

*(Paper No. 3472.)***"City of Chichester Sewage-disposal Works."**

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IN the year 1895 the City of Chichester was sewered, and sewage-disposal works were constructed $1\frac{1}{2}$ mile to the west of the town, on a site having an area of about 10 acres. The works then carried out consisted of three precipitation-tanks having a capacity of 105,000 gallons, the sewage being chemically precipitated by the addition of alumina ferric and lime water. The tank-effluent was afterwards further purified by running it over 6 acres of land laid out in irrigation-areas. Only slight purification was obtained by passing the effluent over the land, owing to the soil being of a clayey character, with layers of peat on some portions of the site, about a foot below the surface. Machinery was erected for pressing the sludge by means of direct-acting ram pumps. After passing through the works the effluent was retained in a tidal storage-tank and discharged into the Chichester Harbour on the ebb of the tide. This scheme was designed with the intention of removing only the suspended solids of the sewage, relying on the tidal change in the harbour, which has been calculated to be about 24,000 million gallons per day, to complete the further purification and aeration of the effluent.

An action at law was brought against the Corporation in June 1901 for causing a nuisance, and for "allowing unpurified and insufficiently purified sewage to flow into the Chichester Harbour." This action was decided against the Corporation, and they were ordered by the Court to alter the disposal-works so that a nuisance could not occur in the future.

In preparing the designs for the new works the following conditions were carefully considered, and governed the general arrangements for the extensions:—

1. The population of the district connected to the sewers discharging at the outfall-works is 12,000.
2. The liquids to be purified consist of a mixture of domestic

sewage and trade refuse; considerable quantities of brewery-waste, and the by-products from a tan-yard, are discharged into the sewers without any treatment. The combination of these various liquids had previously been found very difficult to deal with by chemical precipitation alone; and in order to obtain a clarified effluent very large quantities of chemicals had been used, with indifferent results.

3. The normal dry-weather flow of sewage is about 320,000 gallons per day, but during some portions of the year more than 2,000,000 gallons of sewage passes through the works daily for several consecutive weeks. This abnormal flow is caused by the rainfall, and by the subsoil or underground waters leaking into the sewers, indifferent supervision when laying the sewers having resulted in many of them being defective and not water-tight—a condition which, although a considerable sum of money has been spent to remedy it, is still so bad as to dilute the sewage to about eight times the normal dry-weather flow during a considerable portion of the year. The daily flow of sewage through the works, and the height of the subsoil-water at a well in the centre of the City, are shown in monthly averages in Fig. 1, Plate 13.

4. The outfall-works being below the level of high-water of spring-tides in the harbour, there was a very small available fall between the level of the sewage admitted to the works and the invert of the main outfall-sewer.

5. The necessity of storing the effluent on the works until the tide has receded before it can be discharged.

6. The necessity of putting down works of such a character as to meet all the requirements of the Court, and of being able to treat and purify the whole of the liquids passing through the works, no storm-water overflow-weirs being allowed.

Having regard to the foregoing considerations it was decided, in preparing the scheme, to adhere to the system of chemical precipitation, the intention being to reduce the amount of chemicals used to the smallest quantity that is found to be sufficient to deposit the suspended solids in the sewage.

In view of recent developments in the purification of sewage by preliminary treatment in a septic tank, it may be of interest to state the reasons for arriving at the conclusion that in these purification-works the best treatment, subsequent to filtration through bacteria-beds, was chemical precipitation of the solids. It was anticipated that during the periods in which abnormal quantities of subsoil-water pass through the works all septic action would be destroyed, and large quantities of deposited sludge

would be washed out of the tanks and would cause the filters to deteriorate by the accumulation in them of deposited mineral matter. At various times in the past, great difficulty had been experienced in purifying the mixtures of domestic sewage, brewery-waste, and tan-yard refuse, and no reliable data were at the time available to prove that such combinations of sewage could be dealt with in a satisfactory manner by preliminary treatment by septic action alone. The order of the Court under which the alterations were carried out was stringent in respect of any nuisance arising from the works from any cause whatsoever; and it was thought that it would be impossible to remove the sludge from the septic tanks and dispose of it in such a manner that no nuisance would be created, since according to the most reliable experiments then published there would still be, as compared with a precipitation process, 50 to 75 per cent. of sludge to be dealt with. To effect its reduction by throwing the solid matters into solution, owing to the necessity of retaining the sludge in the tanks, it would require to be dealt with in bulk, and not day by day as is the case in a precipitation process. From a careful examination of the records of experimental installations of filters and contact-beds it is evident that a gradual blocking-up of the pores of the filters takes place, and by precipitating the whole of the mineral matters out of the sewage it is anticipated that the life of the filters will be very much prolonged, and also that their capacity will be increased, especially since a much greater number of fillings per day can be given to beds taking chemically precipitated effluent than can be given to beds taking septically treated sewage.

Having determined the broad general principles, a scheme was prepared showing the enlargement of the precipitation-tanks, and providing for the oxidation of the tank-effluent by treating it on contact-beds 2 feet in depth. This proposal was submitted by the Corporation to Dr. George Reid, D.P.H., Medical Officer of Health to the County of Stafford, who strongly recommended that the sewage, up to three times the normal dry-weather flow, should be purified on a continuous filter or percolation-bed, the remainder of the flow being treated by contact-beds as proposed; the scheme was accordingly amended, and has been carried out on these lines.

