DESCRIPTION OF THE PUMPING ENGINES AND WATER-SOFTENING MACHINERY AT THE SOUTHAMPTON WATER WORKS.

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In 1851 the Southampton Corporation equipped a pumping station at Mansbridge, and obtained a supply of water from the River Itchen, Fig. 1, Plate 12. In 1865 additional plant was added; and this source was used until 1888, when new works were inaugurated at Otterbourne, eight miles from Southampton, drawing a supply from wells and headings sunk in the chalk.

Mansbridge Pumping Engines.—The old plant at Mansbridge consists of—firstly, a pair of single-acting Cornish beam engines, made and erected in 1851 by Messrs. R. and W. Hawthorn, of Newcastle-on-Tyne. The cylinders are 38½ inches diameter with a stroke of 8 feet; jet condensers are used, and the working pressure is 15 lbs. per square inch. The engines make 10 strokes per minute, and in ordinary work consume 4·7 lbs. of Welsh coal per I.H.P. per hour. The pumps are of the bucket and plunger kind, 14¼ inches diameter and 8 feet stroke; they have Harvey and West's valves, and can each lift 734,000 gallons per day against a head of 200 feet. Secondly, a pair of rotative beam engines, coupled together with a common fly-wheel, made and erected in 1865 by Messrs. Harvey and Co., of Hayle. The cylinders are 40 inches diameter with a stroke of 8 feet; jet condensers are used, and the working pressure is 20 lbs. per square inch. The engines make 12½ revolutions per minute, and in ordinary work consume 4·9 lbs. of Welsh coal per I.H.P. per hour. The pumps are of the bucket and plunger kind, 18¼ inches diameter and 8 feet stroke; they have Harvey and West's valves, and each can lift 1½ million gallons per day against a head of 200 feet. Indicator diagrams from each kind of engine are shown in Figs. 9 and 10, Plate 19.

Otterbourne Pumping Engines.—At the Otterbourne works there are a pair of compound rotative beam engines, shown in Figs. 2 to 6, Plates 13 to 16, with supporting columns, entablature, and spring beams attached to the engine-house walls. Each engine is independent, with its own crank-shaft and fly-wheel; but both pump into one delivery main. At a speed of 18 revolutions per minute each can pump 2 million gallons in 24 hours. The cylinders are steam-jacketed and placed side by side; the high-pressure are $28\frac{1}{2}$ inches diameter with 4 ft. 9 ins. stroke, and the low-pressure $38\frac{1}{4}$ inches diameter with 7 feet stroke. The intermediate steam-receivers are unjacketed, and are placed underneath the high-pressure cylinders, forming their bases; they are 2 ft. 9 ins. diameter and 4 ft. 6 ins. high inside. The steam pistons are 9 inches deep, cast solid and fitted each with three plain steel rings. The piston-rods are of steel, $4\frac{1}{4}$ inches diameter.

Valves.—The high-pressure cylinders have valve-chests at both ends, connected together by a cast-iron pipe with a copper expansion-joint. They are fitted with Meyer's expansion slide-valves, giving a variable cut-off from one-eighth to three-quarters of the stroke, three-tenths being the normal. The valves are of cast-iron, and the spindles of steel. The low-pressure cylinders also have valve-chests at both ends, which are connected by means of two cast-iron side-pipes. Each valve-chest contains separate steam and exhaust valves of cast-iron with steel spindles, the valves being of the ordinary double-seated type. Pneumatic dash-pots are fitted to the valves; but as at present the valves fall almost noiselessly, their use is not resorted to, and the plugs are left full open to the air; the dash-pot pistons however form capital guides for the valve spindles. Each valve gear is actuated by means of a steel lay-shaft F, 4 inches to $3\frac{1}{2}$ inches diameter, which is worked from the crank-shaft of its own engine by means of a pair of bevel wheels B, 2 ft. $2\frac{3}{8}$ ins. diameter. The lay-shafts are carried under the floor, close to the cylinders; and by means of cast-iron cams, fitted with steel treads, they raise and let fall the plug rods connected with the low-pressure valves. The plug rods are $2\frac{3}{8}$ inches to $1\frac{7}{8}$ inch diameter, and terminate at bottom with rollers; and as the cams revolve in an oil bath, the wear on them is reduced to a minimum. Close to the high-pressure cylinders the lay-shafts are each connected by means of a pair of spur wheels S, 1 ft. 7½ ins. diameter, with a 3½ inch countershaft, which has at one end a crank and pin with 2⅞ inches stroke; this gives a travel of 5¾ inches to the main slide-valve spindle, to which it is connected by a short connecting-rod. The expansion slides have each a travel of 6½ inches; they are actuated from above by means of rods and cranks, the actual motion being derived from the end of the radius-rod of the parallel motion. The shaft connecting the ends of the rods is hung in brackets, and at one side projects beyond, and has a crank keyed on it, which thus acquires the rocking motion of the radius-rod. A steam starting-gear is arranged, so that with a single lever steam can be admitted into the low-pressure cylinder either above or below the piston at any position in the stroke.

Condensers, &c.—The surface condensers C, Plates 14 and 16, are of cast-iron and vertical, 3 ft. 3 ins. diameter, fitted with 250 brass tubes 1 inch outside diameter and 5 ft. 9 ins. long between the tube plates, to which they are secured by wooden ferrules. The air pumps A are of the usual vertical kind, 22 inches diameter and 30·8 inches stroke. The buckets are of cast-iron 18 inches deep, without rings or packing. The foot, delivery, and bucket valves are all of india-rubber. Pumps for feeding the boilers and charging the air vessel are worked off the same cross-head, which, hung from the beams by double rods, gives motion to the air pumps. These boiler feeds have been put out of use, owing to trouble with the grease in the boilers. The cylinder jackets receive steam direct from the main boilers, which are at a lower level, so that the jackets drain back into them.

Beams.—The engine beams are of cast-iron, each composed of two panelled and moulded flitches, 2¼ inches thick in the panels and 4¼ inches at the mouldings. The flitches are 9 inches apart, 5 feet deep in the centre, and rounded at the ends to a radius of 9 inches; they are 23 ft. $0\frac{17}{32}$ inch between extreme centres. Cast-iron balance-weights are fitted on the cylinder end of each beam. The beams swing in heavy plummer-blocks with brasses 9 inches diameter and

11 inches long, the steel gudgeons being $13\frac{1}{4}$ inches diameter through the beams. The piston-rod cross-heads are hung from one end of the beams by the usual side-links and parallel motion; the air pumps and main water pumps have no parallel motions, but are worked from plain gudgeons fixed in the beams. The fly-wheel connecting-rods are of wrought-iron, hung to a gudgeon between the beam flitches; each has a stroke of 6 feet, and is 20 feet long between centres, $7\frac{3}{4}$ inches diameter at centre, and $5\frac{3}{4}$ inches diameter at each end. Both brasses are 7 inches diameter, the upper 8 inches long and the lower $8\frac{1}{2}$ inches, fixed in the strap ends with gibs and cotters.

Shafts and Fly-wheels.—The shafts and cranks are of wrought-iron, and the crank-pins of steel. The shafts are $12\frac{1}{2}$ inches diameter, except in the outer bearings; and the crank-pins are 7 inches diameter and $8\frac{1}{2}$ inches long. The bearings in the inner plummer-blocks are $12\frac{1}{2}$ inches diameter and 16 inches long, and in the outer $9\frac{1}{2}$ inches diameter and 13 inches long. The fly-wheels, 18 feet diameter with six arms, are cast in three pieces, securely dowelled together and further secured by two wrought-iron rings shrunk on the wheel bosses, one on each side. The bosses are bored out $12\frac{1}{2}$ inches diameter, and secured to the crank-shafts with two keys to each wheel.

Pumps.—There are two pumps worked off each engine, Plates 14 to 16, one low-lift L and the other high-lift H; the former lifts water from the well W, and delivers it up to the softening works; the high-lift receives it by gravity after softening, and forces it up to the high-level reservoir on Otterbourne Hill, Plate 12. Ten per cent. of lime water has to be added to the well water in the process of softening; and as this lime water is made from softened water, the high-lift pumps must always deliver 10 per cent. more water than the low-lift. The pumps are hung from the engine beams so that their strokes shall be 7 feet for the high-lift pumps and 5 feet for the low-lift.

The low-lift pumps L, Plates 14 to 16, are of the bucket and plunger type, and are hung one down each well-tube by means of 23-inch pipes P and two 2-inch hanging rods. The working barrels are 22 inches diameter, placed near the bottom of the suctions. The buckets are of cast-iron, 30 inches deep, with four water grooves but no packing or rings. The bucket and suction valves are alike, with double india-rubber valves working against cast-iron guards and grids. The suction valves can be drawn up the 23-inch pipe for examination by means of a large eye-bolt, when fished for with a chain and hook. The plungers are of cast-iron 20 inches diameter; and from them the buckets are hung by means of 2¼-inch iron rods D with steel couplings and keys. Each rod is about 65 feet long over all; and when running fast it was found that whipping took place, with a consequent loosening and shearing of the coupling keys. To remedy this, each rod has had two sets of rollers fitted to it; there are three rollers in each set, fixed in a strong iron framework which is attached to the rod; and the 23-inch pipe P itself forms the roller path, care being taken to alter the position of the rollers occasionally, so that grooving shall not take place. This plan has proved quite successful, and no difficulty is now found in keeping the keys tight. The pumps deliver through 18-inch stop-back valves V of the regular hinged-flap kind, into a common annular air-vessel R, 4 feet diameter inside and 13 feet 10 inches high; the annular space is formed round a pipe of 23½ inches diameter, and the delivery main Y is 24 inches diameter.

The high-lift pumps H, Plates 14 to 16, receive their water from a higher level, and their suctions are furnished with open-topped stand-pipes T. The pumps are plunger pumps, but so designed that they are double-acting on the delivery, Fig. 7, Plate 17. The plunger is of cast-iron unpacked, 19½ inches diameter and 3 feet 6 inches long in the working barrel; above and in the stuffing-box it is 14 inches diameter. The suction and delivery valves are four-seated, with easy and ample waterways, although the lift is only 1¼ inch; they are of cast-iron with gun-metal seats. The water is forced from under the plunger through a loop pipe and through the delivery valve to the top side of the plunger, whence it is discharged through a 14-inch stop-back valve into an air-vessel J common to both pumps, 3 feet 9 inches diameter and 12 feet 6 inches high with a domed top. From the air-vessel a 24-inch main M leads up to the high-level reservoir on Otterbourne Hill, Plate 12. The delivery valve-boxes are furnished with 3-inch relief-valves.

Each pump has a cross-head and guide attached to the prolongation of the plunger above the stuffing-box, and these work in guide grooves I fitted against the foundation walls. The cross-heads are connected with the beam gudgeons by pairs of braced connecting-rods, 27 feet long between centres; for the low-lift the rods taper from $4\frac{1}{4}$ inches to $2\frac{5}{8}$ inches diameter, while for the high-lift they are $3\frac{3}{4}$ inches diameter at the ends, and $6\frac{1}{2}$ by $4\frac{1}{2}$ inches oval section at the centre. The brasses are alike at both ends, 3 inches diameter and $3\frac{1}{2}$ inches long for the low-lift, and $3\frac{3}{4}$ inches diameter and $5\frac{3}{4}$ inches long for the high-lift; all are furnished with strap ends, gibs, and cotters.

The pumps upon trial were found by actual measurement of water to have a slip of 2·73 per cent.

Boilers.—Steam is supplied by three steel boilers, Plate 16, each 28 feet long and 7 feet diameter, having two flues of 2 feet 9 inches diameter, in which are four Galloway tubes tapering 8 inches to 4 inches diameter. The shell plates are 7-16ths inch thick, the ends 5-8ths inch, and the flue-tubes 3-8ths inch. The average tensile strength of the steel was 27·17 tons per square inch, with an elongation of 24·9 per cent. Each boiler is fitted with a Cowburn's dead-weight safety-valve, and also with Hopkinson's combined low-water and pressure safety-valve. Two boilers easily keep steam at 60 lbs. pressure with both engines working, and the consumption of coal is very moderate.

Cost of Pumping.—The total cost of pumping during the years 1890 and 1891 has been 0·634 penny per thousand gallons.

Trials.—The engines, pumps, boilers, and tools in the repairing shop were all supplied by Messrs. James Simpson and Co., of Pimlico; and the following are the results of the trials which were made shortly after the starting of the engines. Indicator diagrams are shown in Fig. 8, Plate 18.

Trials of Engines.

		A	B
Engine		A	B
Date of Trial	1888	Nov. 1.	Nov. 9.
Duration of Trial	hours	10½	10½
Barometric pressure	lbs. per sq. in.	14·60	14·64
Boiler-pressure above atmosphere	lbs. per sq. in.	60·6	60·0
Vacuum in condenser below atm.	lbs. per sq. in.	14·00	13·98
Revolutions, total during trial	revs.	10,850	11,060
„ per minute	revs.	17·22	17·55
Horse-power, indicated	I.H.P.	115·55	117·93
„ actually obtained	H.P.	98·00	100·02
„ expended in friction	H.P.	17·55	17·91
Mechanical efficiency of engine	per cent.	84·81	84·80
Coal consumed, total during trial	lbs.	1,757	1,750
„ „ per hour	lbs.	168	167
„ „ per I.H.P. per hour	lbs.	1·454	1·416
„ „ per actual H.P. per hour	lbs.	1·714	1·670
Ashes, total made during trial	lbs.	14	15
Quantity of Water raised, high-lift pump	gals.	955,125	973,612
„ „ „ low-lift „	gals.	868,651	885,464
Head of water against high-lift „	feet	159·73	161·15
„ „ „ low-lift „	feet	58·90	57·70
Duty of engine per cwt. of coal, millions of foot-lbs.		129·3	132·8

Water-Softening Machinery.—The softening plant, shown in Figs. 11 to 20, Plates 20 to 26, is capable of satisfactorily dealing with from $2\frac{1}{4}$ to $2\frac{1}{2}$ million gallons per day of 24 hours; and by the addition of seven filters and two lime-water cylinders, for which space is provided, Plate 21, nearly 4 million gallons per day could be treated. The softening process may be divided into three operations:—first, the preparation of cream of lime; second, the preparation of lime water and its admixture with the hard well-water; third, the filtering of the turbid water after softening.

Cream of Lime.—The cream of lime is prepared in the following manner. The raw lime from the kilns is tipped into two mechanical slaking machines K, Plate 21, 4 feet diameter and 3 feet deep, in which it is stirred up by revolving arms, and wetted by the admission of water from the mains. Thus slaked and mixed with water, the cream of lime flows through screens into a large tank C, where it is stored for use, a week's supply being furnished at each slaking. The tank is made of concrete lined with blue bricks; it is 25 feet by 19¼ feet with a sloping bottom, 5 feet deep at the sides and 7 feet at the centre. Compressed air can be discharged into it through pipes, so as to agitate the cream of lime occasionally and thereby prevent its consolidation.

