Thesis

on the

Salem Water Works,

by

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Beverly,

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Salem Water Works.

The necessity and the advantages of an abundant and never failing supply of pure water have never been doubted. Wherever a large population is gathered together on a small area, the limited supply to be obtained from wells or cisterns is liable to be impure and likely to give out at any moment. It is most closely connected with domestic economy, increase of manufacturing and commercial interests, protection against fire, and preservation of health. The certainty of having at all times a supply of good water thus attracts and fixes much business which would probably otherwise be scattered over the country. All these requirements can be met only by a supply, delivered at such a head that the water will rise freely to the tops of buildings even after a considerable loss of pressure by friction.

In writing on such a subject, a few notes of an historical character, upon water-works both ancient and modern, in this and in other countries, may not be out of place.

Of the ancient cities, Carthage, Alexandria and Rome were exceedingly well supplied by aqueducts of great extent, showing wonderful skill in their contruction. The main pipes or conduits of Carthage and Alexandria emptied into large public cisterns, from which the water had to be drawn by buckets, while in Rome the water was carried into each dwelling through earthen pipes, some of which are still in use.

In Mexico and South America, are found aqueducts of still greater size than those on the other hemisphere. One in Peru, following its circuitous course from the mountains to the sea coast, is over four hundred miles in length. With the ancients, distribution to private dwellings was not common, and, as was the case in parts of Europe and Canada until quite recently, the supply was provided by public fountains and water carriers.

Owing to the great weight, the constant and overpowering energy, and the solvent power of a mass of water, the great question in a system of water-works, is in regard to the construction of the reservoir, and underlying this are the questions of stability of banks and the purity of water. The stability of a reservoir embankment is affected by saturation, by action of waves and ice, and by the boring of small animals. The first of these is to be guarded against by the use of clay, either as a slope lining ~~or~~ or as a solid wall near the centre line of the bank. In either case it should be protected by solid hydraulic masonry on the floor and slope, which arrangement is also a protection against waves and ice. The third condition may be fulfilled by using a quantity of coarse, sharp grained engine ashes in the construction of the walls.

In building a reservoir, there are certain general principles to be followed, and in many cases, the neglect to comply with them has proved destructive to the stability of the whole structure. The following are in general the most important.

All soil, spongy and compressible material must be removed from the reservoir site until a firm solid earth or rock, suitable for foundations, is reached.

The bank, especially the puddle wall or slope, must be well consolidated, so as to prevent future settling or sliding as far as possible.

The walls should be built in thin layers, and each layer should be completed before the next is * begun.

The puddle wall or slope, in connection with the floor, must form a water-tight basin, or, if the floor is not puddled, it must be well built into the solid foundation.

In building on sloping ground, the precaution must be taken to cut benches in the slope, to guard against slides, when the water is let into the reservoir.

Considerable time should be allowed for the settlement of a filling, before lining the slope or setting walls or pipes.

Face inner slope and pave the floor with cement masonry or brickwork: and turf the outer face to prevent washing of the bank by heavy rains.

When it is possible with moderate cost, the water should be protected from sunlight, which heats it and aids vegetable and insect life: but the great size of most of our modern works renders this too expensive. For the same reason, the depth of water should be limited to not less than twelve of fifteen feet, and a greater depth, with free circulation of the water, is much better for its purity.

For the purpose of rendering a reservoir water tight, experience seems to show that carefully made clay puddle, laid in a properly built wall or floor, is an excellent material for lining, provided it is well protected by masonry.

The best kinds of puddle are made by mixing one part of clean gravel with one to two parts of compact clay, and working them almost dry. The greatest care must be taken not to make a continuous straight joint of clay with masonry or pipes, as, in shrinking, the clay is almost sure to break away from the wall and leave a clear passage for water. This may be obviated by building the wall with numerous projections on its face, whereby the joint is broken up into a number of small surfaces.

