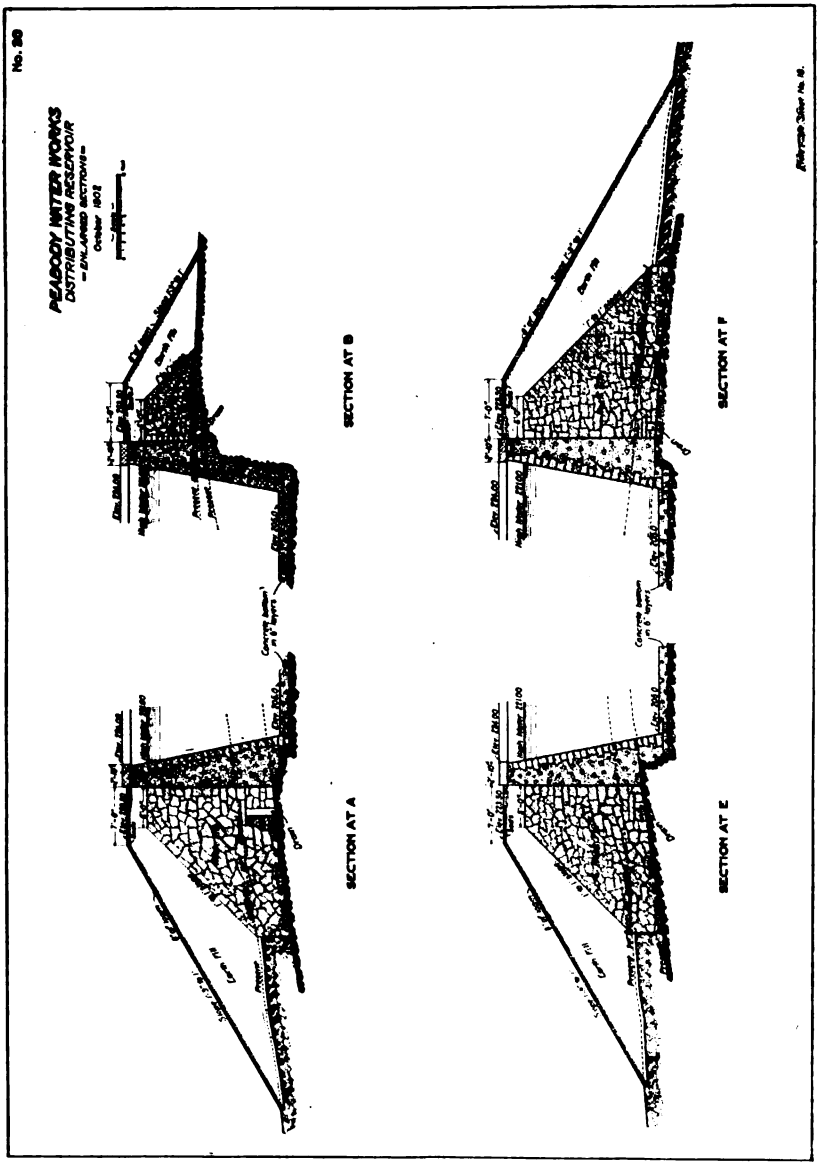

FIG. 5. SECTION OF RESERVOIR WALLS.

Such construction is contrary to the usual method of placing against the lining the most impervious material obtainable. The danger with the scheme adopted lay in the fact that any leakage through the inner wall might be temporarily impounded by the outer layer of earth until it had collected to a point where the earth would be washed away. To prevent this the ledge was stripped as a foundation for the dry wall and on this foundation, and entirely around the reservoir, following the natural contour of the rock, a masonry drain was constructed with its outer wall laid in cement, thus providing a cut-off for all water which might seep through the inner lining. Outlets through the bank to the outside of reservoir were provided at two points and all leakage was led out where it could be seen and measured. Actually this precaution has been of little or no value as the leakage has been practically nothing, one outlet being entirely dry and the other at times showing a dribble which probably comes from a spring encountered in the excavation of the ledge and covered by the concrete floor.

The ledge was very broken and seamy and the bottom of the reservoir was formed of two layers of concrete, the first of natural cement mixed 1: 3: 6, used largely to level up the uneven rock; the upper of Portland cement concrete, mixed 1: 2½: 5 and troweled to a hard granolithic surface.