Lime Water.—For the preparation of lime water are provided two large open-topped steel cylinders L, Plate 22, 9 feet diameter and 11 feet high, with their lower ends coned. Into these the cream of lime is pumped at intervals, and occupies the coned bottom, Fig. 14; softened water from the mains is admitted to a tank fixed above the cylinders, and flows thence through pipes and valves into the cylinders, being admitted near the bottom of each cylinder. This water has therefore to rise through the cream of lime, of which it carries a portion with it, forming lime water. The latter is drawn off by collecting pipes from the upper part of the cylinders, and flows through regulating valves into the mixer M, where it meets the hard water from the well. The mixer is a large open-topped steel tank, fitted with baffle-plates; the 24-inch main Y from the well pumps enters it at one end, and the lime water nearer the centre; and owing to the action of the baffles a thorough mingling of the two takes place before the lime water passes from the end of the mixer into the distributor D, Plate 21. The latter is a long steel trough, into which the lime water flows from the mixer, and from which it is discharged in a thin sheet over the entire 40 feet length of one side of the trough, as over a weir; and as the lime water falls about 3 feet into the softening tank S, the most complete combination is assured of the hard water and the lime water. The softening tank S is of brick and concrete, 76 feet long, 44 feet wide, and 6 feet deep along one side, sloping to 7 feet along the other. The water travels through it slowly, in order to give time for the chemical action of softening to be actually and surely finished before the water is admitted to the filters F.

Filters.—The filters, shown in Figs. 15 to 20, Plates 23 to 26, are thirteen in number, and their function is to remove the carbonate of lime, which is present in the water as an insoluble precipitate after the softening has been effected. Had this to be removed by subsidence, as was the case in the old process, immense reservoirs would be necessary. The filtering material is cotton cloth mounted on perforated zinc. Water from the softening tank is admitted to the filters through 6-inch inlet-pipes, the mouth of each being fitted with a heavy leather-faced flap-valve, which is opened by a lever from the front end of the filter, Plate 24. Each filter consists of a cast-iron open-topped tank, in which is placed a horizontal hollow shaft carrying twenty discs of 3 feet diameter. Each disc is formed of a light circular cast-iron frame, covered on either side with perforated zinc, over which is stretched the cotton filter-cloth, secured round the circumference of the disc by two wrought-iron clip-rings that are just bound together by copper wire wound round studs, Fig. 16, Plate 23, and Figs. 19 and 20, Plate 26. The water percolates through the cloth, and finds its way along the hollow shaft, and through valves and pipes, to the clear-water tank T, Plates 20 and 21, whence it flows to the high-lift pumps. The deposit of carbonate of lime thus accumulates upon the faces of the discs, until the time arrives when it becomes necessary to clean it off. This is done by means of water spray, applied while the discs are revolving. The disc-shaft is mounted in trunnion bearings, and is made to rotate by means of a spur wheel and pinion inside the front end of the filter, Plate 24, driven by bevel gearing outside. Small water-pipes with spray holes in them are placed between each pair of discs; and upon high-pressure softened water being admitted, the issuing jets wash the deposit off the cloth surfaces, Fig. 16, Plate 23. The spray pipes are $\frac{3}{4}$ inch diameter, and are made to rise and fall, so as to command the entire surface of the revolving discs. The filters are furnished with outlet valves V for the filtered water; and also with waste valves W, whereby the deposit washed off is carried away to waste pits outside, Plate 21.

Cost of Softening.—This softening apparatus acts efficiently and economically. The cost of softening during the two years 1890 and 1891 amounted to only 0·243 penny or one farthing per thousand gallons. The machinery was made and erected by Mr. John Cochrane of Barrhead for the Atkins Filter and Engineering Company, the details having been worked out by their manager, Mr. W. G. Atkins. A complete detailed description of the plant and machinery has been given by the author in the Proceedings of the Institution of Civil Engineers, 1892, vol. cviii, page 285.

Discussion.

Mr. MATTHEWS said this paper had been prepared for reading at the last summer meeting, had time admitted, in connection with the visit paid by the members on that occasion to the Otterbourne works. He would anticipate the exception which might possibly be taken to the steam receivers of the new engines being unjacketed, by explaining that the design of the engines had been somewhat hampered in regard to the amount of money to be spent upon them; and this was one of the questionable directions in which it had been thought that a saving in first cost might be effected. As to the whipping or transverse vibration of the long pump-rods (page 57), which had been remedied by putting rollers in, it should be added in justice to Messrs. Simpson, who had built these engines, that they were really not answerable for it; for originally the pumps had been intended to raise water from not such a great depth as was afterwards found in practice to be necessary, owing to the supply at the shallower depth not being so large as had been expected. The engines had thus to lift the water with a much greater head on the low-lift pumps than had been expected; and it was only when they were pumping with the water low down in the well that the whipping had taken place.

As to the cost of the pumping, which was stated (page 58) to be 0·634*d.* per thousand gallons through 1890 and 1891, the cost for the past year 1892 had just been made out; and with various economies which had been effected it had been reduced to 0·612*d.*, the price of Welsh coal being 18*s.* 9*d.* per ton delivered in the siding at the works. Similarly, with regard to the cost of softening, this had been reduced from 0·243*d.* to 0·202*d.* per thousand gallons; and it was anticipated that during the present year it would be still further reduced. Hitherto the waste deposit from the filters had been allowed to go into open pits at the lower level of the works, whence it had to be dug out and carted up to another part of the land, and deposited in an old chalk pit; but arrangements had been completed since the visit of the members, for pumping the waste as it came from the filters at once up to the highest level at the top of the land, and there letting it subside in a pond to a certain extent, and then shooting it direct into the old quarry. By this plan it was expected that a saving would be effected which would probably bring the cost of softening down to below 0·200*d.* per thousand gallons.

The PRESIDENT asked whether that cost included any charge for the sinking fund.

Mr. MATTHEWS replied that it did not. The sinking fund for the works had been calculated on a life of thirty years, and came almost exactly to another farthing per thousand gallons.

The lime used for softening the water was obtained on the site of the works, and was burnt from the chalk. It was found that this was the most important point to which attention had to be paid in connection with the softening. Unless the lime was very pure, free from any admixture of earthy matter, it had a most serious effect upon the filter cloths, causing them to be eaten away extensively.

Mr. EDWARD B. MARTEN, Vice-President, asked at what depth the chalk water was met with down the well, and how high it had to be lifted; also how much it was lowered in the well by the pumping, and whether it became any less hard by more pumping, or whether it was always of the same degree of hardness. Was it the tendency of the water in such wells to become either better or worse in respect of hardness? The wells themselves he thought were particularly interesting, because they had been sunk entirely by boring; they really were big borings, 6 feet in diameter.

(Mr. Edward B. Marten.)

In regard to the whipping that had been found to take place in the long rods by which the buckets were hung in the pump wells (page 57), he enquired whether anything else had resulted from it besides the loosening of the couplings. Did they strike so violently against the inside of the pipes as to cause injury to them, or only to the couplings or keys of the rods?

It seemed from the drawings that all the softened and filtered water from the clear-water tank flowed to the high-lift pumps through the surface condensers, which he believed was not a usual plan for water works, or at any rate not on such a large scale; and he enquired how it was found to answer. Although probably it did not do any harm to the water, he wished to know whether it affected the taste at all: whether the water had a fishy taste or any peculiar flavour after it had been through. Was there any perceptible difference in the taste of the filtered water as compared with the unfiltered? The latter was no doubt extremely fresh and nice for drinking. Was there any analytical difference between the softened water when it went into the surface condensers, and when it came out? If there was any chemical change, he should like to ask what ingredients altered in passing through the surface condensers. Also what was the hardness of the water as it came from the well, and what after the softening?

For cleaning the deposit off the faces of the filtering discs he asked whether any arrangement had been tried of reversing the current, so as to lift the deposit off the surface of the filtering cloth, and so wash it away.

In estimating the duty of the engines (page 59), was it calculated upon the displacement of the pumps? or was an allowance made for their slip of 2·73 per cent.? So small an amount of slip showed that the pumps delivered very nearly the full quantity due to their displacement; and their duty was good, even if it was calculated on the displacement, while it was still better if it represented work absolutely done.

Mr. EDWARD PERRETT asked how long the filter cloths lasted. Also, when the washing took place from the outside, as shown in

Fig. 16, Plate 23, was not the fine deposit from the hard water washed inwards through the filter cloth, instead of simply being all washed off the outer surface? What means were there of replacing the cloths when worn away? had the whole of the filtering apparatus to be taken out, in order to put fresh cloths on?

Professor ALEXANDER B. W. KENNEDY, Vice-President, judging from the particulars given of the trials of the engines (page 59), thought that perhaps full justice had not been done to the engines. Taking the trial of engine A, the indicated horse-power was 115·55, and the horse-power actually obtained was 98·00. The latter he had been working out, and found it corresponded exactly, if his calculation was right, with the quantity of water given at the bottom of the table. Then the difference, or 17·55 horse-power, being expended in friction, the mechanical efficiency of the engine was given as 84·81 per cent. Obviously however the friction included all the friction of the water in the pipes, as well as the engine friction: so that, although it was right to put down the difference of 17·55 horse-power as expended in friction, it was hardly fair to say that the mechanical efficiency of the engine was only 84·81 per cent., because this was really the mechanical efficiency of the engine and of all the pipes to the reservoir, which latter might or might not be a considerable proportion. At any rate 84·81 per cent. was a somewhat low efficiency for the engine by itself, and it might quite well have a fairly high efficiency if the pipe friction were allowed for. He had himself been intending to ask almost the very question which Mr. Marten had already asked (page 64), as to how far the author was sure of the quantity of water raised, or whether this was ascertained only from the number of strokes of the pumps, allowing for a known percentage of slip.

Mr. SIDNEY STRAKER asked whether the standard of purity was maintained throughout the whole period of filtration. It appeared to him likely that the cloth would be more porous when the water first began to be filtered through it, and that, as the deposit of carbonate of lime gradually accumulated on its outside surface, the

(Mr. Sidney Straker.)

water after a certain period would percolate through more slowly than it did in the first instance when the cloth was clean and it could go through more rapidly. It seemed therefore that the standard of purity would be rather variable; but it was fair to presume that, the softening apparatus having now been in use for so long a time, it was found practicable to filter the water pure enough. Some years ago, when feed-water was softened by Clark's process, a good deal of trouble had been experienced in extracting the precipitated carbonate of lime from the water; and the present plan having proved really practicable appeared to him to be a solution of a complex question. The original idea he believed, for cleaning the filter cloth of the solid matter deposited upon it from the water, was to inject steam into the effluent pipe or hollow shaft, during the time that the spray of water from the small water-pipes between the discs was playing on the outside of the cloth, so that the steam might blow outwards through the cloth and prevent any of the deposit from getting driven into the inside of the filter. He should like to know whether that plan had ever been tried; and also whether an injection of air instead of steam had been tried, for counteracting the penetrating action which the impinging water would have upon the filter cloth. In a filter at work at the Barry Docks near Cardiff he believed that, in accordance with another scheme of Mr. Atkins, charcoal blocks were used, instead of cotton cloth; and he enquired whether they had been tried at Southampton. It appeared to him to be a matter of great importance to all connected with this class of engineering to be able to extract the softening agent or insoluble carbonate of lime, so as to enable the water so softened to be used for manufacturing purposes; and any plan by which this could really be done on a practical scale was certain to come largely into use.

Mr. CHARLES COCHRANE, Past-President, pointed out that bicarbonate of lime was itself soluble in water, and was what rendered the water hard; and by the addition of lime water, which was a highly diluted mixture of lime and water, the soluble bicarbonate was reduced to the insoluble monocarbonate. The latter being thus precipitated was then deposited upon the filter cloth, whereby the turbid softened water was rendered clear. This he believed to be the correct account of what took place in the softening and filtering process. In the case of water acting upon any of the limestone rocks, which were found in so many parts of this country, the air with its small dose of carbonic acid imparted a certain minute amount of carbonic acid to the rain-water; and it was only from the carbonic acid in the rain-water falling upon the outcrop of the chalk in the great London basin—and elsewhere when the chalk was covered only by porous beds of gravel or sand, instead of by impervious clay—that the insoluble monocarbonate of lime suspended in the water was enabled to take up the additional equivalent of carbonic acid and become converted into bicarbonate of lime, which being soluble was at once dissolved by the water and rendered it so hard. It was to expel this extra dose of carbonic acid, which had rendered the monocarbonate of lime soluble as bicarbonate, that the process of softening was carried out in the manner described in the paper. The object of calcining the chalk, by burning it in the kiln to expel the carbonic acid, was to enable the caustic lime so obtained to be used as a base for uniting itself with the extra dose of carbonic acid in the soluble bicarbonate, whereby the latter was reduced once more to the original chalk, or rather to chalk in the condition of chemically pure monocarbonate of lime, which was insoluble, and was thus precipitated in the softening process. It was vital to the softening process that the extra carbonic acid in the soluble bicarbonate should be got rid of for reducing it to the insoluble monocarbonate.

With respect to the wear of the filter cloth (page 64), he enquired whether it might not be the case that its destruction was largely accelerated by the presence of sulphate of iron in the water, derived from iron pyrites occurring in the chalk.

With regard to the taste, he was himself able to answer Mr. Marten's question (page 64), because he had tasted the water as it came from the tank, and found it delicious. There was nothing disagreeable at all, not so much as a flavour of any kind that could be objected to. It seemed to him surprising that other towns had not adopted the same process, for it had been a revelation to

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(Mr. Charles Cochrane.)

himself to visit these works at Southampton and to see the result produced by the softening process. All who had had any experience of the water in the south of England—at Brighton and Folkestone, for example—where the water was supplied from the chalk, must have found it so hard as to be really most disagreeable to use for washing in. The excellent example set by Southampton in this matter was one which he hoped would soon be copied more generally.

Mr. WILLIAM SCHÖNHEYDER noticed that in the description of the fly-wheel shaft (page 56) it was stated that the journal in the outer plummer-block was 9½ inches diameter, whereas in the inner it was 12½ inches diameter. As a rule he thought it was well to make the outer journal the same diameter or thereabouts as the inner, not for mere strength but in order to carry the weight of the fly-wheel, and to work without getting hot. The fly-wheel bearing differed from a crank-shaft bearing; the load on the former being always downwards, the oil had less chance of getting in than in a crank-shaft bearing, where the journal was lifted up and pressed down alternately. In several cases of that kind he had known bearings get hot on account of insufficient bearing surface; and he enquired whether anything of the sort had occurred in these engines, and what was the weight of the fly-wheel.

The whipping of long pump-rods he had seen frequently; but he did not agree with the remedy which had been applied, of adding rollers to stop it (page 57). There were two sets of rollers on each rod, three to each set; and as the rollers themselves turned on their pins, there were altogether six bearings working in water quite out of sight, which seemed to him an undesirable arrangement. They might go all right for a long time, but might suddenly go wrong and take to grinding and cutting the pins through; and if a roller were to drop down the pump it would be a serious matter. A much simpler plan, and one commonly adopted, was to provide a guiding cylinder, connected by arms to the pump-rod, and keyed or fastened upon it to work up and down inside the pipe; the inside of the pipe need not be bored; and if sufficient clearance were allowed, both the guiding cylinder and the pipe would last for a long time. The plan was simplicity itself, and nothing could go wrong; he should himself much prefer it to rollers.