The Precipitation-Tanks.—The size of the tanks has been increased to a total capacity of 423,000 gallons by the addition of four tanks, each again subdivided and provided with specially formed outlets to intercept as much as possible of the lighter flocculent matters. Valves are arranged so that the sludge can be withdrawn without pumping out the tanks, but it has been found

necessary occasionally to run off the top water, the deposits being of such a light nature that they adhere to the side walls of the tanks and deteriorate the effluent if not cleaned off. With the normal dry-weather flow at the works of 320,000 gallons per day, the sewage takes about 32 hours to pass through the tanks, and with the greatest flows recorded passing through the works it would take 4 hours for the day's sewage to pass through the tanks. The tanks are constructed throughout of cement-concrete, the copings of the walls being of Yorkshire stone; the sluices admitting and regulating the flow of sewage to the tanks are constructed of English oak. The carriers leading to the pumping-well, contact-beds, and tidal tank are all of concrete, and have iron sluices to shut off or regulate the flow of the effluent to the various parts.

Recording-Gauges and Measuring-Notches.—For registering the flow of sewage through the works, a square notch-plate, constructed of cast iron with planed edges, has been inserted in the main sewer at the point where it enters the works, and a recording-gauge, worked by means of a float, has been erected, so that a permanent record is kept of the daily fluctuations in the flow of sewage through the works. For regulating the flow of tank-effluent to the contact-beds and other places, a system of weirs and V-notches is provided. These are in the positions marked A, B, C, and D in Figs. 2, Plate 13. At B there is inserted in the carrier leading to the contact-beds a combined weir and rectangular notch, the height of the weir being such that there must be three times the normal dry-weather flow of tank-effluent running in the carrier before it can pass over the weir to the contact-beds; the height of the notch is calculated so as to pass the quantity of effluent that can be purified on the contact-beds. At A a weir is fixed, equal in height to the heights of the weir and notch combined, so that when a greater quantity of effluent is passing along the carrier than can be pumped on to the continuous filter, or can pass through the notch on to the contact-beds, it overflows this weir and is dealt with on the land, which is retained for this purpose. At the points C and D are placed right-angle V-notches. Consequently at any time of the day the quantity of tank-effluent flowing to any part of the works can be very easily ascertained, by referring to a Table compiled for that purpose.

The Continuous Filter.—The tank-effluent, to the amount of 1,125,000 gallons per day, or three times the normal dry-weather flow, is pumped on to the continuous filter, which has an effective area of 3,500 square yards, and is 198 feet in diameter at the base of the filtrant and 204 feet in diameter at the top of the same. This

filter is a complete circle, enclosed with earthen embankments, and is lined on the interior with cement-concrete 4 inches in thickness. Under-drains for drawing off the purified water are constructed as shown in Fig. 3, Plate 13. The filter and measuring-chamber are illustrated in Figs. 4, Plate 13. The filtering-material is shingle obtained from the mouth of Chichester Harbour, and is composed entirely of clean flint deposits, free from dirt. Special machinery was erected for crushing and screening the shingle, which is laid in the bed in layers as follows:—The bottom layer, 6 inches in thickness, is composed of particles which are retained by a screen of $\frac{1}{2}$ -inch mesh and passed by a screen of 1-inch mesh. The second layer has an average depth of 3 feet 9 inches, and is composed of particles which are retained by a screen of $\frac{3}{8}$ -inch mesh. The top layer of the filter is 1 foot in thickness, and is composed of particles which are retained by a screen of $\frac{1}{8}$ -inch mesh and passed by a screen of $\frac{1}{4}$ -inch mesh. In working it has been found necessary to rake over the upper portion of the filter occasionally, but otherwise the tank-effluent readily percolates through it when the full quantity of effluent has been pumped on to it for a considerable length of time.

The Spreader.—The tank-effluent is distributed over the surface of the filter by a revolving spreader, 200 feet in diameter, which is illustrated in Figs. 4 and 5, Plate 13. The motive-power for revolving the spreader is obtained from the head of water pumped into and accumulated in the measuring-chamber, which acts through a turbine fixed at the base of the centre column. The head of water necessary to turn the spreader is 6 feet, and the tank-effluent is headed up in the measuring-chamber until 3,000 gallons are stored, when an automatic valve comes into operation and the effluent is then discharged on to the filter, through the turbine in the base, causing it to revolve. The spreader makes about two revolutions each time the measuring-chamber is discharged, and when actually working it distributes at the rate of 0.43 gallon per square yard. The spreader, however, works intermittently, the time elapsing between the periods of working depending upon the amount of sewage passing through the works. The actual rate of discharge of the tank-effluent on to the filter is 322 gallons per square yard per day when the maximum amount of sewage is flowing, but with the normal dry-weather flow the discharge falls to 107 gallons per square yard per day. The continuous filter, being raised so much above the surrounding portions of the country, is exposed to the strong winds blowing from the south-west, which have an unobstructed course up the Chichester

Harbour. Difficulty was experienced in the first instance in overcoming this wind-pressure, which had a tendency to bring the spreader to a standstill at right-angles to the direction of the wind. Advantage was therefore taken of the force of the wind in order to assist the spreader on its course, and, after various experiments to ascertain the best design, two sails have been erected, somewhat on the principle of the sails of a windmill, as shown in Figs. 4, Plate 13. These have proved successful in helping the spreader past the point of greatest resistance. The whole of the revolving portions of the spreader are mounted on ball-bearings, and every expedient that could be thought of has been adopted to make it mechanically as efficient as possible; in actual working it requires very little pressure to start it on a revolution. The apex is stayed by means of six steel-wire guy-ropes, $\frac{1}{2}$ -inch in diameter, so arranged that they can be adjusted to meet variations in the temperature of the atmosphere. The centre column and turbine of the spreader is of cast iron, and the whole of the remaining work is of mild steel, the framed cantilevers being built of angle, flat, and round bars. The trough is built of $\frac{1}{8}$ -inch plates riveted together, and is pierced with holes of varying sizes so as to distribute the same quantity of water per square yard all over the surface. The structure is braced in the longitudinal direction by means of wind-ties, and the whole of the framework is fitted throughout with gun-metal threaded sockets so arranged that any part of the structure can be tightened up when required. The ends of the trough are supported by wheels running on a rail-track, the wheels being fitted with ball-bearings; the structure is, however, so well balanced that there is little or no pressure on the wheel-track.

