Sears

The Brooklyn Water Works.

The usual reference to the water-works of the ancient Romans is here omitted for the sake of brevity, and we proceed abruptly to the consideration of the subject before us.

The average height of the City of Brooklyn is more than fifty feet above any sufficient water-supply upon Long Island. Hence the more ordinary method of supply, by gravitation, is impossible and the more complicated method, of pumping, was adopted.

The water-supply is obtained from a series of ponds situated at distances of from ten to fifteen miles East from the city. When these ponds first came into the possession of the city they were for the most part shallow, and had a deposit of muck and sediment, from the brooks flowing into them, to the depth of six or eight feet; Under the muck was fine sand and gravel.

Six of these ponds were cleaned and otherwise prepared for recieving and delivering the water of their respective districts -

The total area of these six ponds is very nearly one hundred acres; - the total "gathering ground" is nearly forty thousand acres. The average rainfall for the town of Flatbush for the past forty years is 42.89 in. the lowest of any year is 31.12 in. in 1849 - let us take 30 in as the minimum fall which will ever occur; then the total average fall perday over the whole forty thousand acres is 11,848,320 C.f. By very careful guaging of the streams from the different ponds, the total combined flow is found to be 2,509,253 C.f., which is about 21% of the total fall - thus allowing 79% for waste flow, evaporation, absorption by plants &c. Or otherwise taking 30 in as the standard, the minimum flow of the streams gives only 6.7 in. as the available flow, this gives nearly the same percent of waste-flow &c as the other computation - The average daily consumption for the year 1865 was 9,643,150 galls. = 1,236,300 C.f.

X N.Y. Gallons
See sheet No. 4

Should the demand ever exceed the present supply, that supply can be easily increased by the annexation of other ponds and from wells &c. sunk along the Conduit line -

After the ponds had been cleaned, the banks were brought to a uniform slope of 1½ to 1, the top of the bank being 4 ft. above the surface-water in the ponds and eight feet wide on the top, the slope terminating in two feet of water. All the ponds were mill-ponds and the old mill-dams were torn away and a puddle-wall embankment was built in their place.

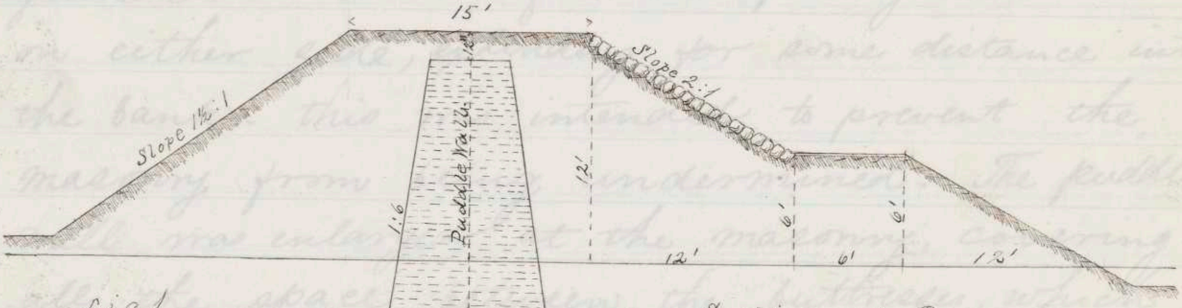

fig. 1 Section of Dam.

The fig. shows the cross-section of the dam at Jamaica pond on a scale of ten feet to an inch. The puddle consisted of fine gravel and clay, well mixed and laid in layers six to eight inches thick horizontally, each layer being allowed to set before the next was put on. The earthwork was carried up simultaneously with the puddle wall, The material of the embankment consisted of fine sand and gravel, it was deposited in layers nine inches thick and well rolled and compressed. The puddle-wall was carried up three feet above the surface-water of the ponds. The banks around the inside of the ponds were paved with nine inches of stone placed upon a layer of three inches of smaller stones, this was done to protect the bank from the action of the waves.