These engines having been erected so recently, he was rather surprised to find that the steam-pressure was not higher than 60 lbs. per square inch. As they were compound engines, he thought it would have been more economical to have 70 or 80 lbs. pressure, or perhaps even more. The works being situated so far out of Southampton, it seemed to him there would have been plenty of space for the hard-water delivery pipe from the low-lift pumps to the softening apparatus to be laid round the outside of the building. For although a symmetrical arrangement was obtained by carrying it along beneath the centre line of the building, yet the cost of building the tunnel over it and of getting at the pipe at any subsequent time must be something considerable. If it had gone round outside the building, much expense might have been saved in that way, and might have been better employed in jacketing the intermediate receivers and any other parts which were not jacketed in the engines.

Mr. ROBERT B. BUCKLEY, having been engaged as an engineer in India, said that until recently the construction of water works in that country had hardly been undertaken. There had been water works in Calcutta and Bombay for many years past; but throughout India generally he thought that ten years ago there were no water works at all. Now however a great advance was being made; water works were being constructed in many of the large towns, and in the course of the next few years there was no doubt that they would be largely increased in number. One of the great difficulties to be dealt with in India arose from the fact that the rivers from which the water supply was generally drawn, although very clear indeed for eight or nine months of the year, became most densely charged during the floods or rainy season with extremely fine muddy matter in suspension. So much was this the case that at the Calcutta water works enormous settling tanks had to be used for enabling the supply to be maintained at all at such times. For about a fortnight

(Mr. Robert B. Buckley.)

at the worst time, at the end of August, the water was allowed to settle in these tanks for four or five days, and was then run through ordinary sand-filters. At times the greatest difficulty was found in keeping up the supply at all. For although the water was allowed to settle for so long as four or five days, the filters nevertheless became completely choked in the course of a few days; they became indeed so absolutely water-tight that they had to be run dry, and their surface had to be scraped off, before any more water could be got through at all. The difficulty it was true lasted only for a short time; but it added of course to the cost of the water works that such large settling tanks and such large filtering power had to be provided for meeting this occasional difficulty. He asked therefore whether it would be possible for the method of filtering described in the paper to be employed for clearing those Indian waters of the extremely soft and fine mud which they held in suspension; and whether any idea at all could be given of what the cost would be, say per thousand gallons discharged a day; or any data for determining whether these filters would be more economical than the large settling tanks and sand filters now used.

As to the cost of pumping, which was given at 0·634 penny per thousand gallons (page 58), he asked what was the height of lift of that quantity of water, and also what was the price of the coal. Both of these were factors which entered largely into the cost of the work done.

Mr. CHARLES E. COWPER asked how long the filter cloths would run without cleaning; and also the length of time that they would last before having to be replaced. If it could further be stated what was generally the cost of filtering on the plan described in the paper, this information would be of value.

Mr. JEREMIAH HEAD, Past-President, as one of those who had enjoyed the opportunity of visiting the water works at Southampton last summer, was glad to express his own high appreciation of the establishment as a whole. It seemed to him to be excellently laid out and constructed, and a great credit to all those who had had to do with it. In the importance of the filtering arrangement he quite agreed with what had been said by Mr. Cochrane (page 68). The time was certainly more and more nearly approaching when in this country and in all densely populated countries it would be necessary to use every water-supply that could be got from anywhere, for the benefit of the increasing populations. A large quantity of the available water-supply came from limestone districts, and was consequently hard, being charged with bicarbonate of lime in solution in the way that had been described (page 67). It was to such water that the softening process used at Southampton was peculiarly applicable. There were also other waters which were hard from containing in solution sulphate of lime or gypsum. Those were the waters which were so much appreciated by brewers; and the existence of the great breweries at Burton-on-Trent was said to be due to the circumstance that the water procured from the wells there was charged with sulphate of lime. The lime process however, described in the paper, would not be applicable he thought to softening that kind of hard water. As employed at Southampton it seemed to be admirably applicable; and of course its great virtue lay in its compactness. Although the Southampton water works were well outside the town, the land they occupied had no doubt to be paid for; and it was therefore desirable for all the operations to be performed in as small a compass as possible. There were many other places where even so much space would not be available as at Southampton, and where with the same kind of water the softening process would be not less acceptable, especially if it could be carried out in a comparatively small space and for so small a charge as at Southampton. The compactness of the softening arrangements appeared to himself therefore to be a highly important feature of the process.

In the trials of the engines (page 59) he noticed that the coal consumed was in one 1,757 lbs. and in the other 1,750 lbs., while the ashes made were only 14 lbs. and 15 lbs. respectively, or considerably less than 1 per cent., including clinkers he presumed. The coal must therefore have been of remarkably good quality; in fact almost too good to allow of forming an approximate idea of what might be expected if ordinary coal were used.

(Mr. Jeremiah Head.)

In these pumping engines he did not quite understand why massive cast-iron beams had been adhered to, and why they should not have been made of steel, either as steel castings, which were now turned out on so large a scale, or of steel plates built up. Steel beams would certainly be much safer than those made of cast-iron. It was true the latter did not often break; but all would remember the fatal accident at the Hartley Colliery in Northumberland (Proceedings 1863, page 265), caused entirely by a cast-iron beam breaking in two, and one end of it falling down the pit, producing so terrible a disaster. Considering that the difference in cost was so little, inasmuch as the steel beams might be made so much lighter, he could scarcely understand why the risk, which at all events did still attend the use of cast-iron beams, should not be eliminated by making them either of steel castings or of steel plates built up.

Mr. HENRY J. COLES had had some experience in the construction and working of the class of cloth filters described in the paper. Dr. Clark's process for softening hard water, of which there was a good example at the Herbert Hospital, Woolwich, was the fore-runner of all attempts to attain this object. The cloth filters had been introduced in order to do away with the large amount of ground area occupied for filtering on Dr. Clark's original plan; but there was this difference between the two, that whereas in the Clark method of filtering, although a large area was occupied and the work of moving the stirrers was rather heavy, yet the most ignorant class of labourers sufficed for it, so long as they were given the right quantity of lime to use. In these cloth filters there was no doubt that the cloth made a good and handy filtering medium; but the plan of putting it on discs, as was done at Southampton, did not appear to him to be the best. The discs, when they were being put together again after they had been taken apart, had all to be threaded on one spindle; and there was often a difficulty in making the joints water-tight: so that it was apt to be found afterwards, unless experienced labour had been employed, that there was one joint defective, and the whole had to be taken to pieces again. Another objection was that often the chains or slings used for putting the discs into their places in the filtering tank would scratch a piece of the cloth; and the whole had then to be taken out for replacing the damaged cloth. Another feature that he thought engineers did not generally approve of was the large stuffing-box, in which the disc-shaft had to revolve every time the discs were cleaned. The method of cleaning by the use of the water spray was no doubt a distinct advance, because by its adoption all necessity for the use of mechanical power for cleansing a suitably designed filter was entirely obviated. The earlier designs of filters had been made with bristle brushes and india-rubber brushes, with the result that, though the outer portion of the coating of deposit was removed, the inner portion was rubbed more thoroughly into the cloth. In the design of the filter it was highly advisable to have each disc or filtering bag entirely independent of the others, so that it could be removed without in any way affecting the action of the rest of the filter, and therefore any defect in one part would not necessitate total dismantling. For small installations a good plan he thought was to have a plain oblong linen bag placed inside a thin perforated metal envelope, dropping into a tank as many of these as might be needed. Being oblong they fitted into an oblong or square tank, and offered more filtering surface than a circular bag or disc. For jointing the bags to the hard-water supply, all that had to be done was to have a cap over each bag, and let the hard water trickle through it into the bag; then for the process of cleaning or for repairs it was necessary only to remove one at a time of these bags with its envelope, which must be stiff enough to support the bag. By simply removing the bag to be cleaned and replacing it by a fresh one, the cleaning could be carried on without interrupting the filtering operation. Moreover when the bag was taken out it had simply to be turned inside out and washed, and was then ready to be replaced; there was no trouble about by-passes, or sediment in the bottom of the filter tank, because into the tank itself nothing but filtered water flowed; all the sediment was intercepted inside the bags. For large installations the cloth should be outside the metal frames, and the water spray so arranged that it would sweep the whole surface of the cloth. Each of the filtering bags should be entirely independent of

(Mr. Henry J. Coles.)

its fellows, so that it could be removed for repairs, and if desired another be substituted without stopping the action of the filter. On this plan filters could be made of any capacity, the labour of cleansing being only equal to that of cleansing those described in the paper, and the use of mechanical power for rotating the discs being entirely obviated. The filtration of the turbid softened water was necessary not merely for the sake of clearness, but also on account of the chemical action mentioned by Mr. Cochrane (page 67); for if cream of lime was simply put into an open tank with hard water and the precipitated carbonate of lime was allowed to settle to the bottom without being removed by filtration, and the water was left exposed to the atmosphere, it would absorb a certain amount of carbonic acid, and after a time the water would become hard again. As to the reason why the Clark process of softening had not been more largely adopted, he believed that about thirty years ago some of the water companies tried it on an extensive scale; and he understood that some of the largest companies were quite prepared now to adopt it, if some good mode could be suggested for getting rid of the carbonate of lime taken out of the filter, without having to pay for cartage. Various attempts had been made to attach a commercial value to the precipitate: it made good tooth-powder, and had also been used as a vehicle for absorbing disinfecting acids; but the cost of drying it was too great, and, even had it been otherwise, the demand was too small to dispose of the large quantities of precipitate which would accumulate. Doubtless however, could any method of using it be devised to cover the cost of its removal, many large corporations would be prepared to adopt water softening.

Mr. John Barr, being unable to attend the meeting, wrote that he had enjoyed the privilege of seeing these engines at work on occasion of the visit to Southampton in July last. The bucket and suction valves of the low-lift pumps he noticed were stated (page 57) to consist of double india-rubber valves working against cast-iron guards and grids; was there no trouble from corrosion of the grids and guards? Did the level of the water in the well vary much? if so, did not this give the engine more work to do on the low-lift side than on the high-lift or delivery side, and tend to throw the engine out of balance? What arrangements were made for keeping the air-vessels charged with air?

The buckets of the low-lift pumps were stated to be of cast-iron and water-grooved, but without packing or rings. Had it been ascertained whether these grooves served any good purpose? or did they act as receptacles for grit? In experiments made by himself some time ago at the Glenfield Works, Kilmarnock, to test the effect of grooving a solid brass piston which was made a good working fit in a mandril-drawn brass tube of $1\frac{1}{4}$ inch bore, the leakage in half an hour under a head of 150 feet of water was as follows:—

Solid piston without grooves			2·22 lbs.
Same piston with two grooves			5·72 lbs.
Do.	with two gutta-percha rings slack in grooves		4·41 lbs.
Do.	do.	tight in grooves	None

How many pounds of water were evaporated in the Lancashire boilers per pound of Welsh coal? and in actual daily work what was the coal consumption per indicated horse-power and the efficiency of the engines?

Mr. EDWARD M. EATON, Engineer of the Sheffield Water Works, wrote that it would be of much interest if the author could give the total cost of lifting a thousand gallons of water through a hundred feet height by the Cornish and rotative engines respectively at the Mansbridge works. The difference in coal was 0·2 lb. per I.H.P. per hour in favour of the Cornish engines; was this balanced or more than balanced by the saving in attendance &c. on the rotative engines? It was not often that both kinds of engines were at the same place and doing the same work.

Mr. E. H. G. BREWSTER remembered that some years ago the late Mr. Robert Briggs, a well-known American engineer—who had made trials extending over some period of water packing for the pistons of pumps, the pistons having a number of grooves turned in them—had stated that, although the arrangement was effective, there was a considerable amount of friction in connection with its use, and he did not employ it on that account.

The PRESIDENT thought that, with respect to surface condensers giving a taste to the water (page 64), experience showed they did not do so. Indeed even when the contents of the hot-well in engines with jet condensers were discharged into the water, they did not give any taste to it, unless the users happened to know that it had been so treated. He had done this twice himself, and knew of two towns in which it was still done; but he would not mention their names, because if it once got abroad the inhabitants would immediately fancy that the water tasted of oil. The quantity was relatively so small that he thought it could not produce any effect whatever upon the water.

The class of engine that had been adopted for the pumping station at Otterbourne was one of which he could not too strongly express his approbation, including the low pressure in the boilers. From considerable experience he believed there was nothing like a good heavy slow-running beam-engine to work regularly and steadily year after year, requiring scarcely any repairs. This, after all, was one of the most important considerations in the water supply of a town. The tendency now-a-days, he thought, was pretty nearly universal to adopt fast-running engines working at high pressures; but the repairs he was certain would prove heavier than those of engines of the older kind working with about 60 lbs. pressure of steam. These slow engines he had known to run for eight or ten years or longer without any general overhaul; an occasional adjustment of the brasses had been quite sufficient to keep them in perfect order. The use of cast-iron beams, referred to by Mr. Head (page 72), was certainly advantageous in view of the circumstance that the weight of a beam was an element in the smooth running of an engine. The momentum of the beam and of the other moving parts in an engine working expansively was an important factor in getting the engine to work smoothly: the excessive pressure in the cylinder at the beginning of the stroke was taken up in getting the beam into motion; and when the pressure diminished towards the end of the stroke, the inertia of the beam helped the forward movement, and produced smoothness of running, which could not be got in light engines. Having himself made engines with beams of steel plate as light as they could be made, he had never found them run so smoothly and so well as engines made with heavier cast-iron beams. Although of course it must be admitted that cast-iron was liable to serious internal stresses, which might render an engine beam of that material liable to break, he could not recall a single instance of a pumping engine in which an accident of that kind had happened, except the one alluded to by Mr. Head (page 72). No doubt other such accidents had happened, but he did not know of them.

With regard to the turbid water of the floods in Indian rivers (page 69), settling ponds were hardly necessary, if at the periods mentioned by Mr. Buckley the water were treated with iron, either on Bischof's plan, or on the plan which he had himself introduced, at Agra for example, where the water was passed through a revolving cylinder, in which it was made to mix with iron in a state of scrap, of punchings or borings. Iron had an extraordinary effect upon water; it seemed to be a sort of coagulating effect. The sediment in the Indian water, which was so exceedingly fine that it could scarcely be filtered out absolutely clear without leaving some opalescence, appeared to curdle together, much as isinglass made brewers' liquors clear or as white of egg clarified a jelly. When so treated, the water filtered easily through a few inches of sand, and the filtering could go on for a long time without cleaning the filter, chiefly because the sediment deposited on its surface was in a much coarser state, not so slimy as when it was attempted to filter the water in its natural state, before treating it with iron. The water of the Nile, for example, in which the sediment would not subside in any reasonable time, certainly could not be filtered by any sand filter; and though it could be filtered by porous earthenware, yet that was an extremely slow process and impracticable on a large scale. If however it were kept in contact with iron for three minutes, it would filter absolutely clear through an ordinary sand-filter with only about three inches thickness of sand. When there was dirt in the water, it must of course be removed; and whether settling ponds or filter beds were used, the dirt must be scraped out of them or off them.

(The President.)

