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THE GREENFIELD WATER WORKS.

BY GEORGE F. MERRILL, SUPERINTENDENT OF WATER WORKS.

[*Read December 9, 1914.*]

At Greenfield, Mass., the water works are owned and operated by a fire district, which contains about ninety per cent. of the valuation of the town, and supplies water to the whole town, with the exception of the farming district.

The water supply is taken from the watershed of Glen Brook in the town of Leyden, by gravity, supplemented by an auxiliary pumping station, taking a supply from a well located in the valley of the Green River, near the river.

The original works, built in 1872, are composed of a reservoir on Glen Brook, of about 24 000 000 gal. storage capacity, situated 225 ft. higher than the main street, and located about five miles from the center of the town. At the time of the construction of the system, cast-iron pipe was very high, compared with the present market, and the mistake was made, which was a common one in our New England towns and cities at that time, of putting in mains that were too small.

As the town grew, and its demands for water and fire protection became greater, it became necessary in 1885 to lay an additional 14-in. main to the reservoir, to give better protection in case of fire. This, together with some essential reinforcements of the pipes in the built-up section of the town, was constructed at a cost of about $75 000. The next improvement, other than the regular extension of the mains within the town, was made in

1894. At this time it was found that the 5.5. sq. miles of area which supplies the Glen reservoirs would not in the drought years, with the available storage, yield sufficient water to supply the town. After considerable investigation by committees it was decided to install an auxiliary pumping station on Green River, taking raw water from the stream, and pumping it into the mains through a 10-in. force main half a mile long, where it connected with the existing main pipes from the reservoir to the town. The equipment then installed consisted of a locomotive type boiler, and a 16 by 10 by 10 steam pump, with which it was possible to maintain a supply of water for the town when the gravity supply failed, although at a very excessive cost for pumping. This excessive cost of pumping (about $40 per million gallons) added considerable to the cost of maintenance, but did not amount to a very serious expense until 1909, when an increased amount of pumping became necessary.

About ten years after this original pumping station was installed, the growth of the town made it necessary to obtain a greater supply to carry the town through the dry seasons. The capacity of the pump was insufficient, and the location was such that, in order to get sufficient water, it was necessary to build temporary dams in Green River to raise the water a few feet, so that it would flow into the pump pit. As the river bed at this point was composed of coarse gravel, a large portion of the flow of the stream was lost through seepage; there were also several small water powers located about five miles further up the stream which held back the flow at times, so that there was not enough water flowing to supply the pump.

At this time it was voted to build a storage reservoir above the existing reservoir on Glen Brook, which was expected to store sufficient water to tide over the dry periods. This reservoir was completed in 1906, at a cost of about $85 000. The dam was designed by E. A. Ellsworth, of Holyoke, who worked in connection with Chas. J. Day, a civil engineer, who was at that time chairman of the board of water commissioners. The storage capacity is 44 000 000 gal. This dam raises the water about 45 ft., but, as the reservoir is located in a narrow valley, and the watershed is abrupt, the result is that a comparatively small amount of storage is obtained. A large item of the cost of the reservoir was the construction of the foundation. A pocket was found in the bed of the stream, which had to be excavated to a point 42 ft. below the water level to obtain rock foundation. The whole structure rests on ledge, and is built of 1 : 3 : 5 concrete with large stone imbedded. From the upper reservoir to the lower, and connected below the lower, a 30-in. cast-iron pipe is laid. The gate arrangement is such that supply may be drawn from either reservoir separately, or water discharged from the upper to the lower. The 30-in. pipe is laid along the easterly shore of the lower reservoir, and has been tapped for 2½-in. fire-hose connections at intervals of about 100 ft. along the whole length of the reservoir. During the spring, when the lower reservoir is being cleaned, we use fire hose for flushing out the silt and mud, and find this method very economical and thorough.

The fire department at Greenfield is operated by the fire district, and there are no steam fire engines, all the fire service being obtained from hydrants. The length and size of the main pipes from the reservoir to the town are such that a large volume of water at reasonably good pressure cannot be delivered. About seven years ago, a short time after coming to Greenfield, I became aware of this condition, and hydrant tests showed that, in the center of the town, not over four efficient hydrant streams were available at the same time.