The Contact-Beds.—For purifying the storm- and subsoil-water passing through the works, four contact-beds have been constructed, each 127 feet in length by 51 feet in width and 2 feet in depth, and lined with cement-concrete 4 inches in thickness. They are filled with screened shingle taken from the harbour, only that which is retained by a screen of $\frac{1}{4}$ -inch mesh and passed by a screen of $\frac{3}{4}$ -inch mesh being used. The bottom of these beds has been kept above the high-water level of the storage-tank, so that they cannot at any time be flooded by the effluent stored in the tidal tank. Automatic valves are arranged to supply and discharge the contents of these beds, the whole working in a cycle—the filling of bed No. 1 opening the inlet-valve of bed No. 2 and so on, and the discharge being effected in a similar manner, Figs. 6–9, Plate 13. The valves are actuated by

the weight of the water flowing into the cylindrical drums, which fall by gravity, causing the motion to be communicated to the valves by a pair of levers. The admission of the water to the cylinders is controlled by an automatic float-valve, which is started by the overflow of the water from the bed last filled.

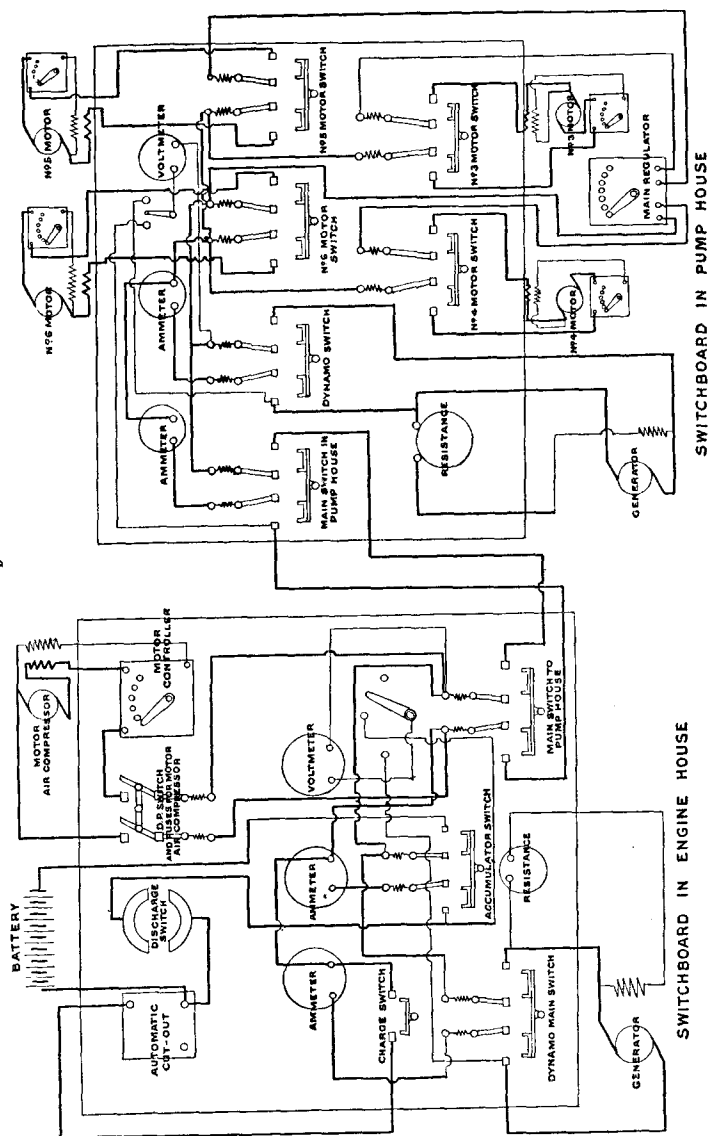
The Pumping-Plant.—In order to pump the effluent, up to three times the dry-weather flow, on to the continuous filter, four electrically driven centrifugal pumps have been put down (Figs. 10, Plate 13), and these have been found to be a great convenience in dealing with the widely varying quantities of sewage passing through the works; for example, if the flow suddenly increases, due to a shower of rain or other cause, it is a very easy matter to switch on a pump of larger capacity. The electrical energy is obtained by means of an existing single-acting engine driving a four-pole dynamo, giving out 70 amperes at 120 to 160 volts, and in addition an oil-engine driving a similar generator is installed in the pump-house and is used as a spare plant. The surplus energy generated by the dynamo, in excess of the power required to drive the pumps, is stored in a 500-ampere-hour battery, and is used to drive the pumps during the night, so that the works can be entirely shut down, leaving only the motor-driven pumps running. The size and output of the motor-driven pumps are given in the following Table, compiled from the results of a number of tests made while the plant was working under ordinary conditions:—

—	3-Inch Pump.	4-Inch Pump.	5-Inch Pump.	6-Inch Pump.
Revolutions per minute . .	1,300	1,205	875	821
Delivery in gallons per minute	295	534	678	774
Voltage at motor terminals .	120	120	120	120
Current in amperes	20	33	35	45

The pumping-main is 12 inches in diameter, the static head on the main being 17 feet. All the pumps are placed below the level of the water in the pump-well, so that they are always charged with water, and this has been found very convenient in working, the pumps being always ready to be switched into work at once. The motors, which are directly coupled to the centrifugal pumps, are four-pole compound-wound machines of the semi-enclosed type. They are designed to withstand heavy overloads, and are capable of exerting an overload torque $2\frac{1}{2}$ times the normal full-load running-torque. A diagram of the switch-board connections is shown

in Fig. 11. It will be seen that in order to run the motors at 120 volts, and at the same time charge the accumulator-battery at 160 volts, a regulator has been connected in the circuit. This is found very convenient in working, the only disadvantage being that a

Fig. 11.