It was rather singular that the application of Dr. Clark's process of softening by the addition of lime to hard water, though it had been known for so many years, had not been more generally adopted for existing waterworks. One of those which were still behindhand in this respect was the Kent works, whose water he had the misfortune to be obliged to use. Their wells were in the chalk, and they could get a supply of lime with the greatest possible ease and economy. The cost was so small that it was surprising they did not set about softening the water for the benefit of their large area of customers. Indeed it seemed a wonder that any waterworks deriving their supply from the chalk were not compelled by law to soften their water, in order to make it fit for domestic use. No doubt the author had studied this subject with a view to deciding which plan of treatment after softening should be adopted: whether the system of having extensive settling ponds or reservoirs, or the process of separating the sediment mechanically; and which of the two would come out the cheaper in capital outlay. The one carried out at Southampton required machinery, but only a certain small extent of tank or reservoir accommodation; in the other, which had been successfully in use at Croydon for many years past, the whole clarification was done by allowing the sediment to settle in large tanks.

Mr. MATTHEWS, in reply to the enquiries (pages 63 and 70) as to the lift of the pumps, said that at the trials the total lift of the high-lift pumps was about 160 feet, and of the low-lift pumps about 58 feet. With regard to the hardness of the well water (page 64), the pumping had now been continued for 3½ years without any difference having been found in the hardness of the water. Originally it had about 18 degrees of hardness, when drawn from the trial borings, and it was practically the same now: each degree corresponding with one grain of carbonate of lime in one gallon of water, or 1-70,000th part by weight. At some stations it had been found that after a while the hardness had become slightly reduced; but it was not so at Otterbourne. The boring of the two wells (page 63) had been described in a paper he had read before the Institution of Civil Engineers (Proceedings 1887, vol. xc, page 33);

they were 6 feet diameter, and were both of them bored out in a single operation without the intervention of any pumping. Originally the intention had been not to line the borings at all, as it had been thought the chalk would be sufficiently hard to stand; but that had been found not to be the case, and they had afterwards been lined with perforated steel tubes.

By the whipping of the bucket rods (page 64) he wished to express the fact that in the low-lift pumps, when the water was at its lowest in the well, and there was such a long length of suction to pump through, the rods being rather light were so elastic that originally they vibrated laterally to a considerable extent, though not enough to touch the sides of the pipe, and the keys were not knocked out. Apparently the rods had also a tendency to twist, corkscrew fashion, at the same time. The guiding rollers subsequently added had been carefully designed and strongly made, with a view to preventing any risk of their going wrong (page 68).

The question of the taste of the water (page 64) had already been dealt with by the President (page 76) and Mr. Cochrane (page 67). No difficulty had been experienced in regard to the taste of the water from its being passed through the surface condensers. As to the chemical difference in the water before and after softening, an analysis made by Dr. Frankland showed that in 100,000 parts the ammonia was 0·005 before and 0·004 after softening; the nitrogen, contained in nitrates and nitrites, was 0·365 before and 0·381 after; total combined nitrogen 0·381 before and 0·397 after softening; chlorine 1·6 in both cases. So that there was practically no difference between the water before and after softening, beyond the all-important difference that the carbonate of lime had been reduced from 23·93 in the well water to 5·67 in the softened water, whereby the hardness of the water had been reduced from 18 degrees to only 6. It was possible indeed to reduce the hardness still lower, down to only 4 or 3 degrees; but the water then became flat and insipid, and was not much appreciated in a non-manufacturing town like Southampton.

The duty of the engines had been calculated (page 64) not from the theoretical displacement of the pumps, but from their

(Mr. Matthews.)

actual displacement obtained by deducting their ascertained slip *of 2·73 per cent.*

The duration of the cotton filter-cloths (page 64) had been rather variable; and it had been a long time before sufficient experience had been gained to know how it was that at some times the cloths wore out quickly, while at other times they lasted as long as seven or eight months. Their quicker wear could hardly be due to the presence of sulphate of iron in the water (page 67), as but one small nodule of iron pyrites had ever been found in the chalk quarry. Eventually, almost by accident, the reason was discovered. It so happened that at a time when there was a great deal of trouble with the cloths it became necessary to start driving the headings again, in order to obtain a greater yield of water. In the process of driving, a large quantity of chalk from the lowest depths was brought up to surface, and instead of being thrown away it was taken to the kilns, and when softening was resumed after completing the headings it was burnt into quicklime; and it was found that the best result with the cloths was during the time that this chalk from the headings was being used. On further investigation it was found that the reason was nothing but the absolute purity of the chalk obtained from those lower depths. Since then no more lime had been burnt from the upper layers of chalk, which were somewhat stained with infiltration of clay from the surface; and much better results had been obtained with the filter cloths than before. The earlier filters put up on this plan had been arranged, as had been mentioned (page 73), for cleaning off by brushes the sediment deposited on the filter cloth; and there had also been a scheme for injecting water at high pressure into the interior of the disc shaft, so that it might pass out through the perforated zinc and the filter cloth, producing an outward flow with the object of washing off the deposit in that way. But the effect of the outward current was found to be seriously to distress the cloth by lifting it off the zinc disc; it became extended, and its elasticity was so far destroyed that it never returned to its original condition; the pores were much opened, and its efficiency as a filtering medium was absolutely ruined. Later on it was found by

Mr. Atkins that steaming the filters (page 66) was a good plan; and now, instead of injecting water into the apparatus, the pipes and valves were utilized for injecting live steam from the boiler at times, giving the cloths a thoroughly good boiling. It was found that a certain proportion of the deposit did get worked into the cloth, and was held there so firmly that no amount of water spray applied externally would get rid of it; but by passing live steam through from the inside at only 5 or 6 lbs. pressure per square inch the deposit which had been arrested in the pores of the cloth got driven out, giving the cloth a much longer duration. With proper usage he thought the life of a cloth might be safely taken to be from five and a half to six months. When it was necessary to renew the cloths (page 65), the hollow shaft with the twenty discs attached could be lifted out bodily by means of the overhead traveller, and the spare shaft and discs, which were always kept prepared in readiness, could be put in its place; the whole operation took less than an hour, and with proper lifting tackle, such as was used at these works, no possible damage such as had been suggested (page 72–3) could be done to the cloths. As to whether the filtering was more rapid and efficient at first than it was at a later period of the operation (page 65–6), that was true to a certain extent; but the efficiency of the filtering did not depend absolutely upon the cloth. Indeed it was not considered that the cloth itself really filtered the water at all; it simply acted as a framework, upon which the small crystals of carbonate of lime were deposited; and when they had collected upon it, they themselves acted as the filtering medium for the water that came afterwards. After the filters had been cleansed, some of the carbonate of lime, as had been suggested (page 65), got washed inside the discs; and when the unfiltered water was first turned on to the cloths, some of it would pass through them without undergoing filtration, until there was built up on the outside the first collection of crystals of carbonate of lime. There was an arrangement of valves and pipes, whereby, for about a minute or a minute and a half after the unfiltered water had been turned into the filtering tank, the water which first passed through the filter did not go into the softened-water tank but into the waste pit, until there was a sufficient

(Mr. Matthews.)

deposit of carbonate of lime on the outside of the cloth to make a perfect filtering medium. The softened water drawn from the filters was thus obtained of equal purity during the whole time. The only variation was in the quantity; the quality did not vary, but the quantity passing through the filters was perpetually varying. There was the same head of water constantly maintained on the filters. After a while there was of course a larger deposit of carbonate of lime on the faces of the discs; and then the filter began to discharge water into the softened-water tank much less quickly than it did at the start. The orders given to the attendant were that when a filter had collected a certain amount of deposit it must be cleansed; and he had to keep the water up to the same height in the filter tank, just as over filter beds the water had to be kept to the same head. If the filters were allowed to go too long, till the cloths got clogged, the flow of water would be entirely suspended. But of course it would be understood that in practice the filters were cleansed in rotation, without waiting till the cloths got clogged. According as they had been a longer or shorter time in use, the attendant was soon able to judge as to the time when the filters should be cleansed. When the cloths were new they would go on an average about nine hours without cleaning; later on, when they had about lasted their time, they would only go about six hours. Carbon blocks (page 66) had never been tried at Southampton, where there had never been any other arrangement than that of filter-cloths; he had heard of carbon blocks having been tried in some places, but he did not know how they had acted.

The outer bearing of the fly-wheel shaft (page 68) had given no trouble whatever. The inner bearing, nearest the crank, which was the larger of the two, had done so. It would be noticed that, owing to the character of the foundations, although the inner bearing nearest the crank was on brickwork, lower down the brickwork had to be supported on a short girder in order to make room for the pump; and that girder had apparently taken a little permanent set, and let the plummer-block down a little, and the crank-pin ran a little warm; the plummer-block had to be packed up with a steel liner 1-32nd inch thick, and after that had been done the brass did not heat. With that exception there had been no trouble at all with the bearings. The weight of the fly-wheels was ten tons each, and for the size of the engines they were comparatively light. Even if the whole weight came upon the outer bearing, which it did not, the pressure per square inch would be only 182 lbs.

As to the reason for adopting only 60 lbs. pressure of steam (page 69), the President, who had had so much more experience than himself, had already given a sufficient reply (page 76). These were slow-moving engines; and engineers who had had to do with pumping water for many years would admit that a slow-moving engine with a long stroke was much better and easier to deal with from year's end to year's end than a fast-running engine. The engines at Otterbourne had now been going about three years and a half, and practically not a farthing had been expended in repairs. There had been no replacing of any single portion up to the present time, except the india-rubber suction and air-pump valves. No metal work had had to be touched, nor did it seem likely to require any touching for a considerably longer time.

The well-water pipe from the low-lift pumps to the softening works was purposely laid under the centre of the building (page 69), because in that position it led away symmetrically from the two low-lift pumps; and moreover an arrangement had to be made as shown in Plate 13, just under the repairing shop, for getting by-passes into the two softened-water pipes leading to the high-lift pumps: so that, if in any emergency the softening works had to be put out of gear, the hard water could be pumped round from the low-lift pumps direct to the high-lift. It was a mere matter of arrangement. The tunnel was of course somewhat expensive in the first instance; but the pipe laid in it could always be got at, and in case of building another engine-house, already contemplated, there would be no difficulty arising from mains being in the way.

In regard to dealing with muddy water like that in Indian rivers in time of flood (page 69), there had on one occasion been an opportunity of practically testing whether the Otterbourne works would deal with muddy water. In extending some of the headings at the bottom of the wells, it became a question whether temporary

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pumps should be put down, and the water be shut off which would be rendered turbid by the men working in the headings; or whether the turbid water should be pumped up and passed through the filters, the softening apparatus being suspended for the time. The latter plan was tried; but after the explanation he had already given as to how the crystals of carbonate of lime acted in forming a filtering material, it would be understood that the chalk, in the amorphous condition to which it had been reduced by being trampled upon in the headings, was not in a similar crystalline condition, but in the condition of mud in a river; it therefore collected on the faces of the filtering discs at once, and in half an hour they were so completely blocked up that nothing could be done with them until the mud was washed off. For filtering muddy water therefore it was evident that to keep washing the filters every half hour would be rather too much of an undertaking; and not only so, but there would be a considerable expenditure of water for washing. A scheme he believed was being worked out by Mr. Atkins, whereby the filter cloth was arranged in such a way as to be constantly moving over rollers, so that in some fashion it could be used continuously for filtering and at the same time could be washed continuously. No doubt if that was possible it would be found practicable to accomplish it; and then there would be no reason why the cloth should not form a filtering material for muddy water, if it could be cleansed almost immediately.

In regard to the application of the softening process to other water than chalk water (page 71), the most noticeable instance in which it had been so used was at Wellingborough in Northamptonshire, where it was employed for softening extremely hard water, having about 37 degrees of hardness, and highly impregnated with iron. The only question in a case like that was the quantity of lime to be used; and in that instance not only was the hardness removed that was due to the bicarbonate of lime dissolved in the water, but the iron with which the water was also impregnated was thrown down with the lime, and the water was rendered beautifully clear. The sulphates (page 71) were not removed in that case, for the simple reason that the attempt to remove them would have involved the necessity of going beyond the use of lime, and using other chemicals which were afterwards objectionable in the water for domestic purposes. If the water were going to be used only for feeding boilers or for certain manufacturing purposes, there was no reason why the sulphates should not be thrown down by the use of caustic soda or some other re-agent, the water being afterwards filtered in the same way as at present; but whether that would have any injurious effect on the filter cloth, he was not prepared to say.

The cost of softening generally at other similar works (page 70) varied from 0·79 penny per thousand gallons at Wellingborough, where the water had 37 degrees of hardness, to 0·34 penny at Henley-on-Thames, where the hardness was 21½ degrees.

The total space actually occupied by the softening works (page 71), exclusive of the pumping works, was only 1,150 square yards. As had been remarked (page 69), the Otterbourne works were situated at a distance of about eight miles from Southampton, so that the question of an acre or two more of land was not of much importance. But although plenty of land had been obtained all round the works, there was no reason to extend them. They had been laid out on a sufficiently large scale for enabling every part to be got at conveniently; but there was really no reason why the space occupied should not have been even a little less ample than it was, if it had been necessary for the works to be got into a more confined area.

The alleged difficulty in making the joints water-tight (page 72), between the filtering discs and the intervening collars threaded upon the hollow disc-shaft, was entirely a question of whether the work had been properly executed in the first instance. If the collars were turned as well as they ought to be, so as to have good true faces, they should be perfectly interchangeable, and there should be no risk of any difficulty arising from getting a wrong collar in a wrong position between the discs. That was entirely a mechanical point, dependent upon having the work done as it ought to be. At Otterbourne no difficulty at all had been experienced in that respect. The practice was to put between each collar and disc a piece of filter cloth, which at first had always been coated with paraffin wax; but it had

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since been found that there was no occasion for any waxing whatever. When a plain piece of cloth was put in between, in less than half a minute there was a sufficient collection of carbonate of lime over it to make as water-tight a joint as could be wished. Nor had there been any trouble with the stuffing-box (page 73), through which the disc-shaft came out at the front end of the filter tank, so as to allow the shaft to revolve. Good care had been taken in designing the stuffing-boxes that they should be of a suitable construction; and they had not given any trouble at all. Some of the earlier works of this kind he believed had been put up probably a little cheaper than they ought to have been; and any of the difficulties which had occurred with them had probably arisen from that cause. But with proper attention to the mechanical details he was convinced there need not be any difficulty whatever. From his own experience he should be sorry to attempt to deal with anything like 2 or 2½ million gallons of water per day by filtering it through the bag and envelope arrangement suggested (page 73). With an apparatus of that kind, of anything like a reasonable size for such requirements, he had not had the opportunity of calculating how many bags would be required of a size that could be handled satisfactorily by one man; but it might readily be understood that the manual labour involved in actually taking the bags out for the purpose of washing them, and then putting them in place again, would be something enormous. It was practically labour of that very kind which had proved fatal to Mr. Porter's original plan; in his method there had been at first really the same arrangement of using filter cloths upon fixed frames, which were put in a trough and had to be removed by hand labour. Another arrangement had now been substituted, because it had been found that the labour involved in so dealing with large quantities of water precluded the original plan from being used.

The disposal of the waste deposit from the filters was of course a serious question (page 74); and no doubt the softening process would be adopted much more extensively, if a market for the waste could be found. At Otterbourne all sorts of directions had been tried; but at present he was sorry to say it was still necessary to discharge as waste, into an old quarry which had been acquired, what possibly might, if a proper use could be found for it, prove to be a valuable by-product. A quantity of it had been offered to the cement makers to experiment upon, in order that they might see whether it was not a material which was practically in a form almost ready for their use; but unfortunately they seemed to hesitate even to give it a fair trial.