At this time I recommended, as a remedy, the construction of a reservoir on Rocky Mountain, about a mile from the town, to be supplied by the present gravity supply, through a 24-in. pipe.

In May, 1909, there was a very serious fire, which demonstrated clearly the lack of water for fire service. Very shortly afterwards a meeting of the voters was held, at which an appropriation of $75 000 was made to build a covered concrete reservoir on Rocky Mountain with the necessary pipe connections, and Mr. Wm. S. Johnson of Boston was employed to prepare the plans. The contract for its construction was awarded to Daniel O'Connell's Sons, of Holyoke. The work of installation of pipe valves and laying about 6 000 ft. of 24-in. pipe to the center of the town was done by the water department.

The reservoir is built wholly on ledge, a portion of it being excavated from the trap rock which occurs on the summit, obtaining in this way sufficient material for the embankment. A concrete floor, 6 in. thick, was laid in alternate sections after the walls were completed. The roof is of groined arch construction, supported by 24 in. square concrete columns, spaced 17 ft. on center. The reservoir has a capacity of 2 000 000 gal. and is supplied through a 24-in. cast-iron main which is laid to the center of the town, and which also protects the main business portion of the town. In operation, this reservoir has a standpipe effect, supplying at all times enough water for fire service. Water flows in during the night to take the place of that which is used during the day. The control of the water level in the reservoir is entirely automatic, and the same 24-in. pipe through which the water supply comes is used for water to return to the town. By the use of two check-valves and a float valve, the water is shut off automatically when the reservoir becomes full, and in case of a slight drop in pressure down-town, a check-valve in the 24-in. outlet pipe opens and water from the reservoir enters the system.

Although the contract to the reservoir was started in 1909, the addition to the system was not completed until the following summer, at which time a hydrant test was made, which illustrates the gain in fire service obtained.

The first part of the test was made with the Rocky Mountain reservoir shut off, and represents the conditions as they were before this addition to the water system. This test was as follows:

With the hydrant pressure at 97 lb. the normal ten fire streams were connected, using 150-ft. lines of 2½-in. hose with 1⅛-in. nozzles. With these streams, the pressure dropped to 27 lb. With six of the above streams, the pressure was maintained at 39 lb.

The Rocky Mountain reservoir was then turned on, the pressure standing at 87 lb., which is normal from this source. With 16 streams the pressure dropped to 81½ lb. and then four more streams were added, and a wagon-pipe with three-way siamese connection, 50-ft. lines of 2½-in. hose and 1⅜-in. nozzle. With all the above streams, which were connected with 150-ft. lines of 2½-in. hose and 1⅛-in. nozzles, excepting the wagon-pipe, which had 1⅜-in. nozzle, the pressure was maintained at 81½ lb.

The streams with 1⅛-in. nozzles should discharge, under the above conditions, about 266 gal. per minute, which indicates that the total discharge with 20 streams and wagon-pipe was about 6 000 gal. of water per minute.

The streams with 1⅛-in. nozzles, when all were in service at the same time, were sufficient to give effective service at a height of 80 ft.

The wagon-pipe as connected will furnish an effective stream 120 ft. in height.

The upper reservoir on Glen Brook did not accomplish the result for which it was intended, as it lacked sufficient storage. In fact, the first year it was used it was necessary to pump water from Green River at the old pumping station. The question of a further additional water supply was given very careful study before anything was done regarding construction. Investigation of a possible ground-water supply was made over a large area. The first work in this connection was done in the valley of the Barton Brook, lying easterly of the Glen Brook watershed. In this valley we obtained some very encouraging results from flowing wells, and located a good supply of water; but analyses showed it to be unfit for use on account of an excessive amount of iron and chlorine. Further investigation on the same stream up the valley developed a supply of good water, but at such a distance from the town that the cost of development would be quite large; and, as the watershed was a comparatively small one (five or six square miles), it seemed better to depend on the larger Green River watershed, if suitable locations could be found. Therefore test wells were driven, making a very thorough exploration of the river valley from a point about half a mile northerly of Greenfield to the present new pumping station which was built last year. At this point the river valley widens out and, leaving the narrow mountain gorge, enters a more level plain. Test wells driven at this location showed a large bed of gravel containing sharp sand of about the quality of filter sand. The gravel, however, contained many large-sized stones, and some bowlders.

