maximum lift there is a considerable waste of power at some of the lower lifts.

This might be to some extent reduced by putting two stations on the higher lifts, thereby reducing the pressure required, but this would involve complications and probably not much greater economy, as by reference to table "B" you can see the actual loss at the ejector station is high.

A velocity of 20 feet per second has been allowed in the branch mains, and 30 feet in the mains, as the maximum velocity could only be reached if all the ejectors were discharging at once.

Table "D" gives the length, sizes and cost of the air mains, and the calculations show that the probable total loss in distribution will amount to 12 per cent., 5 per cent. being due to leakage.

The actual theoretical h.p. required at the central station to lift the sewage would be 191 (see table "C").

But after allowing for the increased head, friction and loss through leakage, 240 h.p. will be required available for transmission at the central station.

The theoretical efficiency of the air compressing plant and the ejectors combined at 50lbs., absolute pressure would be 60 per cent., but after making allowance for friction in compressors, imperfect cooling, losses at ejector, etc., the final resulting efficiency would not be higher than 45 per cent.

Therefore, the power required at the head station would be 533 h.p. as against 191, the actual work to be performed, or an efficiency of 35 per cent.

At the central station will have to be provided a reserve of power to be available during a breakdown of one of the engines or for repairs, etc., and the probable size that the plant would have to be to cover these contingencies would be 783 h.p. The cost of the central station would, therefore, be approximately as follows:—

				£	s.	d.			£	s.	d
Engines	783 H.P.	at		14	0	0	per H.P.	=	10962	0	0
Compressors	,,	,,	,,	10	0	0	,,		7830	0	0
Boilers	,,	,,	,,	7	0	0	,,		5481	0	0
House	,,	,,	,,	9	0	0	,,		7047	0	0
	Total		...			...			£31,320	0	0

The power has been estimated on the assumption that one-half of the dry weather flow will run off in 6 hours. Therefore, the probable h.p. hours per annum will amount to 4380 x 533 — 2,334,540 h.p. hours, and, assuming the coal consumption as being 4lbs. per h.p., which, although seemingly large when the waste for banking fires, etc., is allowed for, will probably be found to be correct.

The coal consumed per annum would, therefore, amount to 4169 tons, which would involve an expenditure, taking the coal as costing 14s. per ton, of £2918 per annum.

The labour at the central station would probably amount to:—

		£	s.	d.		£	s.	d.
One Engineer	@	300	0	0	—	300	0	0
Two Engineers	@	200	0	0	—	400	0	0
And nine men	@	0	8	0 per day	—	1314	0	0
Or a total of						£2014	0	0

The total annual cost would, therefore, be as follows:—

	£	s.	d.
Coal	2918	0	0
Wages	2014	0	0
Interest and re-payments on Capital cost in 100 years equal 3-616 per cent. on £31,320, equals ..	1132	10	0
Eight per cent. on Engines and Boilers and Compressors, or on £24,273, equals	1941	16	0
$2\frac{1}{2}$ per cent. on £7047, being Capi- Cost of House	176	0	0
Petty Stores equal to $\frac{532}{2}$ equals	266	10	0
Re-payments of Air Mains (for cost see table "D") calculated at 3.616 on capital cost of £18,204 equals..................	658	5	0
Four per cent. on cost of mains for repairs, equal to 4 per cent., £18,204	728	3	0
Total annual cost	£9835	4	0

HYDRAULIC POWER.

In the case of the hydraulic distribution of power the hydraulic plungers can be proportioned to the work that they would have to perform, so that there need be no loss, such as there was in the case of the compressed air. The efficiency of the engine pumps and ram may, from actual experience, at the pressure proposed to be used, namely, 750lbs. per square inch, be taken as equal to 70 per cent.

And the loss in the hydraulic mains can be ascertained from the formula—

$$H \text{ equal } K\frac{1}{d}\,\frac{2/V}{2Q}$$

Where 1 is the length of the main in feet h is the final head.

V is the velocity of the water in fee per sec. and k is a co-efficient varying from 0.024 to 0.048 according to the condit on of the pipe.

Estimating on the final head being 700 and the velocity through the mains as being 2.5 feet per second, the sizes of the mains have been arrived at (see table "E").

The loss through transmission would, therefo e, be 6.6 per cent., but with leakage probably not less than 10 per cent., so that at the central statin, in order to have 191 h.p. available at the sub-stations 212 h.p. will have to be available for transmission.

The efficiency of the pumps at the sub-stations being taken as 70 per cent. instead of 191 h.p., we should require 264 h.p., and after allowing for loss of pressure, 292, taking the efficiency of the central plants as being 70 per cent., the total h.p. therefore required will amount to 410, giving an efficiency of the whole scheme of 46 per cent.

The cost of the central station would be as follows:—

Engines,	419 x 1475	x £14	equals	8652	0	0
Pumps,	,, ,,	x £10	,,	6180	0	0
Boilers,	,, ,,	x £7	,,	4326	0	0
Buildings,	,, ,,	x £9	,,	5562	0	0
				£24,720	0	0

Assuming as before that half the total sewage is daily discharged in 6 hours, the annual h.p. hours would amount to 4380 x 419 quals 1,835,220 h.p. hours.

Taking the fuel consumption as before, namely, 4lbs. per indicated horse-power, there would be required 3277 tons of coal, costing, at 14s. per ton, £2293 18s.

The labour will be the same as for compressed air, viz., £2014.

By reference to table "E" the cost of the hydraulic mains is seen to be £35,909, and, taking interest and repayments at 3616 per cent., the annual liability would amount to £1398 9s. 3d.