The PRESIDENT supposed it could not be converted into lime again by burning in a kiln.

Mr. MATTHEWS said that unfortunately it was in a state in which it was difficult to deal with; it was so dense and heavy that it would almost want moulding into blocks, so as to be able to keep the kiln open and get the draught through it. In the state in which it came from the filters it was found that it killed the kilns altogether.

In reply to Mr. Eaton's enquiry (page 75) about the relative cost of pumping by the two pairs of engines at the old Mansbridge works, the lift was identical and the attendance was identical in both. They both lifted 200 feet, and there was one attendant required in each engine-house: so that the difference in cost of pumping could be almost exactly calculated from the total quantity of water pumped per day and the coal consumption, as given in the paper.

There had been no trouble from corrosion of the grids and guards of the suction valves (page 74). Although they were made of cast-iron, it was found that with the hard water from the wells all the iron work after a short time became coated with a fine enamel, almost as good as a white enamel; and there had been no trouble from corrosion of any sort.

The level of the water in the wells (pages 63 and 74) varied of course considerably with the pumping; and after pumping say twenty-four hours from starting, the water would be 35 or 40 feet lower in the wells and headings. The engines would certainly be somewhat out of balance when pumping from any other level than the normal for which they were designed; but the variation of level was small, probably not more than five feet either way, inasmuch as

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pumping was continuous day and night, including Sundays. There was an air-charging arrangement of the usual kind for charging the two air-vessels, which was worked off the same cross-head and rods that actuated the air-pump.

With the water-grooves in the buckets of the low-lift pumps there had not been any trouble (page 75); and the double-acting plungers of the high-lift pumps were also grooved upon the same plan. The grooves were semicircular, 5-16ths inch diameter and 6 inches apart. In arranging what kind of packing to adopt, it was necessary to have regard to the nature of the water that was being dealt with. If it were sandy water, and there were any liability of bringing up sand with it, the use of water-grooves would probably be out of the question, as the sand would score the working barrels all to pieces. But the pumps had already been drawn two or three times, and the barrels showed hardly any sign of wear at all at present. What was the amount of friction due to the water-grooves he did not know; but judging from the comparatively high efficiency of the engines generally, he thought the friction could not be anything considerable. The leakage or slip of the pumps altogether was only 2·73 per cent. in the trials, as actually measured by pumping into the reservoir with the outlet closed.

The suction bucket in the low-lift pumps (page 63) was situated down at the bottom of the well, as close as it could be got to the foot-valve, so that at the very beginning of the pumping stroke there was only just sufficient clearance above the foot-valve. The plunger portion of the low-lift pumps was higher up, at the top of the well; and the bucket was hung from the plunger by the long rod which was steadied by the roller guides.

In the trials of the engines (page 59) the coal used (page 71) was Nixon's Navigation, hand picked; and great care had been taken in stoking and in working generally, in order to obtain the best possible result. In regard to the efficiency of the engines in every-day work and the water evaporated and the coal consumption (page 75), with coal from the Powell Duffryn Colliery the consumption in ordinary work was about $2\frac{1}{4}$ lbs. per hour per actual horse-power in the water lifted, the slip of the pumps being from 4 to 5 per cent.

The engine efficiency was about 82 per cent.; while the consumption of feed-water per hour was $21\frac{3}{4}$ lbs. per actual horse-power, or $17\frac{1}{2}$ lbs. per indicated horse-power.

In reply to the question asked by the President (page 78) as to the capital outlay required for the two processes of filtering—by settling ponds or reservoirs, or by mechanical filtration,—the relative cost had been worked out at the time when it was being decided what kind of arrangement should be adopted at the Otterbourne works. The first cost of the original Clark process with settling ponds, which was adopted at Croydon, would have been about £3,000 more than of the present mechanical filters at Otterbourne, exclusive of the cost of the extra land required for the large settling ponds.

The PRESIDENT was sure the members would wish to accord a hearty vote of thanks to Mr. Matthews, first, for having been so good in showing them all over the works when they visited Otterbourne last summer, when many of those present had been so glad to take advantage of his kindness; secondly, for the paper which he had prepared for their information; and last, but not least, for the complete manner in which he had answered all the questions put to him in the discussion.

SOUTHAMPTON WATER WORKS.

Plate 12.

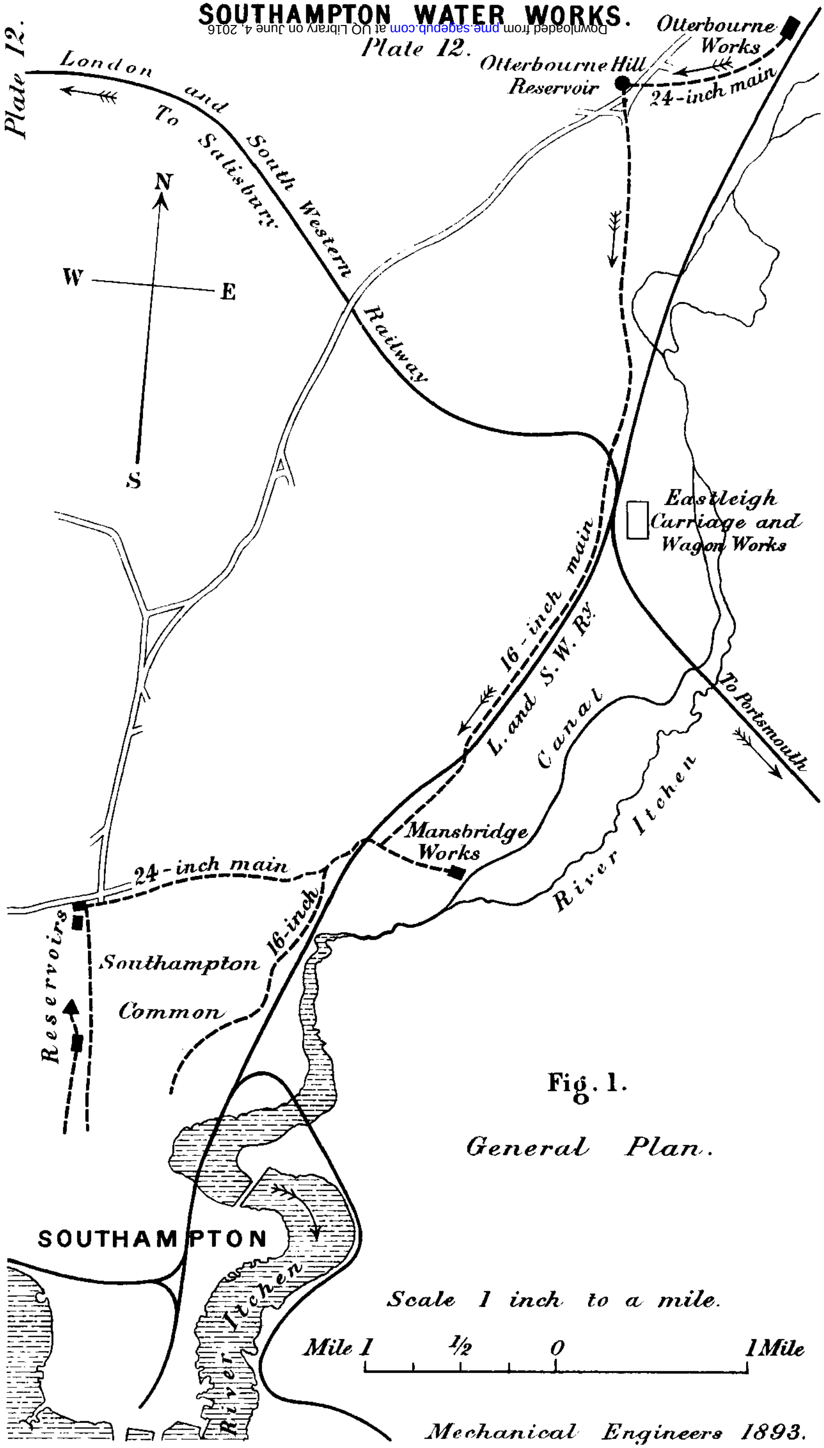


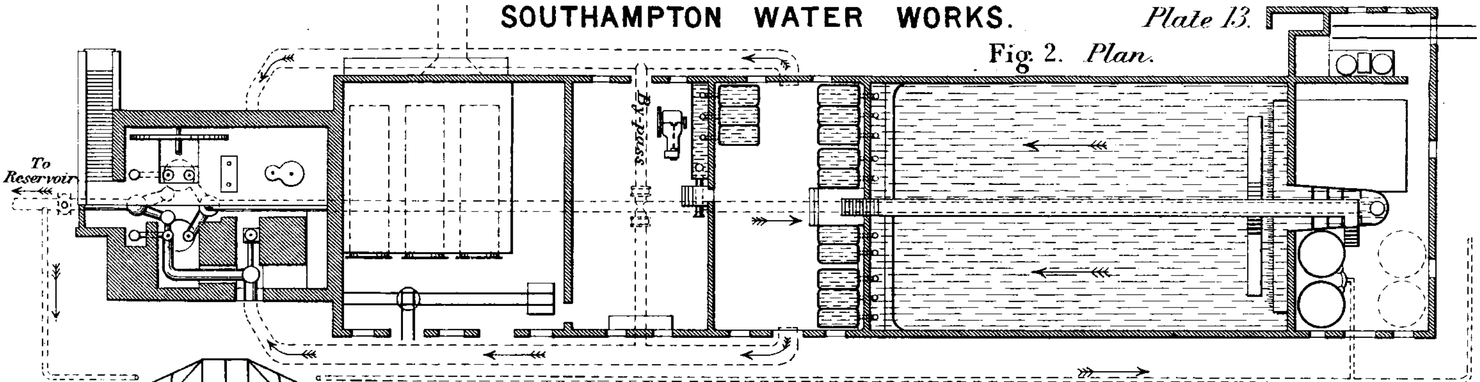
Fig. 1.

General Plan.

SOUTHAMPTON WATER WORKS.

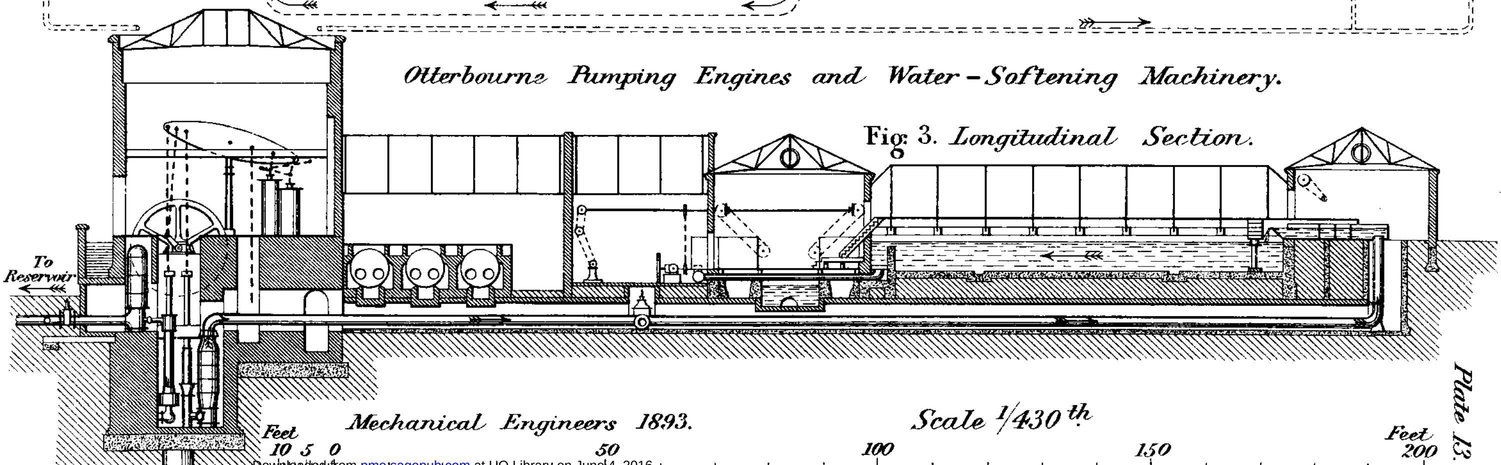
Plate 13.

Fig. 2. Plan.



Otterbourne Pumping Engines and Water-Softening Machinery.

Fig. 3. Longitudinal Section.



Mechanical Engineers 1893.

Scale 1/430th

Feet 10 5 0 50 100 150 Feet 200

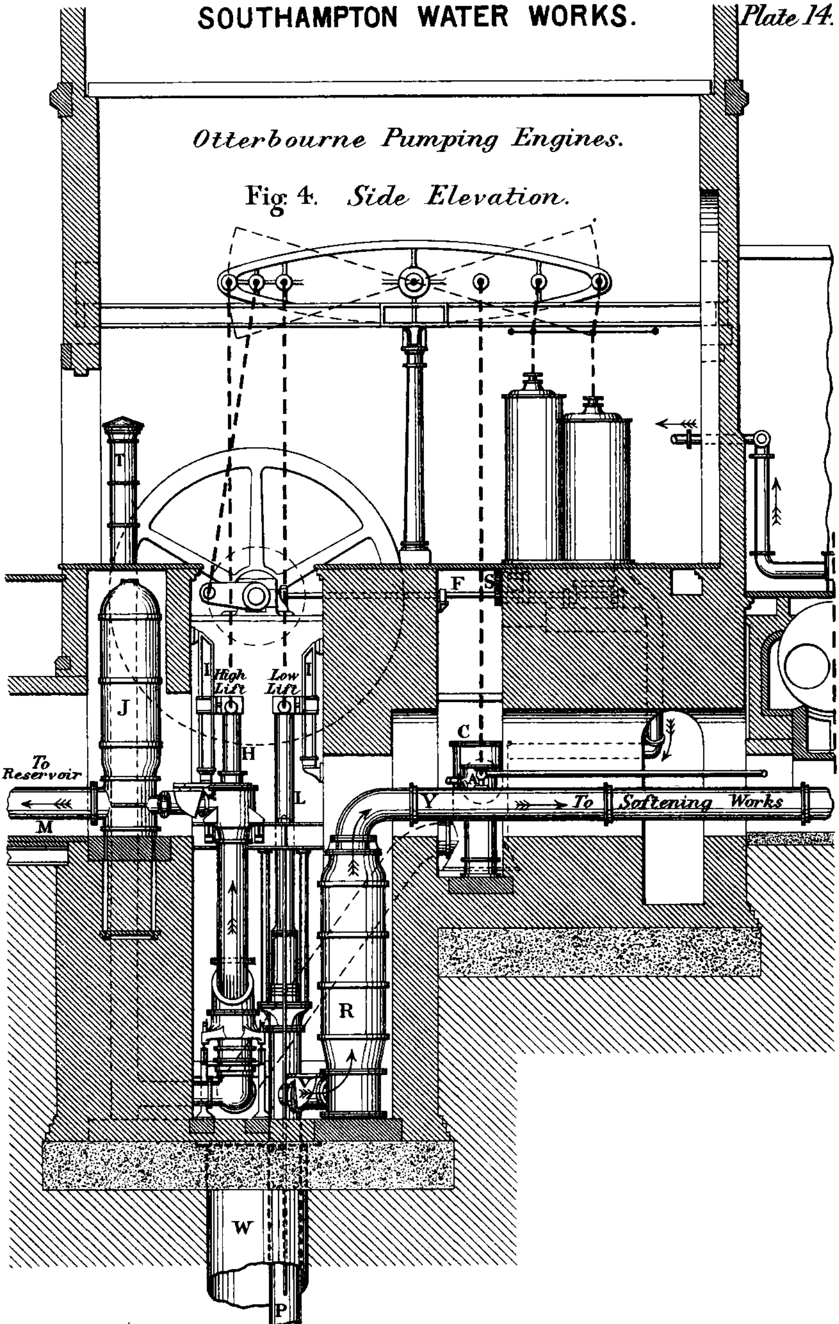
Plate 13.