In connection with further investigation of additional water supply, surveys were made up the valley of the Green River to determine the cost of obtaining a gravity supply; also surveys were made above the existing reservoirs on Glen Brook watershed for a storage reservoir. On the Glen Brook watershed a favorable dam-site was located where storage could be obtained at a cost of about $300 per million gallons. The capacity of a reservoir on this site would be about 400 000 000 gal. with a sufficient watershed to easily fill it in the driest years. When we compare the cost of storage at this proposed site ($300 per million gallons) with the cost of storage at the present upper reservoir (about $2 000 per million gallons) it was evident that proper engineering investigation was not made before the upper reservoir was constructed.

On the Green River watershed, surveys indicated that a gravity supply could be obtained, but it was necessary to construct about 11 miles of pipe line to bring it into town. Green River has a watershed of about 50 sq. miles above our new pumping station. Its source is in the state of Vermont. Our taking would occur at a point so near the Vermont line that a large portion of the watershed would be over the line, where it would be difficult for us to exercise sanitary control. A gravity supply from Green River was not considered the best for our present needs, because of the expense — estimated cost being about half a million dollars, our present needs requiring slightly over 100 000 000 gal. per year to carry us over the dry period, as shown by our pumping records.

The ground water supply which was completed last year was decided upon because of the comparatively small outlay, and the better, cleaner supply of water available. All the work of construction was done by the water department.

Some of the features connected with the new supply were the construction of a large well, and a filter-bed which was built in the gravel about 100 ft. from the well. A low dam was constructed on Green River, about 800 ft. northerly of the well, which raised the water 8 ft., sufficiently to flow on to the filter bed. The pumping station is a brick building with concrete foundations, in which is installed an electric driven pump. There was also laid a 16-in. force main about 2 600 ft. long, which is connected to the existing main from the reservoir to the town.

The construction of the well was done under unusual conditions, and, therefore, may be of interest to water-works men. The wall is built of reinforced concrete, circular in form, and it was sunk

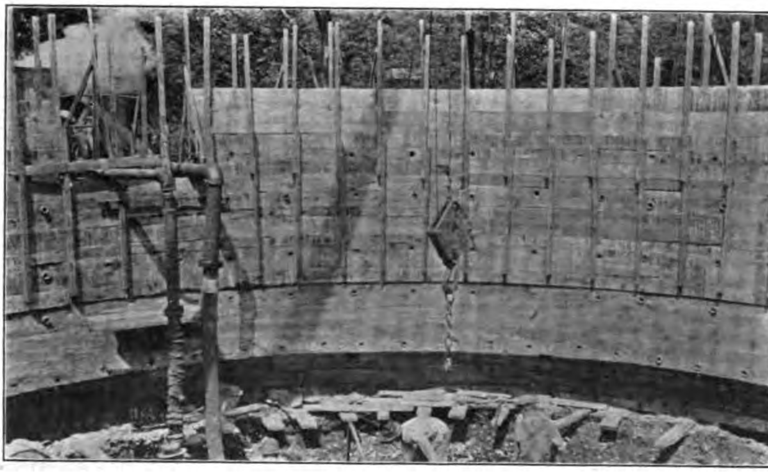

FIG. 1.

FIG. 2.

CONSTRUCTION OF THE WELL.

into place. The bottom of the wall was designed to act as a cutting edge, and was beveled at the inside lower corner, heavily reinforced. The bevel was made to allow workmen to shovel underneath the edge.

The well is 40 ft. in diameter and 30 ft. deep, twenty-five feet of which is below the ground water level. The first five feet of excavation was made to the water line, and forms were built and the walls of the well constructed about 10 ft. high, projecting out of the ground about 5 ft. Excavation was then carried on inside the well, the water being pumped out; and the wall lowered down by excavation underneath it; also more wall was added to the top until the well was sunk to its depth. It was found necessary to place a pump inside the well, on account of the excessive suction lift, and a centrifugal pump, placed on brackets bolted to the wall, driven by an electric motor and belted connection, was installed. This 6-in. pump worked very nicely under this arrangement, as it was not necessary to lower the suction pipe, the pump following down with the wall of the well as the work progressed. The discharge pipe was constructed in such a way that it would turn on an elbow outside the wall as the well lowered down, without straining the connections. As this pump was about 8 ft. below the ground water level, it was necessary to keep the well pumped out at night.