The over-fall of Jamaica pond (for example) is twenty one feet wide, the width of the sluiceway is five feet. The sluiceway delivers into a brick conduit 42" in diameter. The masonry of the over-fall and sluiceway was of heavy, cut granite - A row of sheet piling was driven on either side, extending for some distance into the bank - this was intended to prevent the masonry from being undermined. The puddle-wall was enlarged at the masonry, covering all the space between the buttresses, which were built to break lines with the masonry -

At first it was proposed to build the Covered conduit from the Pump-Well to Jamaica Pond only, but it was afterward decided to build the conduit, covered, to all the supply ponds.

The conduit from Jamaica Pond is capable of delivering forty million gallons per day with a fall from the pond to the pump well of six inches to a mile -

To determine the dimensions of an uniform channel which shall discharge Q c.f. of water per second with the declivity i, Rankine's formula for m the "hydraulic Mean depth", is $m = m'\left(\frac{4}{5} + \frac{i'}{5i}\right)$. where $m' = \left(\frac{Q^2}{8{,}512\, n^2 i}\right)^{\frac{1}{5}}$. $i' = \frac{f}{m'}\,\frac{v'^2}{64.4}$.

$v' = \frac{Q}{n\,m'^2}$, and $n = \frac{b^2}{A} = \frac{A}{m^2}$, is the proportion of the sectional area to the square of the hydraulic mean depth. When the cross-section is a half-square, the value of n is $n = 8$.

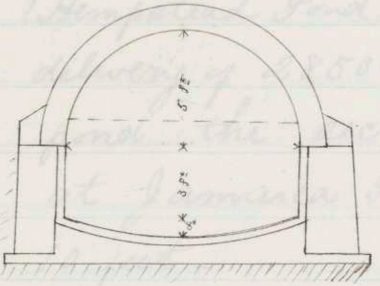

fig 2.

The fig. 2 shows the actual cross-section of the Conduit. The dotted line shows the position of the water-line in the Conduit, under ordinary circumstances. five feet above the invert. This part of the cross-section differs so little from a half-square, that we shall be sufficiently accurate in taking it as such.

The inclination is six inches to the mile, equal to 0.0001 nearly. Thus we shall have for the value of m' — $m' = \left(\frac{\overline{59.3}^2}{8.512 \times 8 \times 8 \times 0.0001}\right)^{\frac{1}{5}}$, 59.3 being the number of cubic feet of water per second, and $m' = 2.3$ nearly. For an approximation to the velocity $v' = \frac{59.3}{8 \times \overline{2.3}^2} = 1.40$. From these data we find an approximate value of i', by the formula $i' = \frac{f}{m'}\frac{v'^2}{64.4} = \left(0.00741 + \frac{0.000227}{v'}\right)\frac{v'^2}{64.4\,m'}$

$i' = (0.00741 + 0.00016)\frac{1.4 \times 1.4}{64.4 \times 2.3} = 0.0000\underline{9}$, and the <u>correct</u> <u>hydraulic</u> <u>mean</u> <u>depth</u> is $m = m'\left(\frac{4}{5} + \frac{i'}{5i}\right) = 2.25$

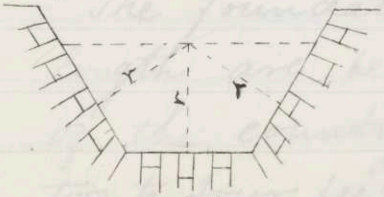

fig 3

In the section proposed by Mr. Neville, the radius of the circle tangent to the sides, for this hydraulic mean depth is $r = 4.5$ feet, and for a section, similar to the one adopted, i.e. having vertical sides, an invert of eight inches at the bottom and a width of ten feet, the height of the vertical sides for this value of m is 3.36 feet.

The width of the Conduit at the last pond (Hempstead Pond) is 8'.2" with a capacity for the delivery of 28,500,000 gallons. At the inlet of each pond the sectional area is increased so that at Jamaica Pond, as we have seen, the width is 10. feet.