SOUTHAMPTON WATER WORKS.

Plate 14.

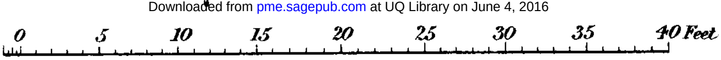
Otterbourne Pumping Engines.

Fig. 4. *Side Elevation.*



Scale 1/144th

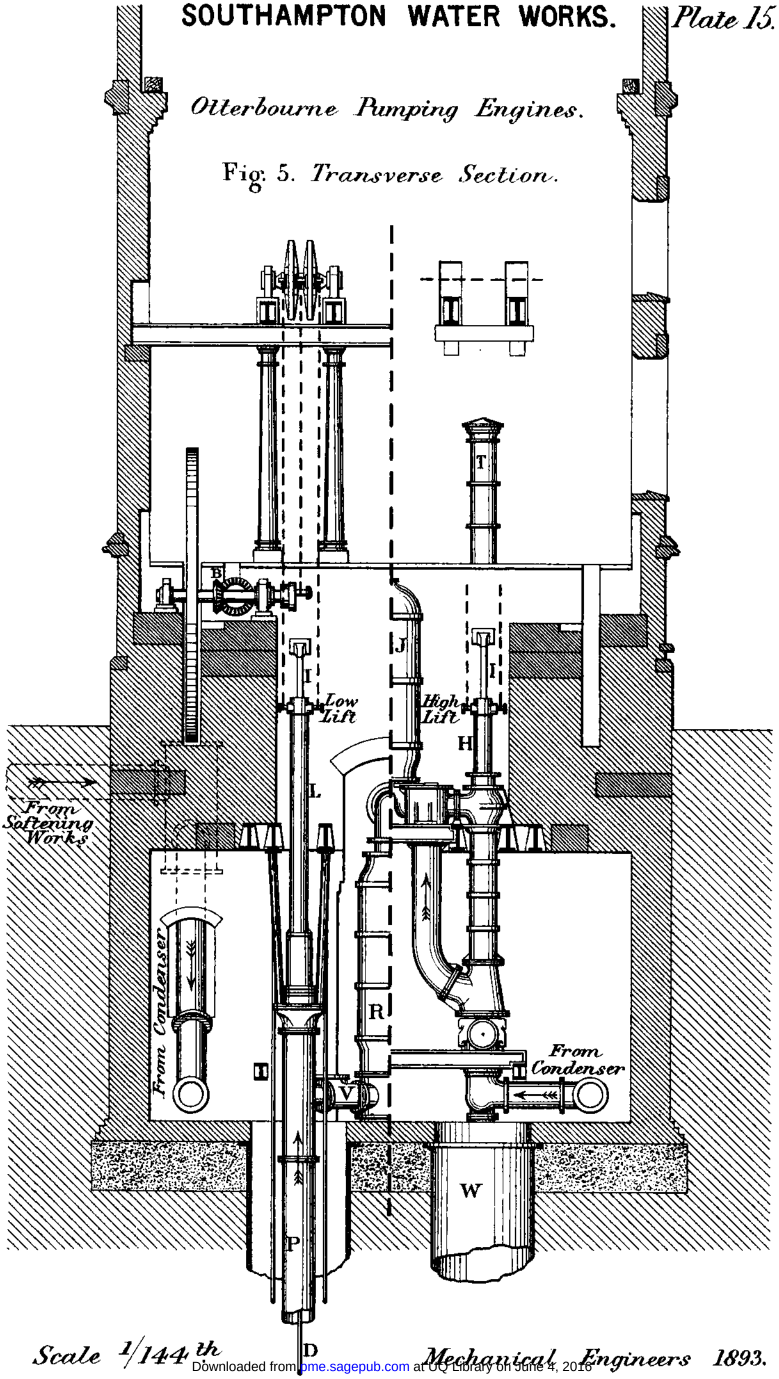
Mechanical Engineers 1893.



SOUTHAMPTON WATER WORKS. *Plate 15.*

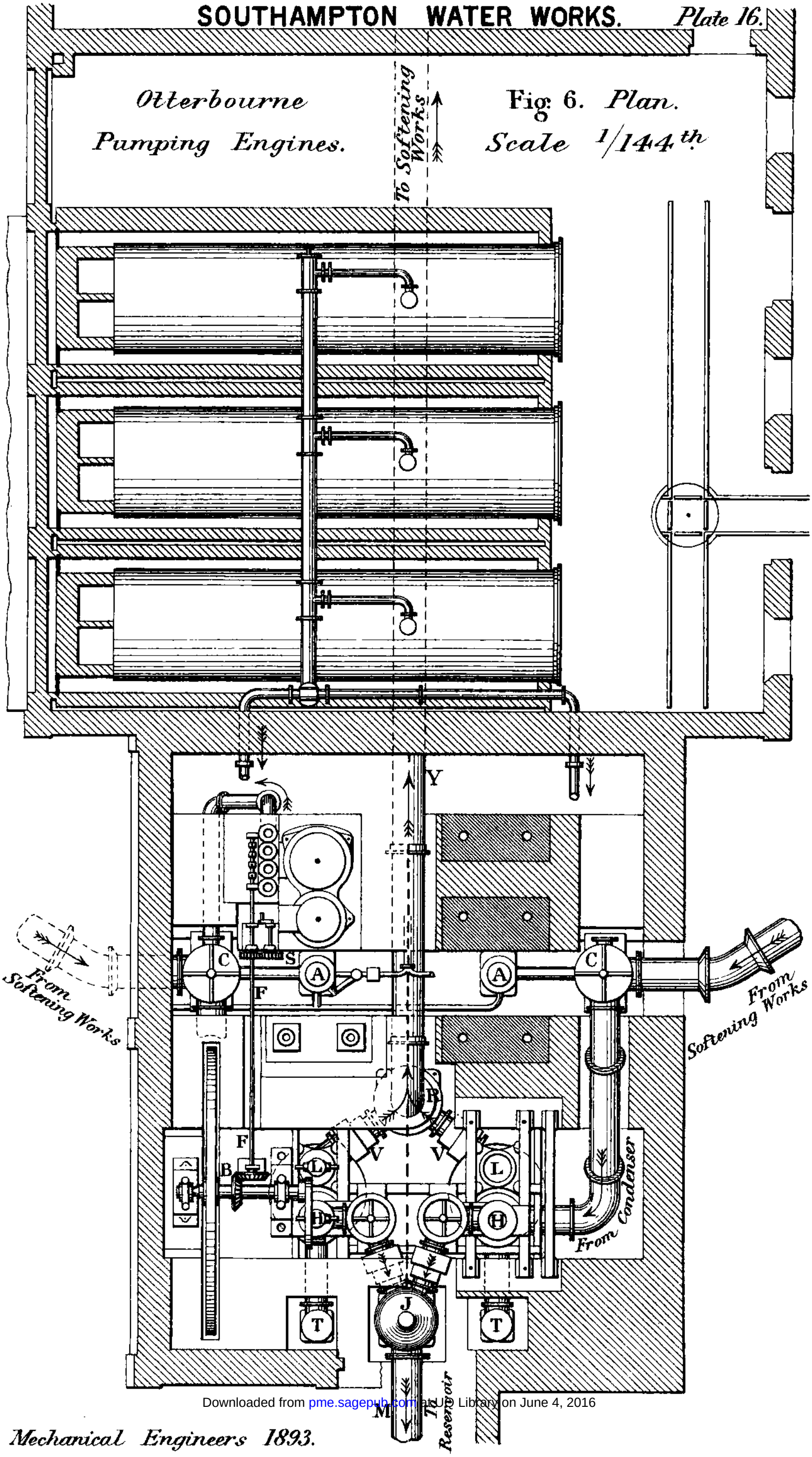
Otterbourne Pumping Engines.

Fig. 5. *Transverse Section.*



Scale 1/144 th *Mechanical Engineers 1893.*

0 5 10 15 20 25 30 35 40 Feet


Otterbourne
Pumping Engines.
Fig. 6. Plan.
Scale 1/144th
To Softening Works
From Softening Works
From Softening Works
From Condenser
To Reservoir
A
B
C
F
H
J
L
M
R
S
T
V
Y

Otterbourne Pumping Engines.

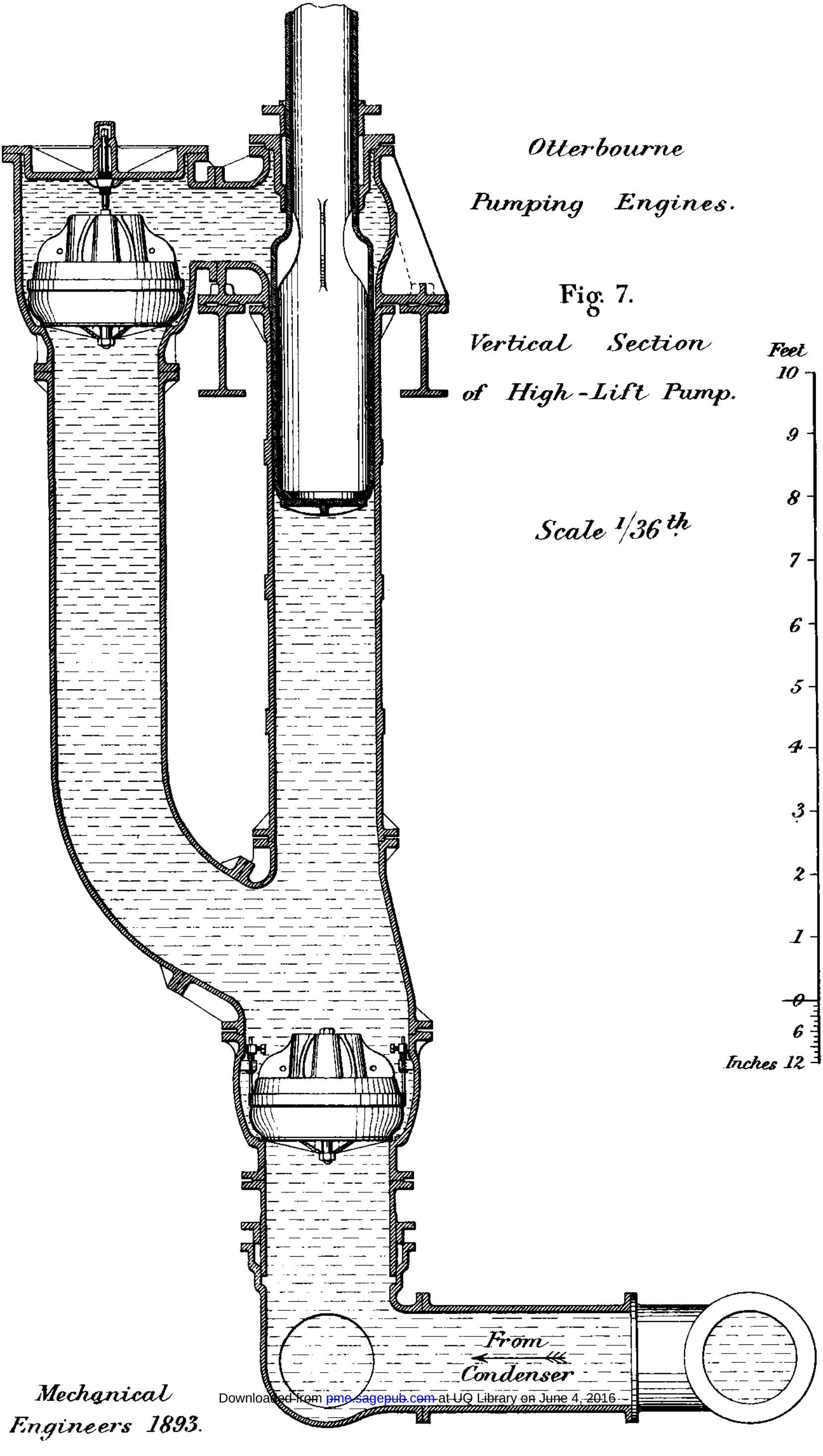


Fig. 7.

Vertical Section of High-Lift Pump.

Scale 1/36th.

Mechanical Engineers 1893.

SOUTHAMPTON WATER WORKS. *Plate 18.*

Fig. 8. *Indicator Diagrams from Otterbourne Compound Rotative Beam Engines.*

Boiler Pressure 60 *lbs. per sq. inch above atm.*

Revolutions per minute 18.

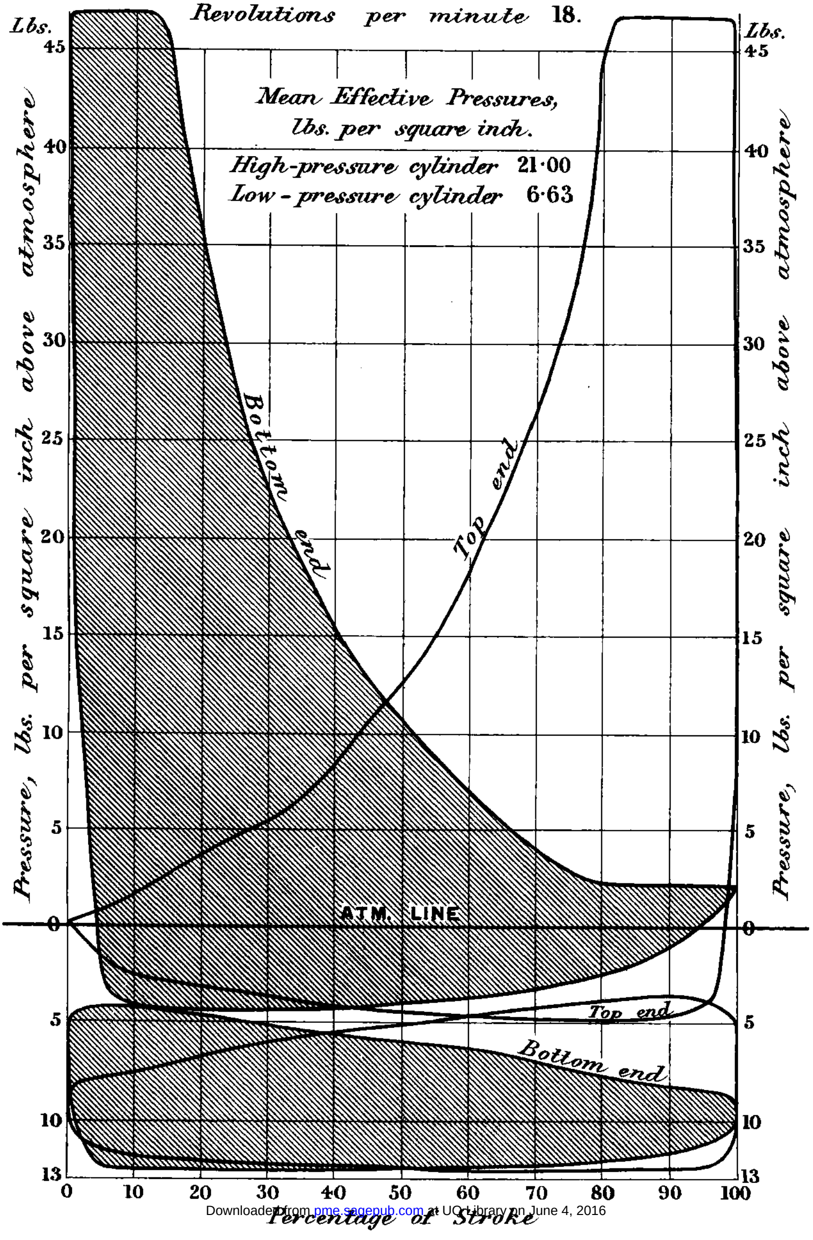


Fig. 9. *Indicator Diagrams from*
Mansbridge Single-Acting Cornish Beam Engine.
Strokes per minute 10.