The well is covered with a reinforced concrete dome, and about 2 ft. of earth, leaving a manhole over the suction pipe. A large number of pieces of 2½-in. pipe were placed in the concrete wall as it was constructed, to allow the water to come through the wall readily.

The pump was built by the Platt Iron Works Company, of Dayton, Ohio, and has a capacity of 3 000 000 gal. per twenty-four hours, against a head of 285 ft. It is a 16 by 18 duplex, horizontal pump, direct connected to a 200 horse-power, slip-ring type, two-speed motor, through a single-reduction or herring-bone gears. After erection, a test was made to determine the mechanical efficiency of the pump, the discharge water being passed through a Venturi meter, and it was found that the plant efficiency was a little better than 75 per cent., which exceeded the guaranty of the manufacturers by 3 per cent.

The cost of electric current, taken on a five-year contract, is 1¼c. per kw.-hr. The present cost of pumping is about $18 per million gallons. The power cost is about $13.50 per million gallons. During the last season we pumped 2 000 000 gal. of water per day from the well for about two weeks, which filled up the lower reservoir more than was consumed; and for the balance of the pumping season we operated the pump during the night hours (one shift) and obtained in this way sufficient water for our needs, about 1.2 million gallons per day.

The system is about eight per cent. metered. Meters are placed on hotels, railroads, manufactories, and any consumption that comes outside of the ordinary flat rate basis. The average water consumption is about 1 200 000 gal. a day, population supplied being 11 500. Through the summer months, when garden hose is used, this is considerably increased; also during cold weather, when people allow water to run to prevent its freezing, it reaches a million and a half gallons a day.

Total cost of work, about $450 000. The total bonded debt is $150 500. Cost of supplying water per million gallons, based on total maintenance plus interest on bonds, $52.68.

It is interesting to note how the last two extensions — the construction of Rocky Mountain Reservoir and the additional supply — have overcome two serious defects, the lack of fire service and the insufficient supply of water, at a reasonable cost.

In connection with this new work, I have worked under the direction, had the hearty support and aid of our able board of water commissioners, Messrs. C. C. Dyer, Wm. F. Aiken, and Thos. L. Lawler. Wm. S. Johnson, civil engineer, of Boston, was employed as consulting engineer in connection with the Rocky Mountain Reservoir, also on work of additional water supply. George A. Kimball, civil engineer, also of Boston, was consulted regarding details of construction of Rocky Mountain reservoir. Allen Hazen, consulting engineer, of New York, was consulted regarding additional water supply.

FIG. 1.
FORMS FOR THE DOME OF THE WELL.

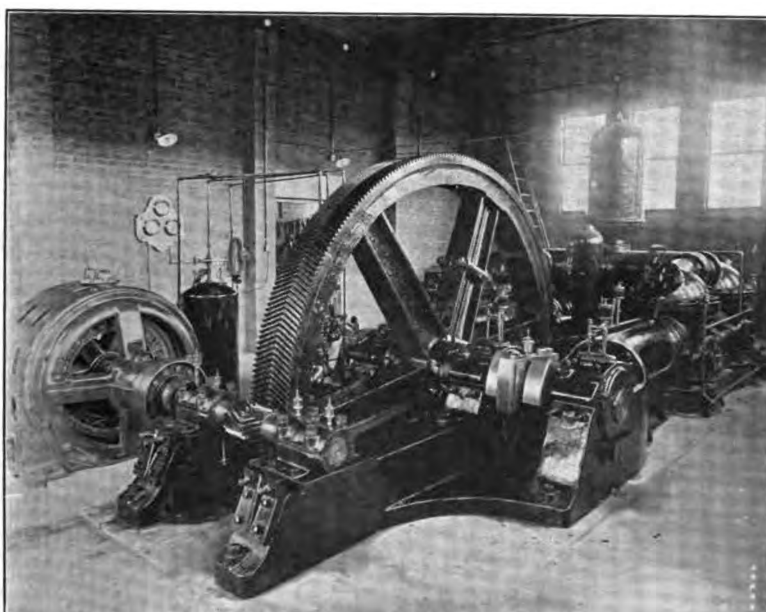

FIG. 2.
VIEW OF THE PUMP.