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The City of Salem was among the first in this country to be supplied with water brought into the city by means of an aqueduct.

From the Historical Collections of the Essex Institute, it appears that in July 1796, Daniel Frye bought the privilege of building a reservoir on Gallows Hill and carrying the water of the same in the direction of Salem and

Danvers. In 1797 the first steps towards the formation of the "Salem and Danvers Aqueduct Co." were taken, and in a short time, water was supplied through wooden pipes, leading from a fish-hogshead on Gallows Hill. During the next year a reservoir of 43000 gallons capacity was built; and in the years 1804, 1818 and 1821, as the demand increased, larger logs were laid, until in 1836, the first iron pipe, one of six inch diameter, was put into the main line. About this time complaints were often made of the short supply, and continued until the city works were well under way. The property is now owned by the Town of Peabody, and embraces the ~~A~~ whole of Browne's and

Spring ponds, besides the original fountains.

The first act of the City in regard to a public supply was taken in 1858, when the plan of purchasing all the property and privileges of the Aqueduct Company was advocated by many of the citizens. But is was not until 1864 that the City, believing that these sources were inadequate, decided to take the water of Wenham Lake.

This lake or pond is an irregularly shaped basin, three hundred and twenty acres in extent, situated in the towns of Wenham and Beverly, about four and one half miles from the City Hall in Salem.

Its estimated capacity is about 3000000 gallons per day, but by the use of a small dam at its outlet only two feet high, an additional supply of 2000000 gallons per day for one hundred days, may be stored.

Sir Charles Lyell says of its water "it is alway clear and pure, and the bottom covered with white quartzose sand. It is fed entirely by springs, and receives no mud from any inflowing streams."

The fundamental rock of the neighborhood is syenite, and the whole lake is bordered by smooth sandy or gravelly beaches, which accounts for the almost unequaled purity of its water.

Dr. Jackson, who made an official analysis of the water, says, "One imperial gallon contains only 2.22 grains of impurities. It is a clear colorless water, very soft, and has a slight taste of vegetable matter, but less than that of Cochituate water."

The water is taken from the southerly end of the lake and carried into the pump well by a conduit of three distinct parts. The first or lake section is a 36" cast iron pipe, of which there are about 175 feet, extending from the inlet to the gate well. The mouth piece is a bell shaped enlargement of the pipe, facing upwards and covered with a grating of iron bars. The whole is protected from ice and waves by a cofferdam of a double row of sheet piles, firmly framed and covered by a plank platform. This pipe is also provided with a man hole for access to its interior. The second section is the gate chamber, containing the screens and machinery for regulating the flow of water. In opposite sides of the chamber are two grooves cut in the granite, in which are placed double screens of copper wire, straining the water as much as is possible without filtering. Next to these is another another set of grooves in the wall for the insertion of a timber bulkhead, if the conduit needed repairing.

Across the inner end of the chamber is built a wall of accurately dressed stone, provided with four openings, two feet wide and three feet high, two being at at the bottom and two near the surface. Each opening has a separate sliding gate, with composition faces, and worked in a vertical plane by a large screw. The gate well connects with a conduit of brick laid in cement twenty six feet long, ten feet high and eight feet wide.

This empties into the pump well, which is a solid basin of masonry lined with brick. It is about thirty two feet long, sixteen wide and fifteen deep.

In excavating for the foundations of conduit and wells, a great difficulty was encountered in the shape of quicksands. The earth many feet in depth consisted of coarse gravel containing large boulders, alternated with strata of quicksand. Three rows of sheet piles were driven, and the soil was removed at a sufficient depth for the foundations. Upon the quicksand was built a framing of large square timber, and then floored with several thicknesses of plank, which were covered by a mass of hydraulic concrete, two feet in thickness, forming a very firm base for the weight of the building.

The engine house is a brick and stone structure, adapted to a pair of pumping engines placed side by side over the pump well.