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portion of the energy generated is lost in the resistance-coils of the regulator. The generators are shunt-wound, and are similar in all respects to the motors, being semi-enclosed and having carbon brushes.

Motor-driven Air-compressor.—In the engine-house an air-compressor, belt-driven by a 2-HP. electric motor, supplies air at low pressure for mixing the chemicals for the sewage treatment. This motor is also fitted with a regulator, so that it can be used while the battery is being charged.

Storage-battery.—The storage-battery consists of sixty-five cells and has a capacity of 500 ampere-hours, the maximum discharge-rate being 80 amperes. A regulating-switch governing fifteen cells is provided, together with a double-pole switch and the necessary cut-outs.

Electric Lighting.—The premises are lighted electrically throughout by means of twenty-one 16-candle-power lamps, and these are arranged on a separate main connected to the storage-battery, so that when the battery is being charged the lighting is not interfered with.

Switch-boards, Cables, etc.—Two switch-boards are provided, one in the pump-house and one in the engine-house, both of which are constructed of enamelled slate; the general arrangement of the switchboards is illustrated diagrammatically in *Fig. 11*.

Sludge-pressing Plant.—The plant originally installed for pressing the sludge was direct-acting; this has been converted into a pneumatic pressing-plant, which has enabled the work to be proceeded with in a more expeditious manner, and has effected a saving in the cost of labour. The existing direct-acting sludge forcing-rams have been fitted with new air-cylinders, which compress the air into a steel receiver. Two steel-plate forcing-rams have also been fixed, and these are used either to lift the liquid sludge into the overhead sludge-vats, or to force it into the sludge-presses. The working pressure of the pneumatic plant is 65 lbs. per square inch, and this pressure is found to be sufficient to produce a good firm cake within a reasonable period of time. The reason that a higher pressure is not used is that the existing engines are not capable of withstanding the strain that a higher pressure would involve. The arrangement of the sludge-pressing plant is shown in *Figs. 12, Plate 13*.