From Jamaica Pond to the Pump well, a distance of 4.848 miles, the conduit is of uniform section (fig 2). The side-walls are of stone, with a lining of brickwork, giving a total thickness of 2 feet. The arch was of brick, twelve inches thick. These dimensions are not sufficient to sustain the thrust of the arch, therefore the centres were not allowed to be struck until the earth was well packed and rammed around the outside to a depth of four feet and a width of eight feet over the top. The same plan was adopted in the Croton, Washington and Cochituate Conduits.

The foundations of the conduit for the whole length are below the Spring- or Water-line of the country; the head of water varying from two to four feet, and near the pump well it is six or seven feet.

For a distance of some two thousand feet from the pump-well, where the springing of the arch was some four to five feet below the Spring-line, thirty small openings were left. The delivery of these, by careful guaging, was found to be 1,402,000 galls. in twenty-four hours. These openings are now closed, but if necessity should require, they might be safely relied on for 750.000 galls. per day.

The conduit terminates in a small arched basin 10 ft. wide and 52½ ft. long, placed at right-angles with the conduit line. The thickness of the arch is 24". The basin connects with the pump-well by four sluices. The bottom of the pump-well is two feet below the bottom of the basin, so that when there are five feet of water in the conduit there are seven feet in the pump-well. The pump-well is divided into two parts so that the pumps of one engine may be reached for repairs without interfering with the working of the other.

The engine house includes within its interior the pump-well and sufficient space for four large pumping engines, capable of delivering into the reservoir ten million gallons of water, each, per day

Wherever the word gallon is used, the New-York gallon is referred to; A New York gallon weighs eight pounds - one hundred gallons measure 12.8 cubic feet and one cubic foot contains 7.8125 galls.

The boiler houses form wings to the engine-house and are each designed to contain the boilers of two engines - There are three boilers to each engine - The boilers are thirty feet long by eight feet in diameter. The furnace gas passes through two large flues to the back of the boiler, then through several smaller flues, back to within six feet of the furnace, thence through a large flue 48" × 48" to the chimney. The chimney itself is one hundred feet high, the internal diameter is 48".

At present only two engines are in use, the foundations for a third, of a somewhat different style are being laid, The foundations of each engine are very heavy granite -

The two engines now in use are condensing beam engines, with some of the peculiarities of the Cornish engine and believed to be an improvement on that class of Engines, both as regards economy of first cost and of working expenses - The Cornish engine has a single acting cylinder and only one pump, The Ridgewood engine is double acting and has two pumps: the pump at the steam end is directly beneath the steam cylinder. In the Cornish engine the steam raises a column of cast iron and this acts upon the water, while the Ridgewood engine acts directly upon the water. The action is indirect in the one case and direct in the other.

The piston of the lower pump in ascending drives its water through the piston of the upper pump, whose piston, with open valves is descending at the same time. and vice versa.

A Cornish engine to do the required amount of work, raising ten million gallons of water per day, one hundred and fifty-two feet, would have been nearly twice as large as the Ridgewood engine, hence the economy in first cost. Neither form of engine has its stroke limited by a crank, hence its length is variable. This peculiarity renders the engine so sensitive that great care must be exercised on the part of the fireman in order to keep the pressure in the boilers as nearly uniform as possible. Still there will sometimes be an overreaching of the stroke, but an arrangement of beams is so placed above the pump cylinder that it must be destroyed before any injury can be done to the cylinder.

The diameter of steam cylinder of engine N°. 1 is 90 in. that of Engine N°. 2 is 85 in., The full stroke of each is ten feet - The two pumps of each engine are 36 in. in diameter with the same stroke as the engine _