The reservoir was enlarged from the original plan to a capacity of about 3 200 000 gallons. The total cost was about $48 000, or 1.5 cents per gallon of capacity. The price paid for rock excavation, which included the building of the dry wall, was $2.25 per cubic yard. The actual cost of drilling was 37 cents per cubic yard; of dynamite, .09 cent per cubic yard; of barring out, breaking up, and removing to the wall, 1.05 cents per cubic yard; and of placing in wall, including construction of inner face, 34 cents per cubic yard. These figures do not include any allowance for rent of machinery.

The 20-inch pipe connecting the distribution system with the reservoir branches in the gate chamber,— one branch, the inlet, extending across the reservoir; and the other, the outlet, just through the wall. By check valves the water is compelled to traverse the reservoir and to pass through screens set over the outlet pipe. At times some sediment is settled out of the water. Gates are also provided in the gate chamber to shut off either

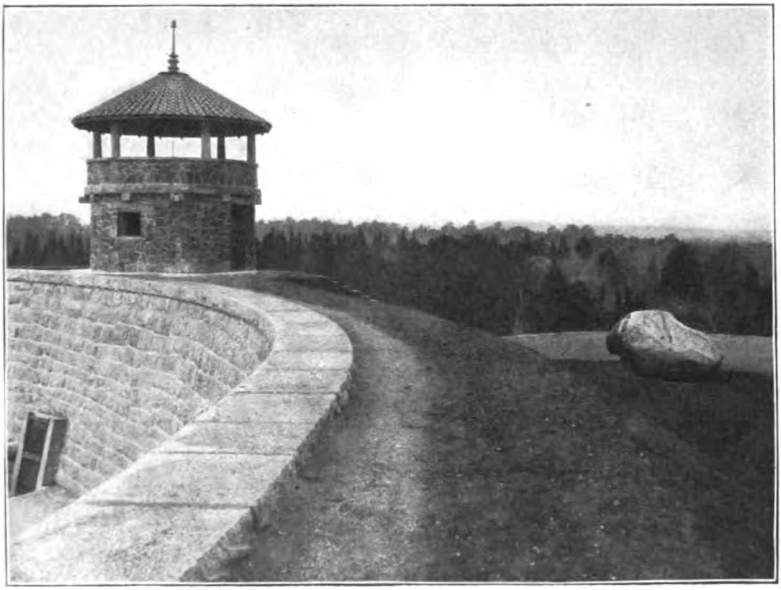

FIG. 1. GATE HOUSE AND LOOKOUT BOULDER.

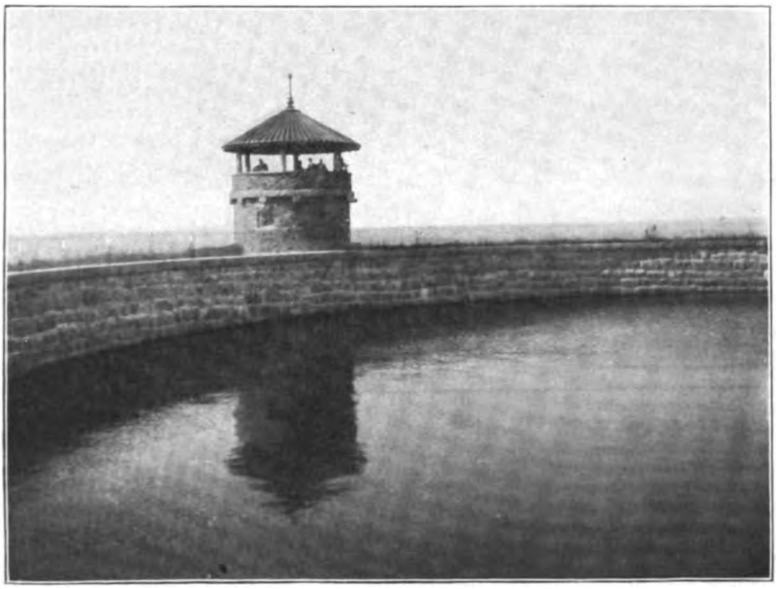

FIG. 2. RESERVOIR IN SERVICE.