The power is furnished by a Worthington Duplex Engine of 112 horse power. It consists in the main, of two horizontal direct-acting engines working upon the same column of water, and so connected with each other, that the motion of one will operate the valves of the other. This class of engine was selected above all others, on account of its first cost, the size and cost of its foundations and buildings, expense of running, repairs and especially immunity from accidents. In regard to the last item it may be said that, for four years the only accidents were the breaking, on two occasions, of a small bolt, interrupting the pumps for about an hour. In both instances the engine stopped itself without the slightest injury. A similar accident to a Cornish engine would probably have resulted in great damage, owing to the danger of giving motion to ponderous masses of iron.

A second engine exactly like the first has since been put in position, but with the present demand, one is amply sufficient.

The supply is drawn from the well through a suction pipe and delivered into the water cylinders, connected with a large air chamber, and then pumped through the force main into the reservoir.

This main is a cast iron pipe of 30" diameter and sixty six hundred ft. in length. Its total rise is one hundred and twelve feet above the level of the lake. Its thickness varies as the pressure to which it is subjected, being 1¼ 1⅛ and 1 inch respectively at its lower, middle and upper sections. At the reservoir the grades were very accurately adjusted, and each length of pipe was supported upon brick piers, extending below the bottom of the embankment into the hard pan.

In the main a few rods from the engine house is a check valve, or enlargement of the pipe with a diaphragm, supporting two clack valves opening towards the reservoir. Its principal work is to sustain the weight of the water in the main, when the engine is at rest. In case of accident to the pumps it will prevent any serious damage by sudden emptying of the pipe. Near this valve is a man hole and a 12" blow off pipe for discharging the water into the pump well.

The force main passes through the bank of the reservoir above the puddling and discharges its contents one foot above high water, or at an elevation of one hundred and forty three feet above mean high tide.

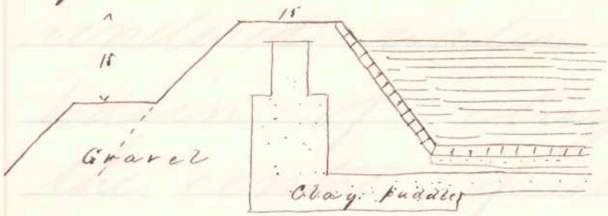
About four hundred feet north of the reservoir is a branch in the main extending around the westerly side and uniting with the supply mains a short distance to the south of the reservoir. A part of this branch, to a point nearly opposite the centre of the reservoir, is a 30" pipe while the remainder is 20" in diameter. At the junction of these pipes is a stand pipe, the object of which is to provide a steady pressure in the pipes whenever the reservoir should be drained for cleansing or repairing. It is fifty five feet in height thirty inches in diameter and

and built of double rivetted boiler iron 5/8" in thickness. At each end of the branch pipe is a gate for breaking connection with the reservoir, and blow-offs for emptying it when not in use.

The site of the reservoir is known as Chipman's Hill, situated in the town of Beverly near the Wenham line. It is an irregular knoll built of ledges and banks of hard pan, containing large boulders, and is about one hundred and thirty feet above tide water. In removing the surface preparatory to laying the puddle floor, a ledge of solid rock was struck, which was removed several feet below the proposed bottom, and the material used in paving the slopes and floor, thus saving the great expense of blasting and carting rock from the valley below. All the soil and porous materials were removed from the site until a solid foundation of rocks or earth was reached. None of this was directly used in the embankments but was put into the roads or beneath the sodding on the outer slopes.

The basin is four hundred feet square measured on the upper edge of the inner slope, and twenty three feet in depth. Its capacity is a little over 20-000000 gallons (U.S. standard) when filled up to the twenty foot mark, which is at grade 142, or 142 feet above mean high tide.