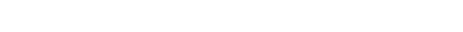
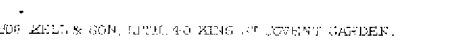
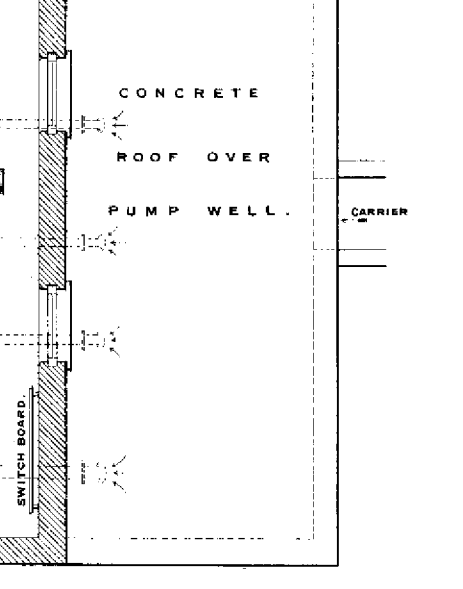
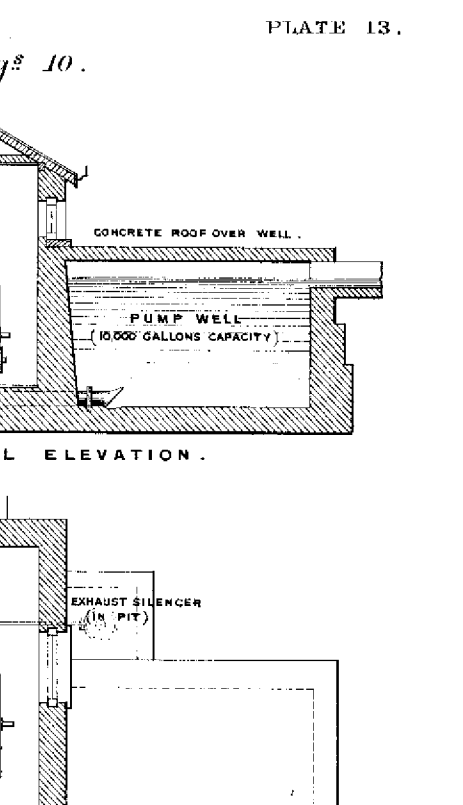
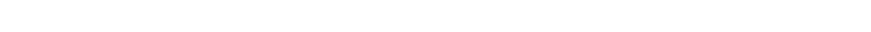
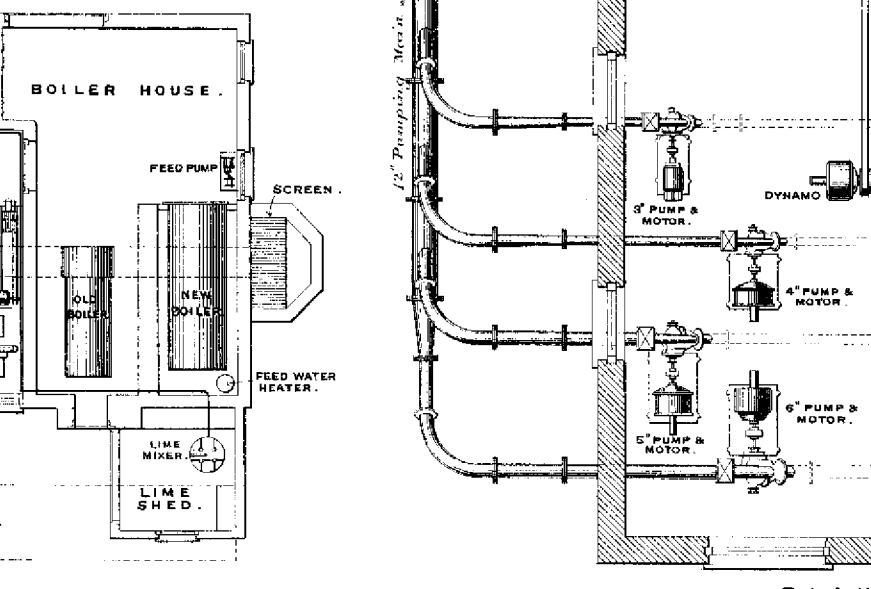
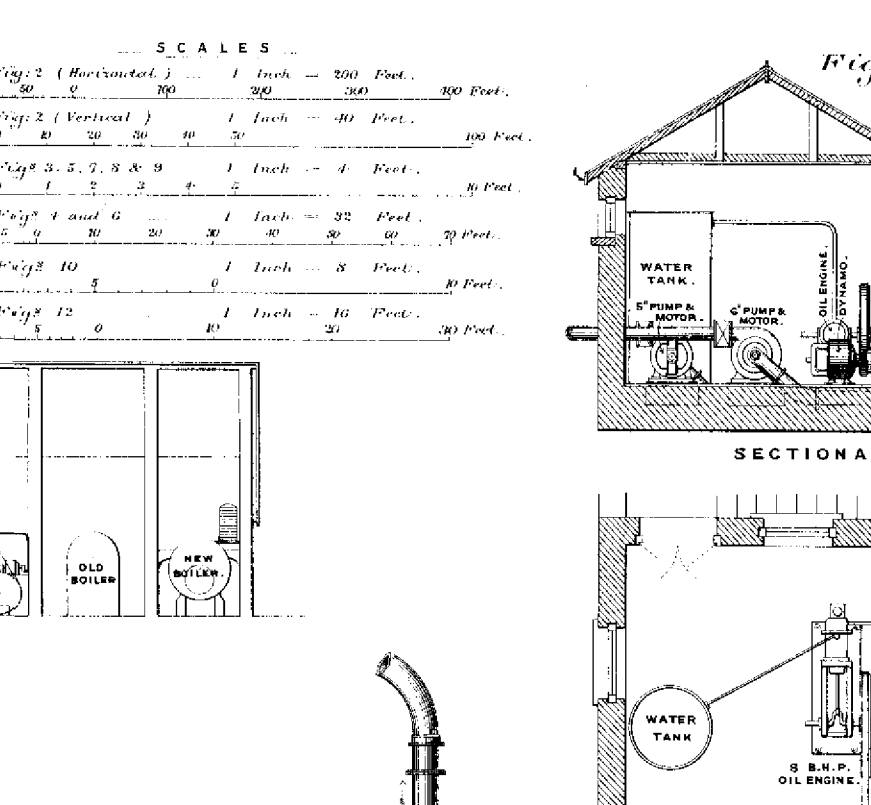
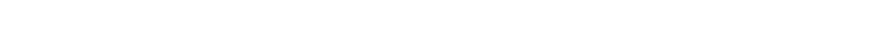
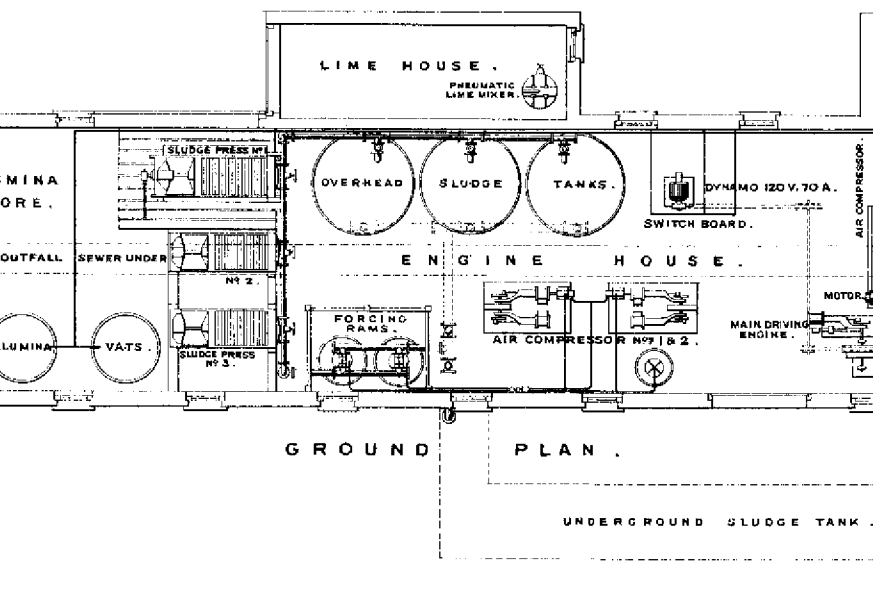
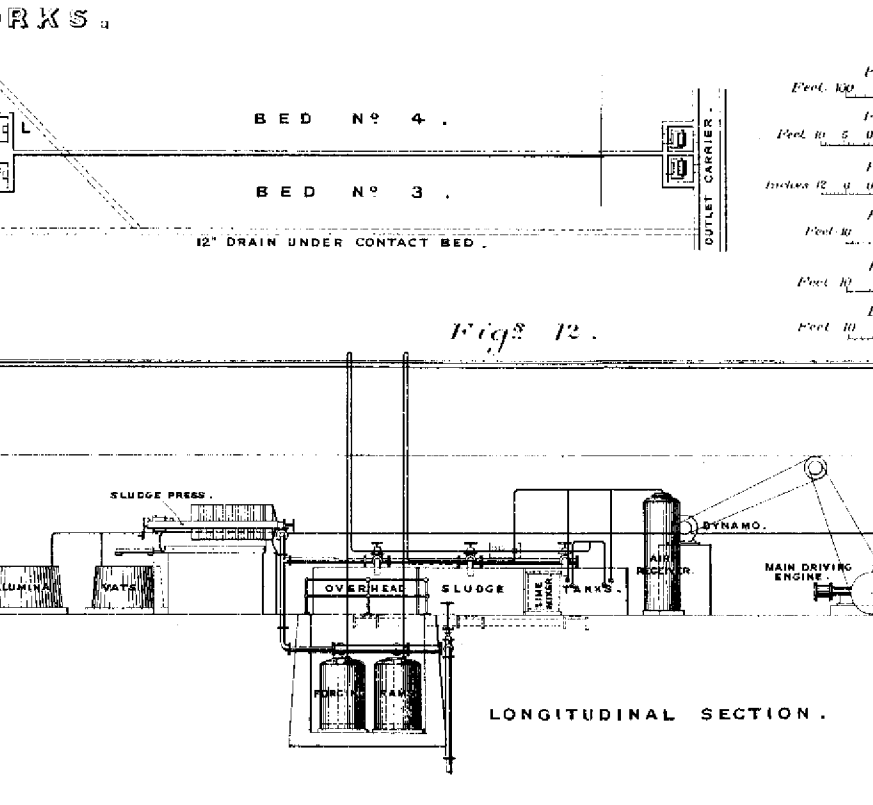
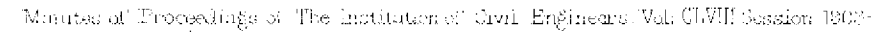
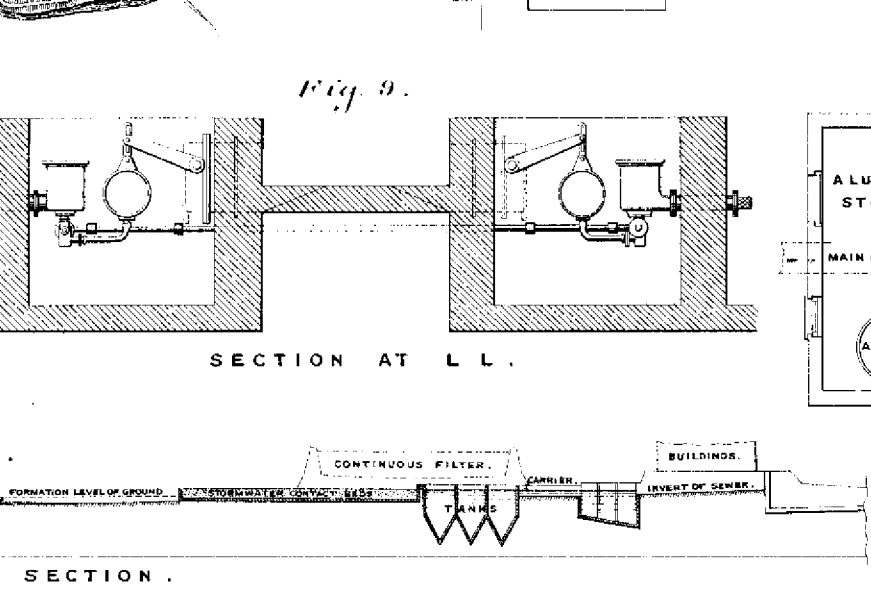
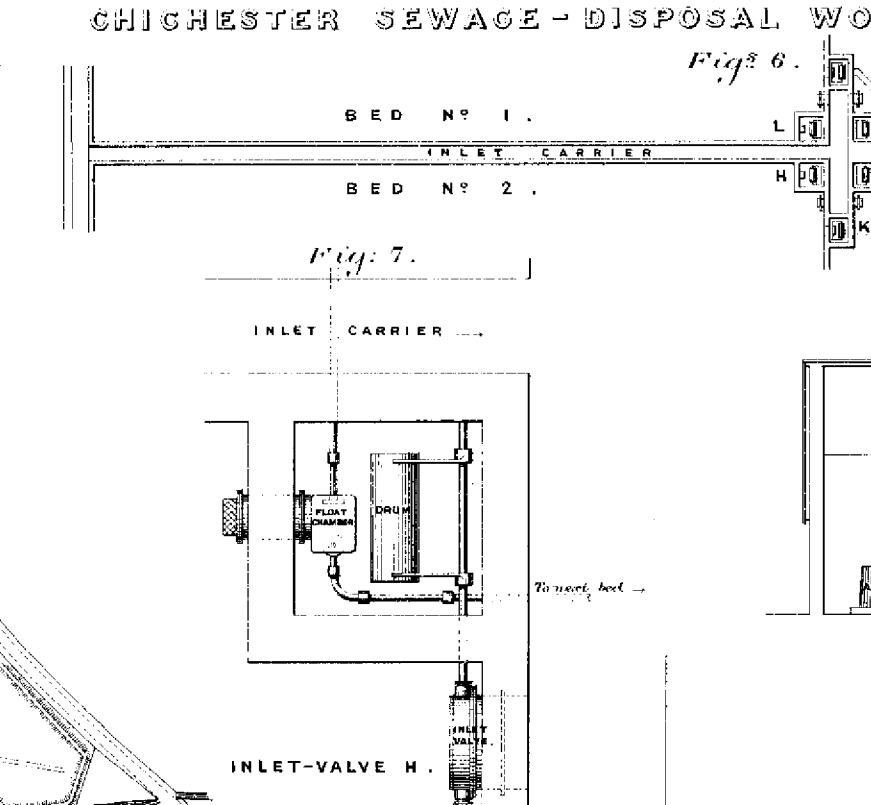