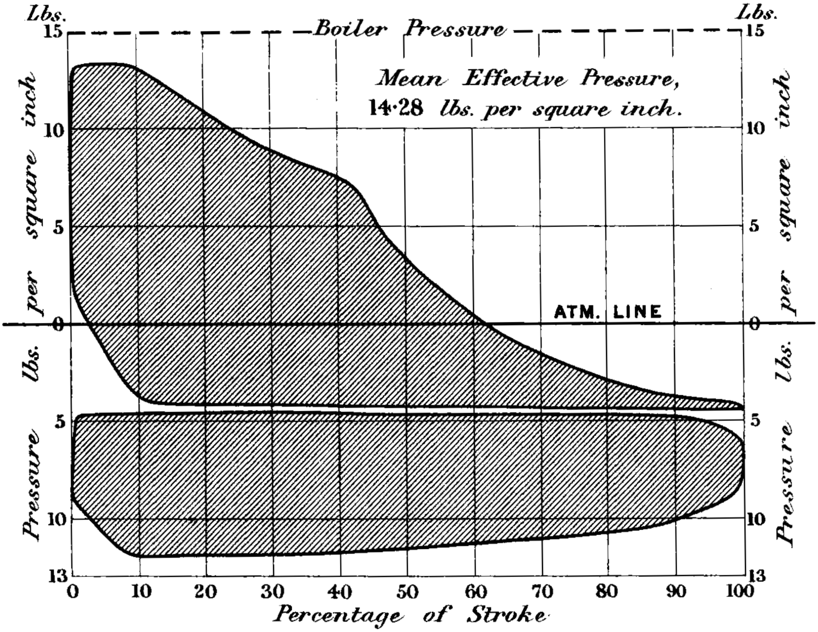
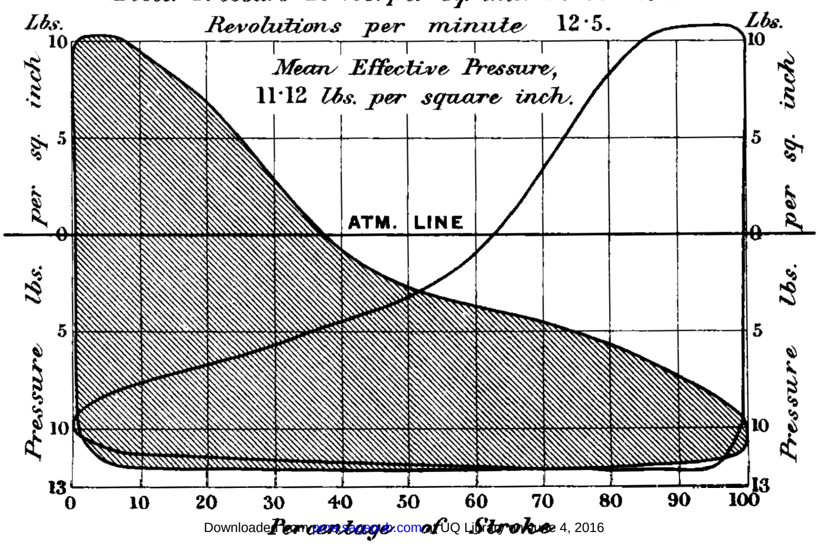


Fig. 10. *Indicator Diagrams from*
Mansbridge Rotative Beam Engine.
Boiler Pressure 20 *lbs. per sq. inch above atm.*
Revolutions per minute 12·5.



SOUTHAMPTON WATER WORKS.

Plate 20.

Water-Softening Machinery.

Fig. 11. *Longitudinal Section.*

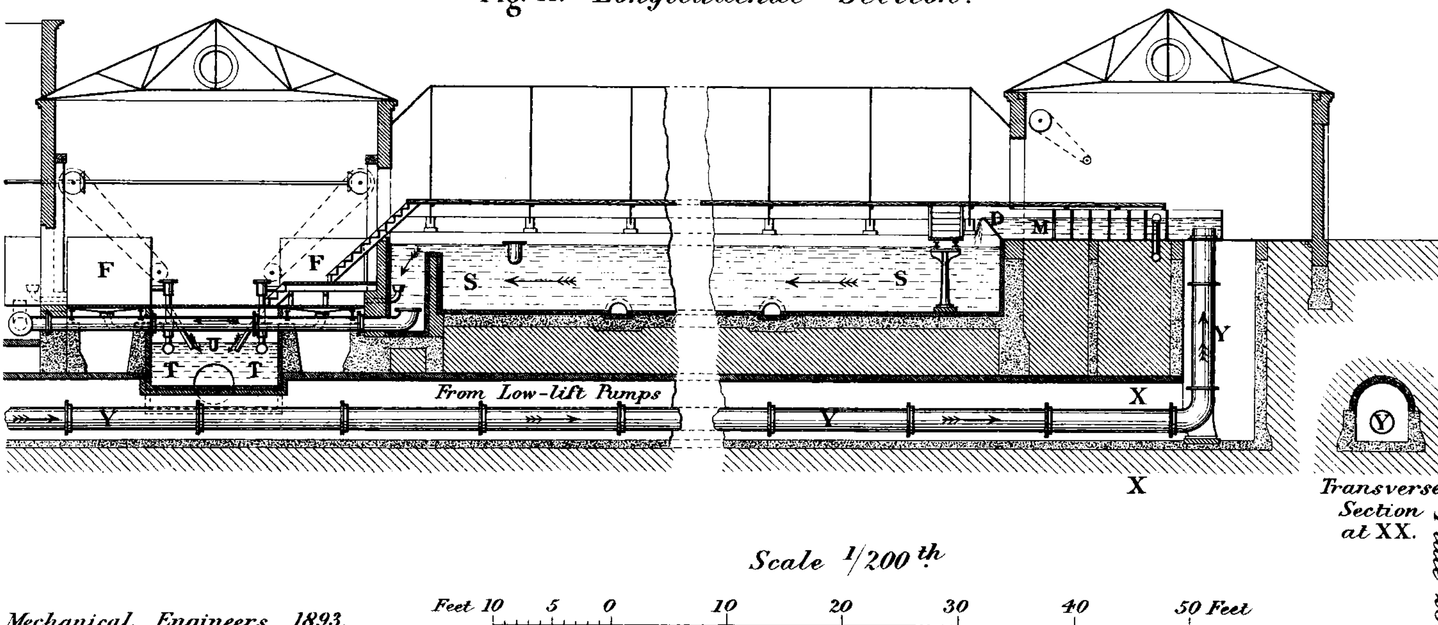
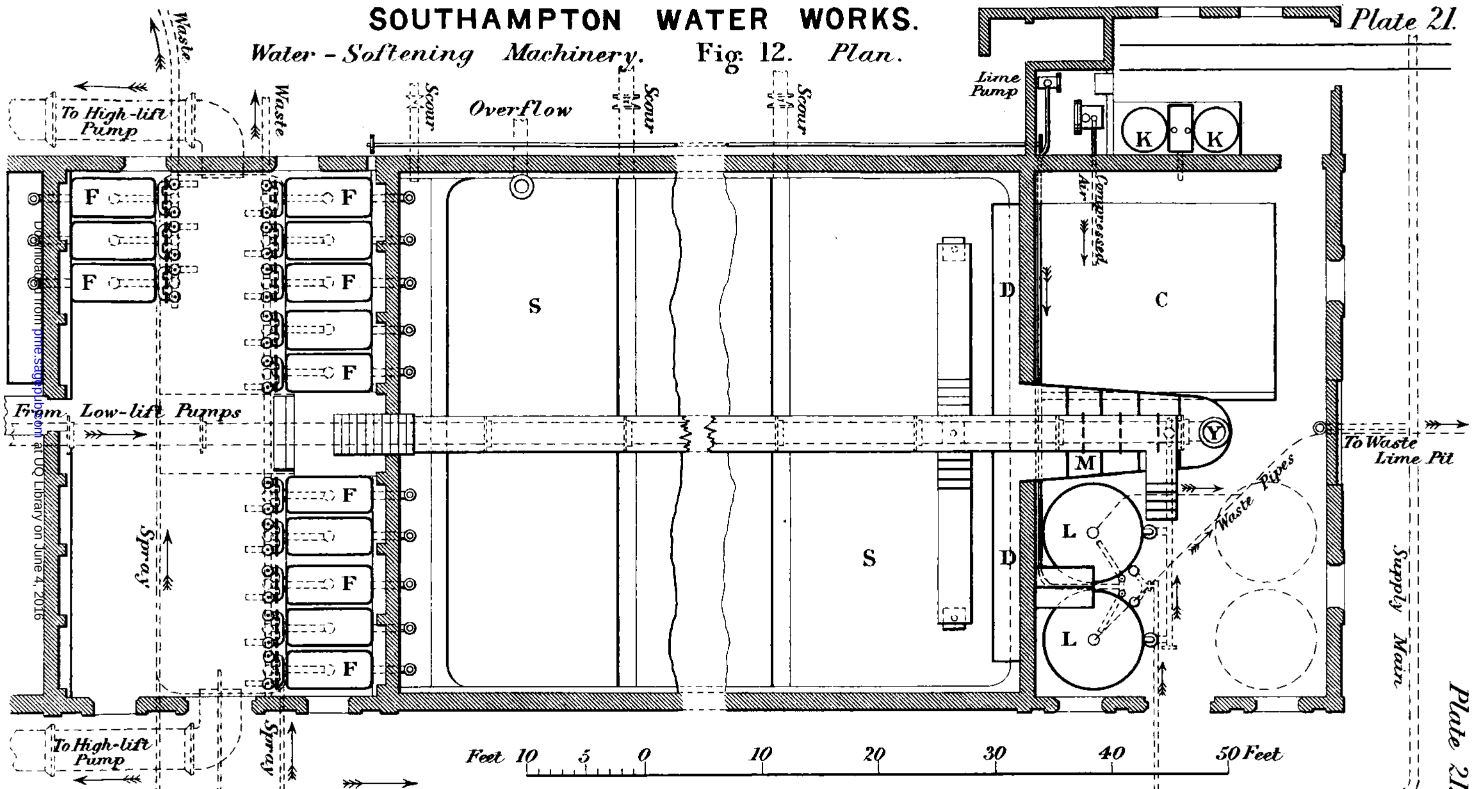


Plate 20.

Mechanical Engineers 1893.

SOUTHAMPTON WATER WORKS.

Water-Softening Machinery. Fig. 12. Plan.



Mechanical Engineers 1893.