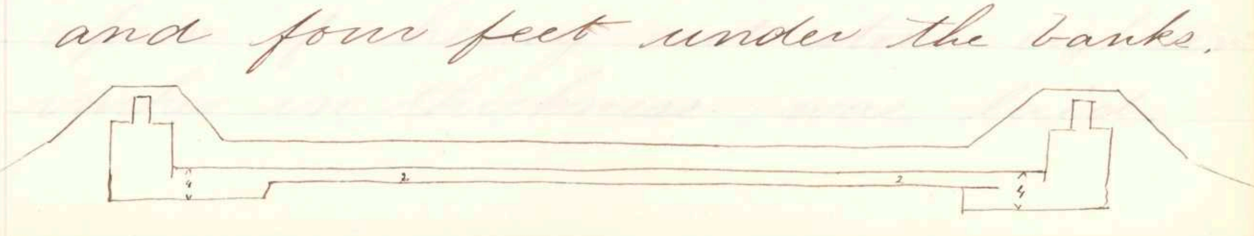
The embankments are fifteen feet in width at the top, and have a slope both inside and outside of one and a half to one. But on the northern side, where the bank was necessarily much higher than else-where, the precaution was taken to build on the outer slope about fifteen feet below its upper line, a



horizontal bench or berme several feet in width and terminating in a slope of the same incli-nation as the bank.

The banks are raised above the hill on all sides, and are built of earth obtained by leveling the hill after the porous soil had been removed. They were built in six inch layers, each one having been thoroughly hardened by the passage of loaded carts over the surface, before the next one was laid. All stones were thrown aside and wherever the foundation was much inclined, steps were cut into it to prevent future sliding of the bank.

The whole reservoir is rendered water tight by a square basin of clay puddle. In the centre of the banks is a wall of puddle ten feet thick from the lower layer to a height of twelve and one half feet and five feet thick to the top, which is one foot above high water line in the reservoir. Connecting with this wall is the flooring of the same impervious character, two feet thick in the middle and four feet under the banks.



The puddle is made of two parts of clay to one of gravel, thoroughly mixed with water and worked in six inch layers. Upon the clay floor was spread a layer of clean coarse gravel one foot deep and over this a paving of stone laid in cement.

Beneath the inlet pipe this paving was made of dressed stone of extra thickness to resist the heavy wash of water when filling the reservoir. The water slope was covered with a layer of gravel and a lining of granite 15 inches in thickness. At the inlet a nine inch layer of concrete was substituted for the gravel on the slope and a part of the bottom, and on this an apron of heavy cut stone eighteen inches in thickness was laid.

The outside slopes and top of the embankment each side of the gravel walk around the reservoir, are covered with loam and sodded to prevent their washing by heavy rains.

The water enters the reservoir ~~as~~ by the Influent pipe at the northerly side, and passes out by two Effluent pipes, one at each southerly corner, twenty five feet from the foot of the banks in each direction. The effluent pipes are twenty inches in diameter, and rise two feet above the bottom, so that they can draw no water from the lower portion whith contains most of the sediment.

Each pipe is provided with a square screen crib having double copper screens.

The screens are eight feet high and have a screenage area of about twenty five square feet on each side or one hundred at each outlet. The cribs are built of three inch oak plank, and have a trap door in the cover for the access to the pipe without moving the screens.

For further security each pipe is fitted with an iron grating in its mouth. These pipes pass down into the puddle and horizontally through it under the bank, each length of pipe resting on two brick piers.

Great care was taken to avoid a continuous line of contact between the iron pipe and clay or masonry, for the reason that water will readily follow a joint of this kind, gradually enlarging the fissure until the whole structure is destroyed. In this case two brick walls two feet in thickness were built across each outlet pipe, besides the supporting piers. These walls extend all around the pipes several feet, one being between the puddle wall and the interior of the reservoir, and the other outside of this wall. They were placed in such a position that a joint of the iron pipe came in the centre of each, thus causing a break in the joint between the pipe and wall.

The clay around and above connects with clay on all sides except where the walls are built into the solid rock.