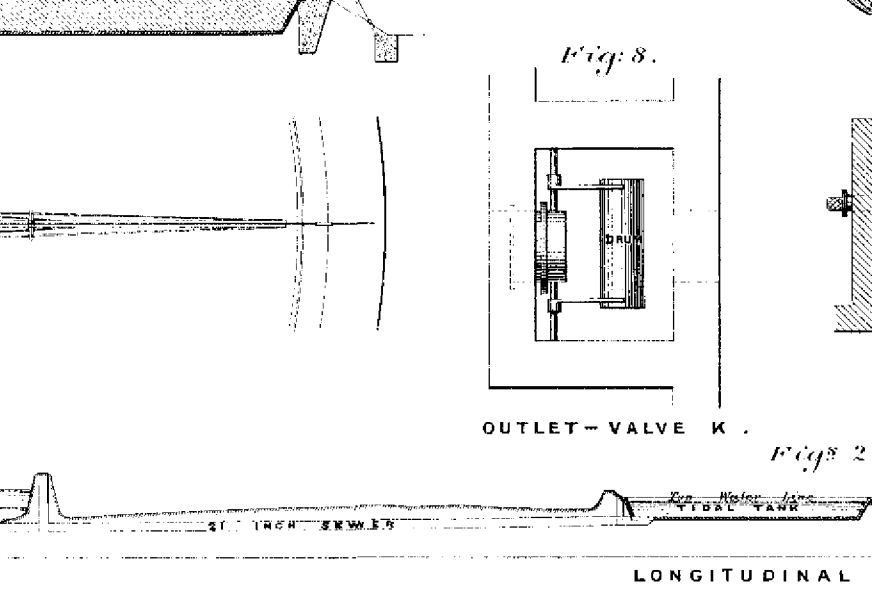
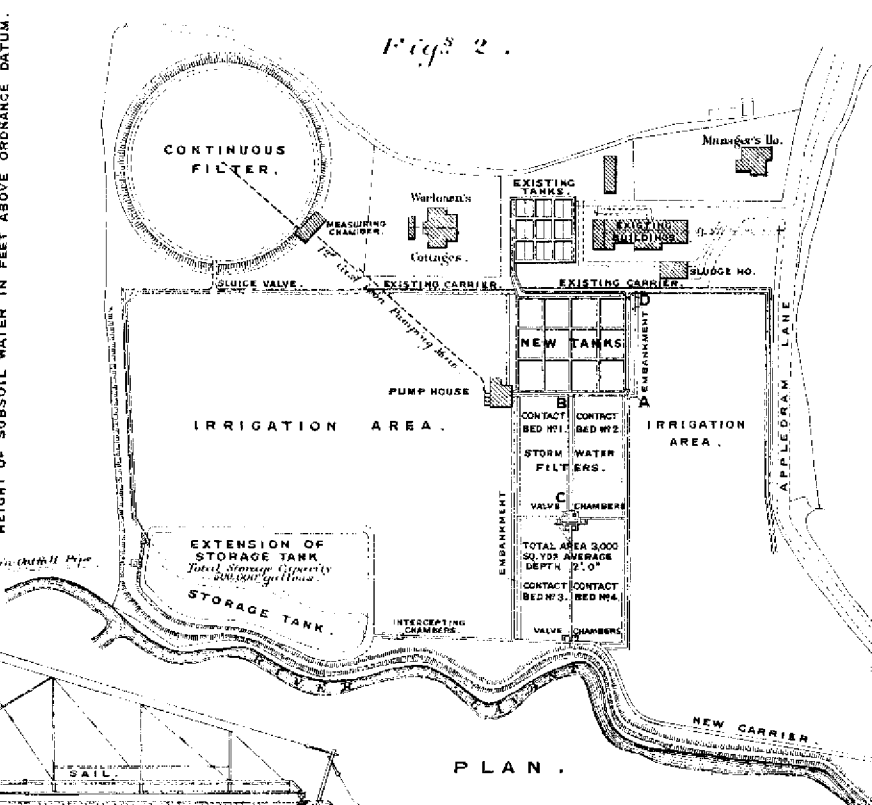
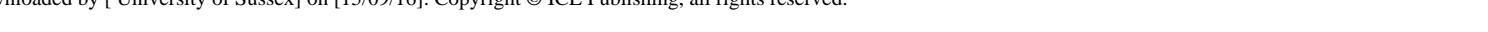
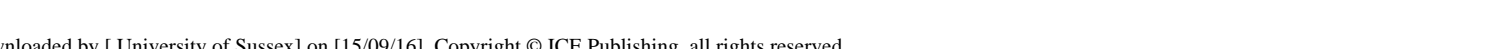
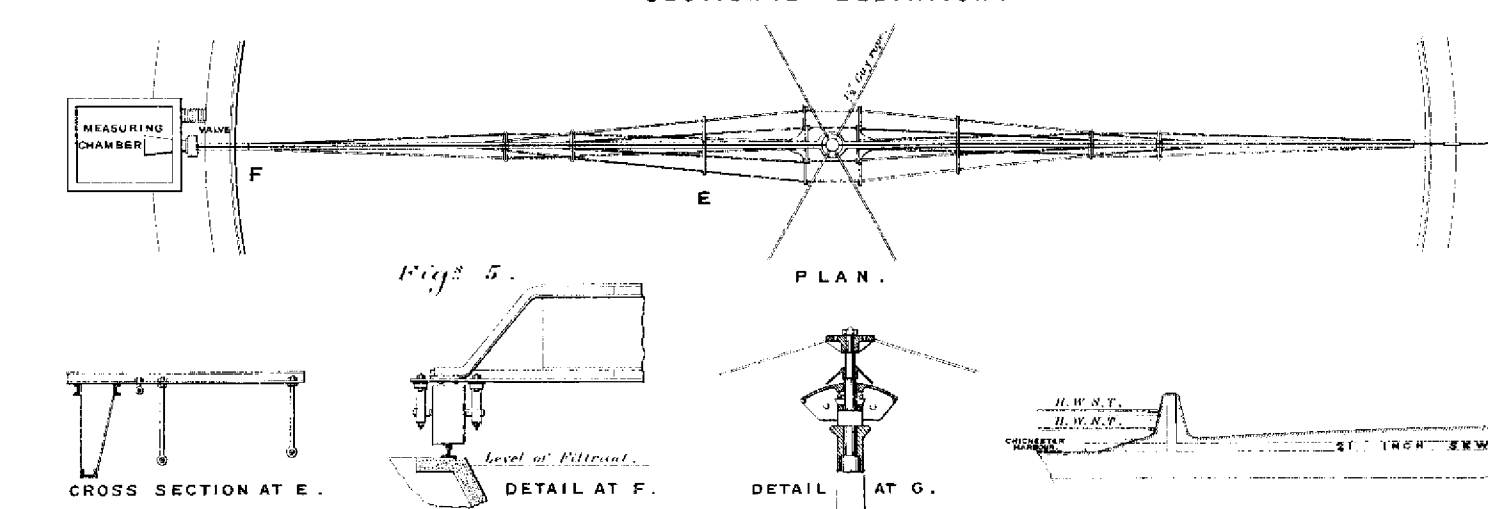
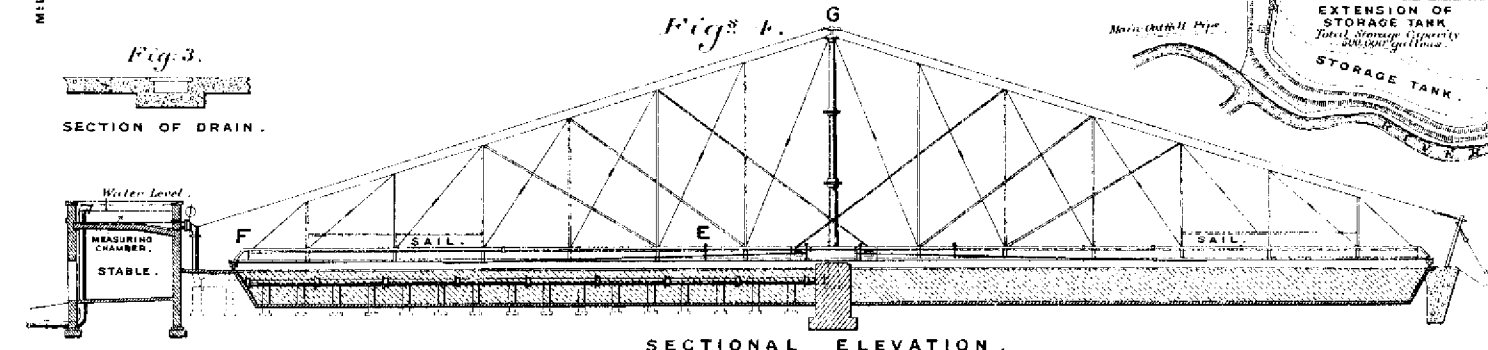
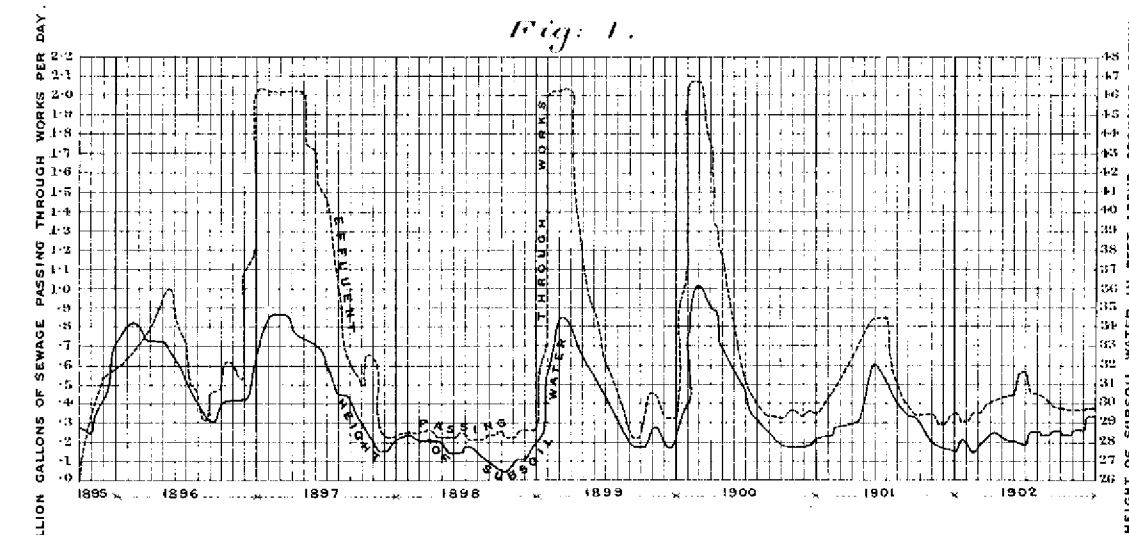
Chemical Mixers.—The chemicals used for treating the sewage are dissolved in water before being added to the sewage, and for this purpose two alumina-vats and two lime-mixers are fitted with air-pipes so that the liquids in the vats are kept constantly in a state of agitation.

Storage-tank.—The storage-tank used for holding up the effluent until the tide has ebbed, in order that it may be liberated, has been enlarged to a capacity of 500,000 gallons. This work has been carried out in concrete, without rendering on the face. A valve-chamber has been erected over the outlet, and in this a recording-cylinder has been placed which registers the time of opening and shutting the valve.

Cost of the Works.—The total cost of the works is £12,500, the following being the costs of construction per square yard of the various portions of the works, including all charges:—

	£	s.	d.
Precipitation-tanks	1	10	10
Continuous filter, including distributing-gear,)			
per square yard of effective filtration-area . }	17	9	
Storm-water contact-beds	12	4	
Storage-tank.	7	1	

The Paper is accompanied by six sheets of drawings, from which Plate 13 and the Figure in the text have been prepared.



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