The "duty" of the engine was calculated as follows - "The friction of the water was ascertained by reliable guages and added to the weight of water due to the height between the pump well and the point of delivery - The load on the pump piston, thus ascertained, multiplied by the length of the stroke, in feet, and by the number of strokes and the product divided by the number of pounds of coal used during the experiment gives the 'duty'." The friction was ascertained by an Allen guage and was found together with the static pressure, to be 61 pounds on the square inch to this add 13.077 for the difference in level between the position of the guage and the average level of the water in the pump-well 30.26 ft and we have 74.077 pounds per square inch _ The diameter of the two pump-pistons is thirty-six inches, deduct the area of the section of the lower pump piston rod and we have for the area of the two pistons 1,982.3 sq. in. and the load on the pistons is 74.077 × 1.982.3 - 146,842.83 - The number of strokes during the experiment was 14,923. The average length of the stroke was 9.83. The net quantity of fuel used was 35,430 lbs. and we have $\frac{146.842.83 \times 14.923 \times 9.83}{35,430} = 607,982$ f^{t}. lbs. as the duty of 1 lb. of coal -

The duration of the experiment was 26.^{h} 5' -

The amount of water delivered into the reservoir as measured in the reservoir and by a weir as it flowed into the reservoir is as follows - By reservoir measures 15.521,719 galls
" weir " 15.603,117 "

A second test of sixteen hours duration gave
By reservoir measures 10,293,102 galls
" weir " 10,095,125 "

By the requirements of the contract the "duty" was to be 600,000 f^{t}. lbs. per 1 lb. of coal and ten millions gallons of water raised to the reservoir in twenty-four hours at the same time.

Thus the engine exceeds the contract both as regards "duty" and capacity for delivery.

The pumps of each engine deliver into an air chamber 78½ in. internal diameter, and thence into the rising mains which start from the air chamber. A lifting valve separates the pump from the air chamber, opening and shutting with each stroke - The air chambers are of cast iron in three pieces, with spherical ends, flanged and bolted together.

The rising mains are of cast iron pipes, twelve feet long by thirty-six inches in diameter. The length is 3.450 ft with a rise of 152 ft. Mr. Kirkwood's modification of M. Depuis formula for the thickness of a pipe for a given head, is $t = 3.4\,n\,(0.0016\,d) + c$. n is the pressure in atmospheres, (corresponding to a column of water 33 ft high). d is the diameter in inches. c is a constant which for a pipe 36" in diameter is 0.36

$$t = 3.4 \times \frac{152}{33}(0.0016 \times 36) + .36 = 1.26$$

Weisbachs formula for a pipe tested at ten atmospheres pressure is $e = 0.0238 \times d + 0.33$. $e = 1.18$

As actually laid, the mains were in four sections, the thickness for the first was taken as $1\frac{1}{2}$ inches; the second section was $1\frac{3}{8}$ in. the third $1\frac{1}{4}$ in and the fourth was $1\frac{1}{8}$ in thick.

The sockets were 6" deep - leaded inside and out and well caulked. The mains deliver nearly at high water of the Reservoir - The water flows into a chamber of masonry, in order that the whole length of the mains may be accessible for repairs without lowering the water in the Reservoir - A check valve is placed near the centre of each main in order to reduce the damage which might be caused by the failure of a pipe - Owing to the influence of the air chamber the flow is so continuous that these valves only close when the engine is stopped.

The Reservoir is on the highest part of a range of hills lying between the city and the gathering grounds of the supply-ponds.

The surface of the water in the reservoir when full is one hundred and seventy feet above mean high tide –

The reservoir grounds include 48.4 Acres. The reservoir at present occupies about two-thirds of this area, the remainder being left for similar use hereafter. It is at present divided into two parts – the one containing 11.85 Acres, the other 13.73 Acres equal to 25.58 Acres. Owing to the irregularities of the ground, the embankment varies from four feet in some places to thirtyeight in others.

The soil was first stripped from the ground and then the excavation was commenced – The material of the excavation consisted, generally, of a stiff coarse earth full of stones and bowlders. The earth separated from the stones and bowlders, was used to form the embankments; the bowlders were broken and used for paving and the stones were entirely removed.

The outer embankment is twenty feet wide at the top and four feet above the high water level of the reservoir; The division embankment is fifteen ft. wide at the top, and three ft. above the water level. The slopes are one and a half to one. The puddle wall in the centre of the division embankment rises to within two feet of the top where it is three feet wide; it has a slope of one inch to a foot.