The lower two feet of water can be drawn off and the reservoir scoured out by a twelve inch pipe laid by the side of the effluent pipes. They have gratings of iron bars, and brick silt basins at their inlets to prevent their being filled with gravel. Each effluent and scouring pipe has a gate just outside the embankment for shutting off the water, and an air cock for allowing the escape of air while they are being filled. Each side embankment has two surface drains passing under the sodding and connecting with the scouring pipes and system of drainage around the reservoir.

A few hundred feet south of the reservoir, the effluent pipes unite and form the supply main, extending to and through the more thickly settled parts of the city. It is a cast iron pipe of twenty inches diameter throughout its entire length of about four miles.

It crosses Bass river on a pile bridge, fifteen hundred feet in length, passing beneath the channel through an inverted syphon, sunk into a trench in the bed of the stream, leaving for the passage of vessels, an opening of over fifty feet with a depth of fourteen feet of water at low tide. At another point where the Lowell Rail Road passes under the street, it crosses the tracks on a pair of wrought iron girders.

This main is not tapped at all ~~x~~ by the service pipes,

they being supplied by dupli-
cate distribution pipes of
smaller sizes, laid by the
side of the main; all
hydrants are also separated
from it by the intervention
of gates, the object being
to reduce the liability
of being obliged to shut
off the supply of water
from any large section of
the city.

The system of distribution
embraces supply main, distri-
bution and service pipes,
hydrants, gates, air-cocks and
blow-offs, and is controlled by
the supply and demand, the
pressure of water in the pipes,
and by the cost, the last
item being generally the
most ~~most~~ expensive in the

construction of water works.

The most perfect system is that which supplies the consumer with the least loss of pressure by friction or otherwise. The city is divided into numerous sections by circuits of large pipes; these are subdivided into smaller sections by pipes of medium sizes, and the subdivisions are filled by small pipes, so arranged that any part of the city may be isolated from the remainder, without depriving that remainder of its supply of water.

The large distribution pipes are made of cast iron, while those of smaller diameter are made of the best sheet iron, lined and covered with hydraulic cement, forming a very clean, strong and comparatively cheap ~~pi~~ material for pipes of not more than ten inches diameter.

Having given a general description of the Salem Water Works as they are built, it may be said, in conclusion, that they have been constructed in a most substantial and durable manner in every detail, and remain today in almost perfect condition, supplying most satisfactorily the City of Salem and the Town of Beverly, covering a population of about thirty three thousand people.

Frank S. Dodge,

Beverly,

April 26th 1875. Mass.

Explanation of the Plates.

Figure 1. is a section through the middle of the engine room, showing the conduit pipe, the screen and gate chambers, brick conduit and pump well.
Scale 10ft = 1in.

Figure 2. is a ground plan of the same.
Scale 10ft. = 1in.

Figure 3. is a cross-section of the screen chamber.
Scale 3ft = 1in.

Figure 4. is a longitudinal section of the screen and gate chambers, and a small portion of the brick conduit.
Scale 3ft = 1in.

Figure 5. is a cross-section of the brick conduit.

Scale 9ft = 1 in. In the last three figures, the timber foundation has been omitted, being shown sufficiently in figure 1.

Figures 6, 7 and 8, are three views of the sliding gates for closing the conduit.

Scale 1¼ in. = 1ft.

Figure 9. is a section of the check-valve for force main.

Figure 10. is a plan of the same.

Scale 1½ ft = 1 in.

Figure 11 is a plan of the reservoir grounds. The 30, 20, and 12 inch pipes are shown

by red, blue, and brown lines.
Scale 50 ft = 1 in.

Fig. 12 is a section of the bank at the entrance of the force main, showing also the general form of the puddle wall and floor.
Scale 10 ft = 1 in.

Fig. 13. is a section of the embankment at each effluent pipe.
Scale 10 ft = 1 in.

Figures 14 and 15 represent elevation and plan of the screen cribs at the outlet pipes.
Scale 3 ft = 1 in.

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