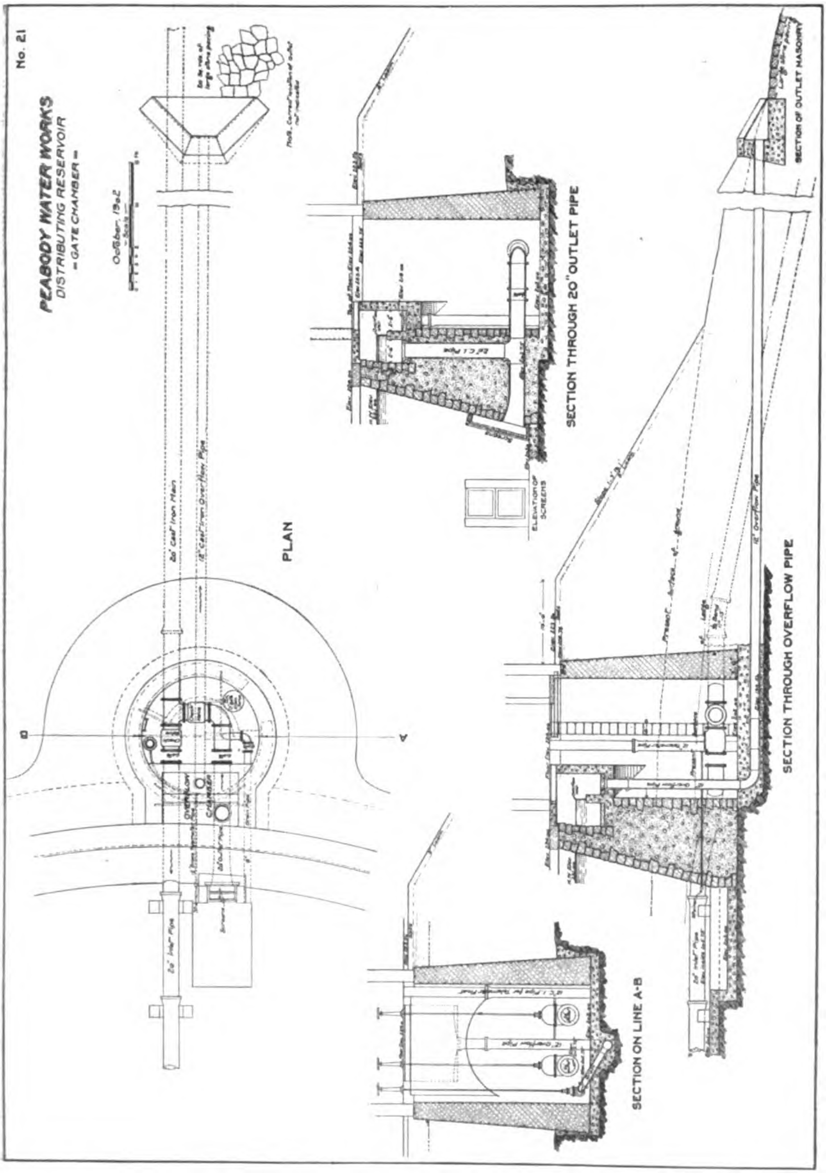

FIG. 6. DETAILS OF GATE CHAMBER.

branch and permit examination of the check valves. A 12-inch pipe makes possible the draining of the reservoir and the blowing off of any accumulated deposit.

The gate chamber is a dry well 13.5 feet in diameter, connected with, but outside the wall of, the reservoir, and containing, besides the various valves, the pipe for the float of the Winslow recording instrument. In this chamber, supported by an arch thrown across on a chord of the circle, is an overflow weir, connected on the reservoir side, by a pipe laid in the wall, with the water in the reservoir, and on the outlet side, by a 12-inch pipe, leading to the blow-off pipe in such a way that at all times there is a free vent, which cannot be closed, for any water which passes the crest of the weir set at the desired maximum water line. Numerous accidents have occurred in reservoirs not provided with overflows, and these even where the water is pumped. The design herein described, while supplying a free outlet, does not weaken the wall nor place the overflow in such position that it will be frozen in winter.

The gates are provided with extension stems and are operated at the level of the ground in a circular masonry gate house constructed over the gate chamber. Above this gate house is an observation gallery open to the public at all times, surmounted by a conical roof covered with red Spanish tiling. The gate house is constructed of stone obtained in the excavation, with seam faces colored by the iron contents. The view from this gate house, which extends over a wide stretch of country to the north and along the shore from Boston Light to Eastern Point at Gloucester, is well worth the trouble of climbing the hill to the reservoir. The town of Peabody owns a considerable amount of the adjoining land which, in its topography and situation, may well form the basis for some future park system. With these conditions in mind the committee believed that the construction of this gate house and observation gallery was justified, a fact which has been proved by their popularity as an objective point in the recreation wanderings of the citizens of Peabody.

Mr. H. F. Walker was chairman of the special committee under whose authority the work was carried out, and Mr. A. N. Jacobs is superintendent of the water works. The C. E. Trumbull Company were the contractors for the reservoir.