DISCUSSION.

Mr. G. A. Sampson. I would like to ask if you had any trouble in sinking your well.

Mr. Merrill. We had no difficulty whatever. The well went down readily. I believe in the case of the first section, which was only about ten feet high, one side of the well got uneven bearings on some bowlders and caused a very slight crack in the wall, probably about one sixty-fourth of an inch. But we saw it before the pressure became great enough to do any damage, and we had no further difficulty. As the well went down, the height of the wall and the reinforcement made it much stronger against a breakage of that sort.

Mr. W. S. Johnson. In connection with the construction of the reservoir, we had some experiences which might be of interest which Mr. Merrill did not mention. The bottom of the reservoir was entirely upon trap rock, and there were six inches of very rich concrete, which I certainly expected was going to hold water; but when the reservoir was completed the bottom leaked like a sieve, so much so that we could not fill the reservoir. Mr. Merrill got busy, after the contractors got through, and pumped grout into the bottom and made it practically watertight. But it certainly was something which I had not anticipated, that six inches of concrete on that rock, and a very rich mixture, could not hold water under a 20-ft. head. Mr. Merrill speaks of the filter bed beside the Green River. That is hardly a filter bed. The well is located in a comparatively limited deposit of sand of good filtering quality, and this so-called filter bed is simply an area prepared by scraping off the soil, so that the water discharged on it can enter the sand and find its way at a very slow rate to the well. The idea is simply to keep the sand stratum saturated with water and thus keep up the supply of the well.

Greenfield is one of those towns which was unfortunate enough to build water works before the eighties. They didn't know in those days what our modern water-works system meant. The pipes in such systems are always too small, and every town that built works at that time has suffered ever since from lack of sufficient capacity. Of course some of the large cities have remedied that, but comparatively few of the smaller towns, and it is due solely to Mr. Merrill's activity and his method of presenting things so that the citizens could see them, that this water-works plant has been remodeled and made up-to-date. Of course he would have been a good deal better off if an earthquake had come and destroyed the whole plant, so he could have rebuilt, but considering what was there, and considering the fact that the plant was producing a big revenue, he has certainly accomplished wonders. There is one thing, however, which remains a relic of the past, and that is the system of charging for water. They have, as Mr. Merrill says, but very few meters. The water takers seem to feel that they are paying for all the water they can use, and at times they can use a very large quantity.

Mr. Merrill. Regarding leakage of the Rocky Mountain Reservoir, one might infer from what Mr. Johnson said that it was due to defective concrete. This, however, was not the case, as practically all the leakage that we were able to detect was due to contraction of the floor slabs and wall sections, which were all poured in separate sections. The floor slabs were about seventeen feet square, and the wall sections not over twenty-five feet in length.

The concrete was poured during the hottest summer weather, and the reservoir was filled about the first of November, when the water had a temperature of about 45° or 50° fahr. The work of repairs was done during the coldest winter weather, in order to allow the concrete to contract all that the colder water we have during this season would make it.

The repairs were made by drilling holes in the concrete in the joints and inserting a short pipe nipple which was calked in with jute packing so that it would hold pressure. The discharge hose from a grout pump was then connected to the pipe and grout pumped in. In the walls we used pressure as high as 100 lb. per sq. in. It was necessary, as the grout began to flow out of the joints, to calk them with jute packing in the same manner that the joints of a boat are calked.

In one or two cases, while repairing the floor, the grout appeared in joints about fifty feet distant from the drill hole where it was being pumped in. We did not use as high pressure in repairing the floor as we did for the walls, as there was danger of lifting the floor slabs.

We used about one carload of cement, reducing the leakage from about 400 000 gal. a day to practically nothing.

In connection with the repair work, we were indebted to Mr. A. E. Lockridge, of Springfield, Mass., for advice, and we used the same method used by him in repairs at Springfield.