Scale 1/200th

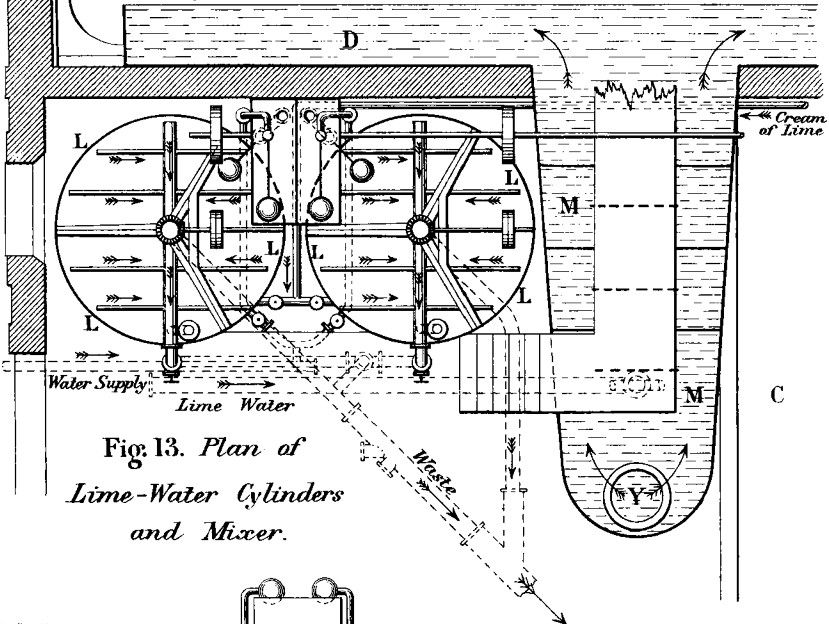


Fig. 13. *Plan of Lime-Water Cylinders and Mixer.*

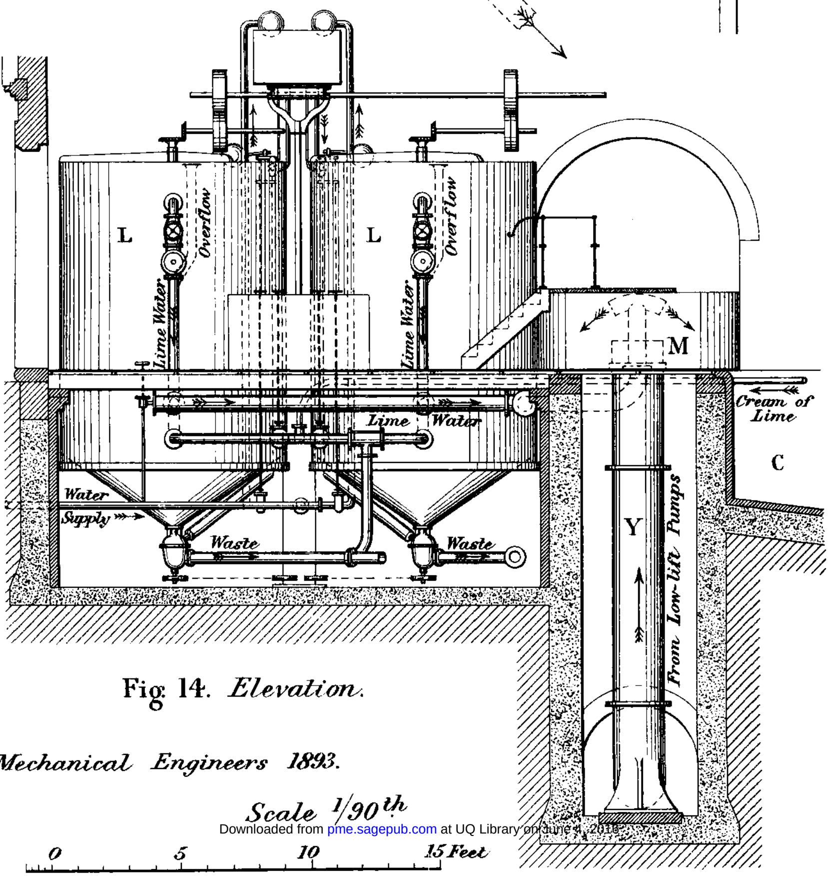
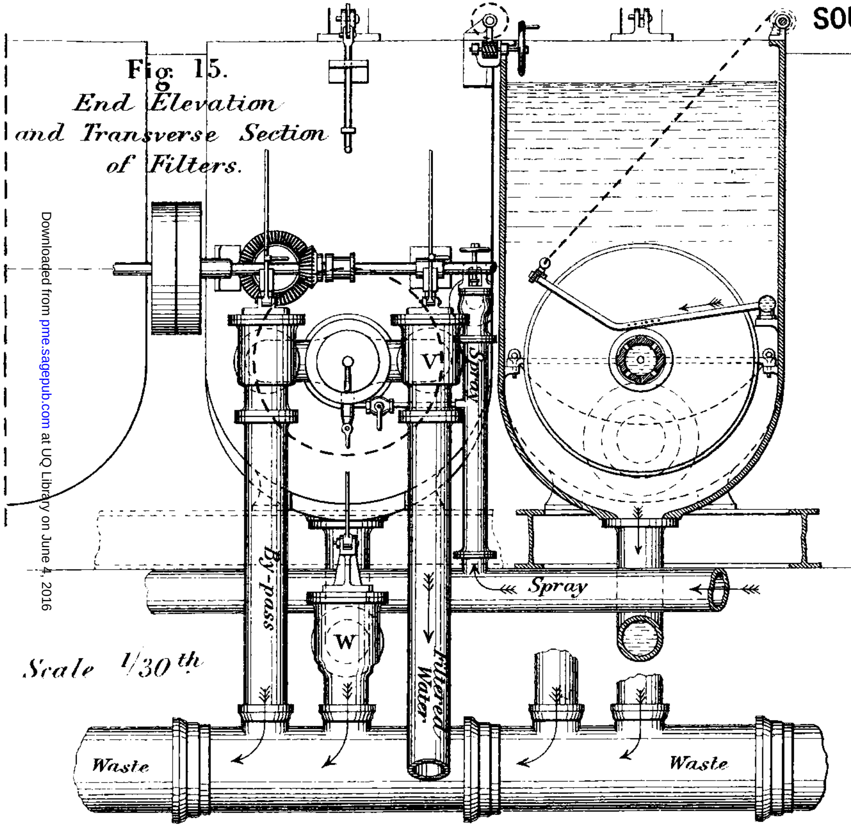


Fig. 14. *Elevation.*

Mechanical Engineers 1893.

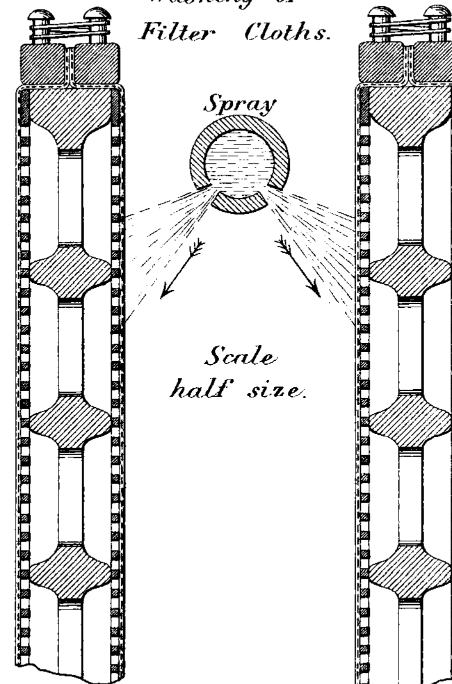
Scale 1/90th

Fig. 15.
End Elevation and Transverse Section of Filters.



Scale 1/30th.

Fig. 16.
Washing of Filter Cloths.

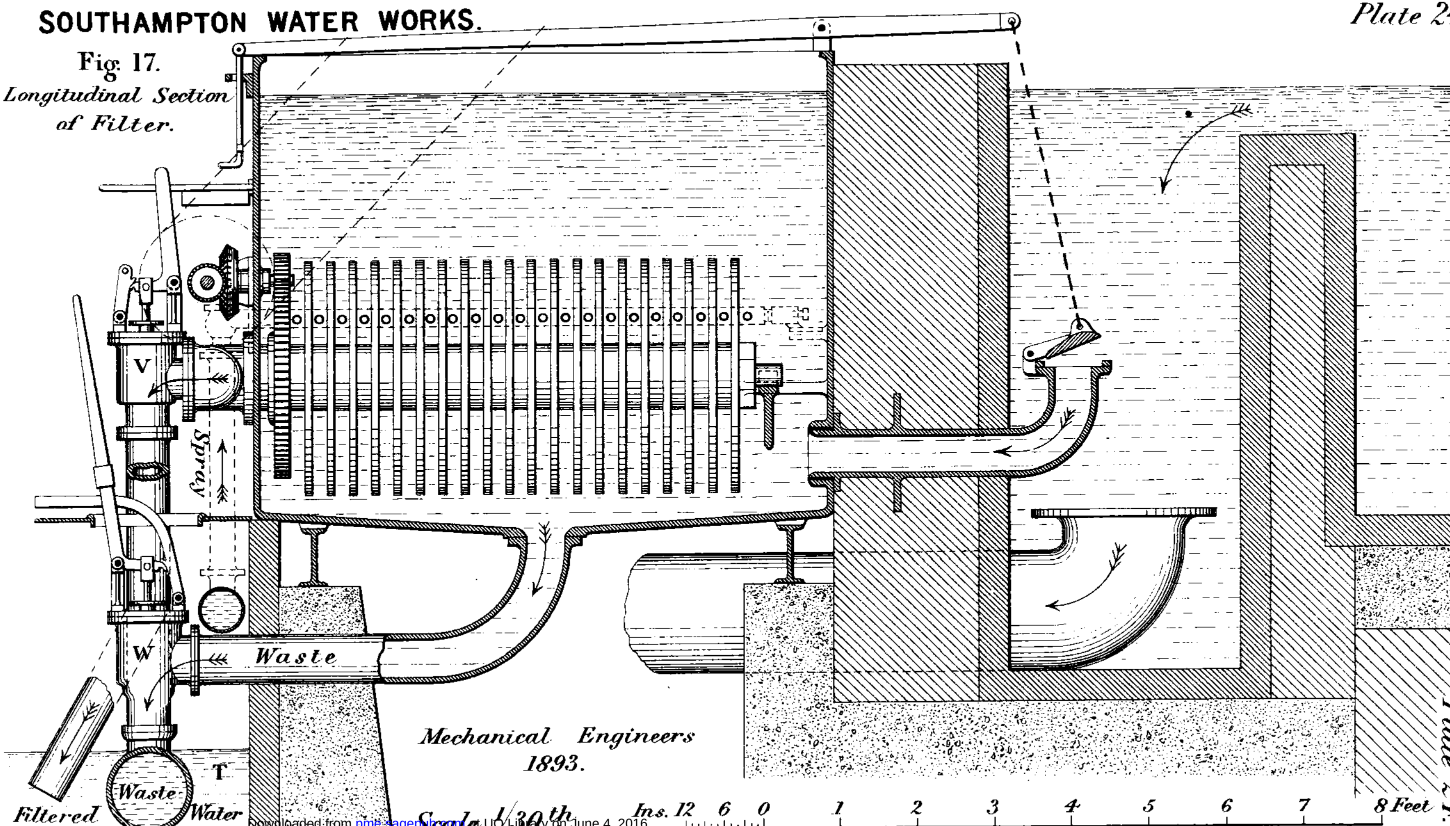


Scale half size.

SOUTHAMPTON WATER WORKS.

Fig. 17.

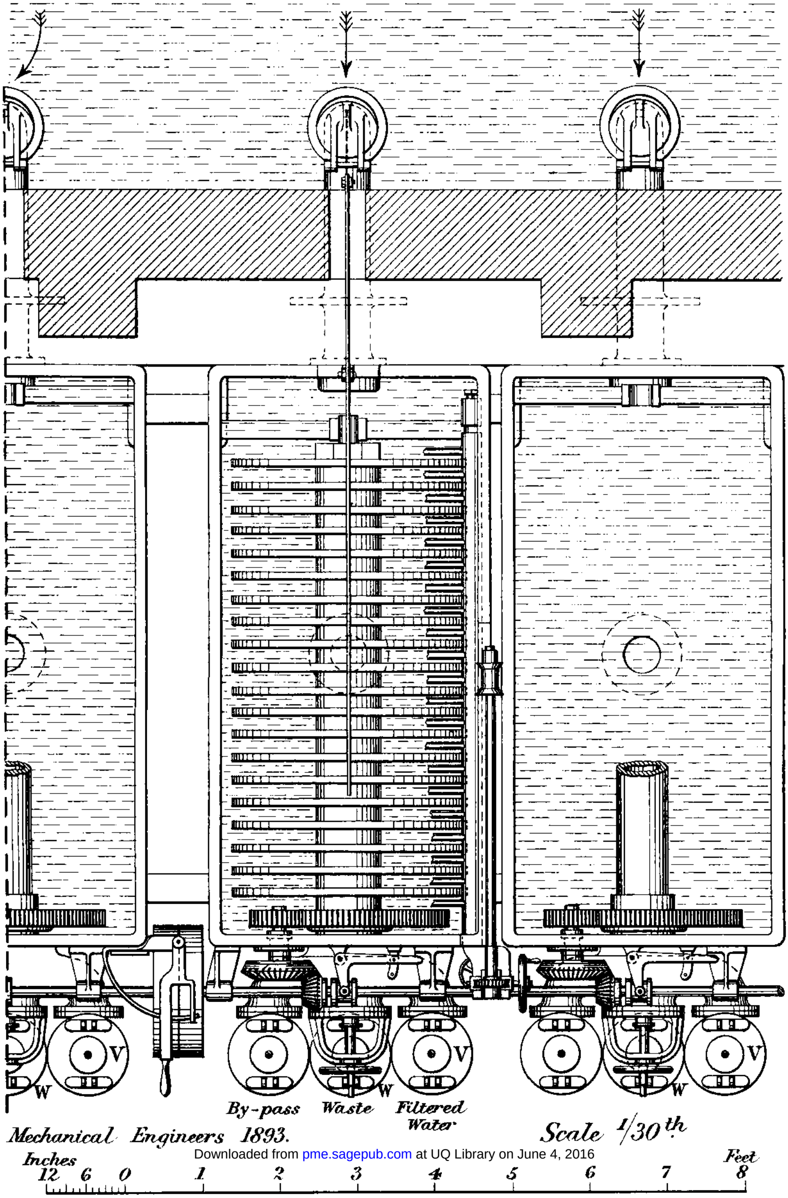
Longitudinal Section of Filter.



Mechanical Engineers 1893.

Scale 1/30th

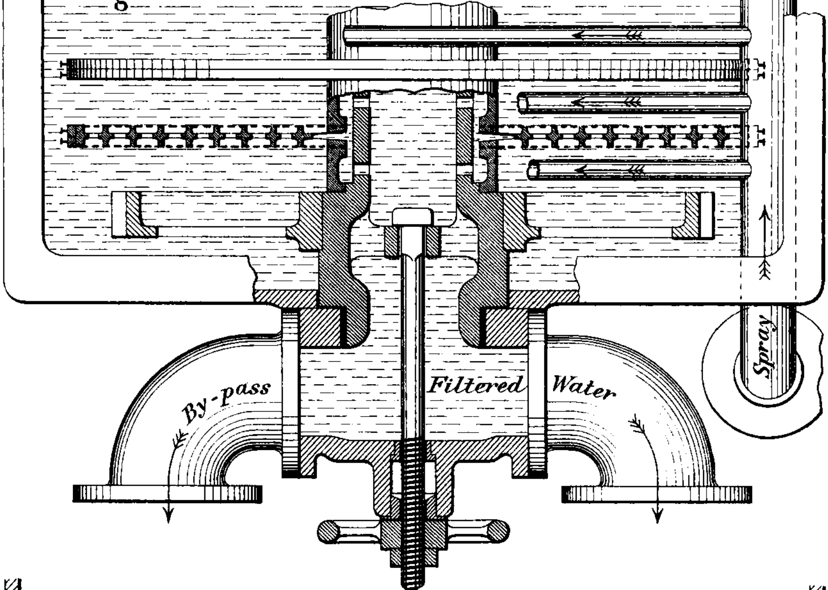
Fig. 18. *Plan of Filters.*



Mechanical Engineers 1893.

SOUTHAMPTON WATER WORKS. *Plate 26.*

Fig. 19. *Sectional Plan of Filter Discs.*



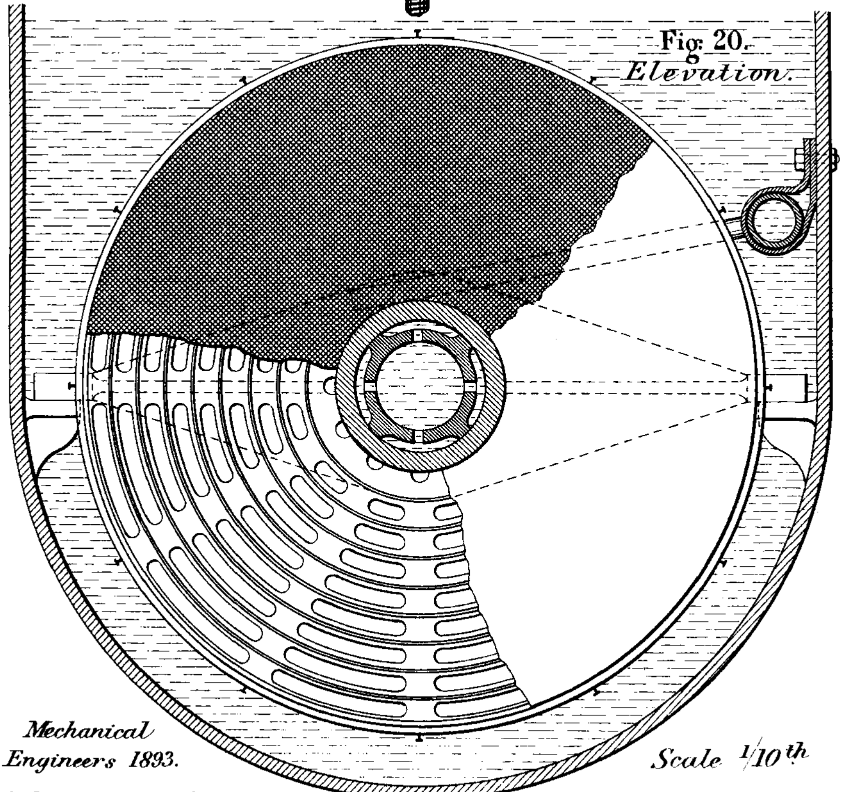


Fig. 20. *Elevation.*

Mechanical Engineers 1893.

Scale 1/10th

Inches 12 6 0 1 2 *Feet*