Where the inner slope rests upon the natural ground the puddle wall is placed upon the slope twenty-four inches thick: where the artificial embankment begins, it is carried into the centre of the embankment.

The puddle consisted of the earth of the excavation, mixed in the proper proportions with a white clay found in the neighborhood. It was laid in horizontal layers six inches thick, each layer was worked to a paste with water and allowed to set before the next layer was put on. In order that a puddle-wall may be impervious to water it should be kept constantly moist, and its position, in the centre of an embankment, accomplishes this. The embankment itself should be of such dimensions as to be water tight, the puddle-wall being added to ensure against defects or accidents.

The bottom of the reservoir is covered with two feet of puddling and upon this a few inches of clean gravel.

The bottom has a fall of eight inches towards the effluent chamber in order that the whole may be drained off when necessary. -

The outer slopes are covered with soil and grass, and the inner slope with a dry stone pitching. - It is found preferable to lay the stone eighteen inches deep rather than less, especially in a reservoir exposed to high winds -

The contract provided for the laying of the following lengths and sizes of pipe -

36" mains	5 miles.
30" "	5 "
20" "	40 "
12" "	12 "
8" "	30 "
6" "	64 "

The hydrants not to exceed eight hundred. Four inch pipes connect the hydrants with the street pipes. The stop-cocks were as follows.

36" stop-cocks	3 in number.
30" " "	9 " "
20" " "	17 " "
12" " "	65 " "
8" " "	168 " "
6" " "	402 " "

There are six blow offs and fifty air cocks.

The word "main" applys to pipes of twenty inches and over, these supply the twelve inch pipes and under and these supply the water-takers by means of the service pipes.

The mains are never allowed to be tapped owing to the risk of splitting which might occasion great damage.

The head of water for the Brooklyn pipes is nearly one hundred and seventy feet.

Mr. Neville gives two expressions for obtaining the thickness of pipes

$t = 0.0024(n+10)d + 0.33$ — for pipes cast horizontally

$t = 0.0016(n+10)d + 0.32$ — " " " vertically

His equivalent for the formula of M. Dupuis — Engineer of the Paris water works is

$t = 0.0016\,nd + 0.32 + 0.013d$.

These all give results less than those in use in the United States.

In these expressions $\underline{t}$ = thickness of pipe in inches

$\underline{n}$ = the number of atmospheres of pressure at 33 ft each, to which the pipe is to be subjected.

$\underline{d}$ = the diameter of the pipe in inches.

Mr. Kirkwood's formula, (given before) is a modification of that of M. Dupuis

$t = 3.4n(0.0016d) + C$.

The value of C varies with the diameter of the pipe. For a 6" pipe $C = 0.40$ and for a 36" pipe $C = 0.36$

Formerly all pipes less than twenty inches in diameter were cast horizontally or with a slight inclination - This practice produces pipes of a variable thickness. In pipes cast vertically the thickness is much more uniform, and this method is in much more general practice than it was ten years since - The test to which the pipes are generally subjected is four times the extreme head - The hand hammer however is the surest method of discovering defects - The pipes were protected from corrosion by the application of Dr. Smiths preparation of coal pitch and oil. The pipe is dipped into a vessel containing the preparation which is brought to a temperature of 300° F. The pipe after attaining this temperature is slowly removed and allowed to dry -

A certain portion of the southern part of the city is situated above the level of the Ridgewood reservoir - This part was provided for by building a separate reservoir on the highest part of this ground called Mt. Prospect. It is supplied with water by a pumping engine whose pumps derive their supply from a branch main from the Ridgewood reservoir. Its high water level is twenty eight feet above that of the

Ridgewood water. The depth of the water is twenty feet.

Any further description would merely repeat what has already been written in regard to the Ridgewood reservoir.

We have thus followed the construction of the Brooklyn Water Works, from the supply ponds to the distribution through the city.

It is but just to add that most of the descriptive part has been obtained from the most excellent and comprehensive report of Mr. James P. Kirkwood the Engineer in charge.

Walter H. Sears.

Brooklyn N.Y.
August 1868.