Renewals and repairs at 4 per cent. would require £1436 7s. Petty stores as being equal to 10s. per annum per h.p. equals—

$$\frac{419}{2} \text{ equal } £209 \text{ 10s.}$$

Therefore, the total annual cost would be as follows:—

Interest and repayments on Capital Cost in 100 years equal to 3.616 per cent. on £25,720, equals	930	0	8
8 per cent. on cost of engines, pumps and boilers, renewals and repairs, or on £19,158, equals .	1532	12	9
2½ per cent. on £6562, being capital cost of buildings, equals	164	1	0
Petty stores, as above, equals ..	209	10	0
Repayments on mains equals.. ..	1398	9	3
Renewals and repairs to mains equals	1436	7	0
Wages..	2014	0	0
Coal..	3293	18	0
	£10,978	18	8

ELECTRICAL DISTRIBUTION OF POWER.

In the case of the electrically-driven pumps we can estimate the annual cost with more certainty, as the cost of the central station need not be estimated, the Railway Commissioners having agreed to supply the energy required at 1d. per B.T.U. The annual cost for energy, taking the efficiency as set forth in table "F," will amount to £5000, and the cost of mains, switchboard and electrical fittings at the sub-station will amount to £28,003. Taken as before, £3616 interest and repayments, and 4 per cent. for repairs, the annual cost would amount to £2132 14s. The annual expenses would, therefore, be as follows:—

	£	s.	d.
Cost of energy	£5000	0	0
Wages for attendant at Controlling Stations			
1 man at £300	300	0	0
2 men at £200	400	0	0
3 men at 8s. per day	419	0	0
Interest and repairs to Mains, Switchboards, Cables, etc.	2132	14	0
	£8251	14	0

It would thus appear that there is a considerable margin in favour of the electrically-driven pumps, and the average effiicency is higher than could have been obtained in either of the other schemes.

He would now give a description of the method adopted in controlling the electrically-driven pumps.

It was decided that eighteen of these stations should be controlled from one central station, situated at the intersection of Pyrmont and William Henry streets, this being also the site of one of the largest pumping stations, and the remaining two stations from a sub-station at Rushcutters' Bay.

Both pumps and motors are in duplicate at each pumping station; the sizes of the pumps and motors varied to suit the amount of sewage collected at the various stations.

The method of controlling the stations is as follows:— At each pumping station there are two large collecting wells into which the sewage flows; connected with these is a hollow cast-iron column, inside of which works a balanced porcelain float; this rises and falls with the level of the sewage in the wells.

This float actuates an electric switch. When the float has risen to the top of the column, and when it has sunk to the bottom, it allows a current from a battery to actuate a very delicate instrument situated in the controlling station, and shows the attendant the level of the water in the sewage wells, at the same time ringing a gong to call his attention. The principle under which this instrument is constructed is as follows:—There is a permanent magnet fixed horizontally, and an electro-magnet fixed vertically. The four poles (two to each magnet) are arranged round a centre, so that those of the permanent magnet are one on each side of the centre, whilst the two poles of the electro-magnet are one above and one below. Working on the centre between the four poles is a spindle carrying a specially-constructed armature, which consists of two light, soft iron plates, and to this same spindle is attached an aluminium pointer, which is arranged to pass over a suitable dial. On the left-hand side of the dial is the word "Empty," and on the right-hand side "Full." When the instrument is at rest—that is, when the pumps are at work emptying the sewage wells at the distant station—the pointer hangs vertically and points to the centre of the dial. It is caused to do so by the action of the permanent magnet, which, by means of its attraction, holds the soft iron plates in this position. When the pumps have emptied the sewage well, and the porcelain float, before referred to, has operated the switch, the current from the battery traverses the wire in the electro-magnet and makes it also magnetic. There are now, it will be noticed, two magnets acting at right angles to one another, and the practical result is the same as if a new magnet had been placed with its poles intermediate to the two magnets. The soft iron plates are immediately drawn round to this new intermediate position, carrying the aluminium pointer with them, causing it to point to the word "Empty," when the attendant cuts the current off and stops the pumps. The switch actuated by the porcelain float is so arranged that when the sewage rises it reverses the current, so when the sewage well becomes full the current acts in the reverse manner on the electro-magnet, and this has the effect of changing its polarity, so the pointer then flies over in the opposite direction to the word "Full." Thus, when the needle points to "Empty," the current will be switched off, and when the needle points to "Full," the pointer will be again started.

There is little doubt that the man at the controlling station will be able to observe nearly any defect that may arise in the running of the pumps.

He will be supplied with a sensitive ammeter in connection with each wire carrying current to the pumping stations, so that a variation of the power being consumed by the motors would be immediately noted. Thus, if a bearing become excessively warm, the power consumed in driving the pumps would be proportionately greater. Or, if the pumps for some cause (say, an obstruction in the suction pipe) were not doing their full work, the power consumed would fall below the normal. and the movements of the ammeter pointer would follow suit. Provision is also made at the controlling station so that the attendant can, by means of a specially arranged telephone communication, actually hear the machinery working at the different stations.

Means are also provided to enable the attendant at the head station communicating to any of the small staff of men who will be employed travelling from one station to another, looking after the oiling of the machinery, etc. For this end, a specially-devised switch is attached to the ladders in the pumping stations, so that on one of the staff entering a station the fact is made known to the attendant at the central station.

The starting of the pumps is carried out by cutting out resistances placed in the central station on the same principle as already explained for Double Bay.

In the central station, also, are placed automatic switches to cut out the current if for any reason it should become too heavy and liable to damage the motors. It must, therefore, be allowed that every possible precaution has been taken to safeguard the running of the pumps from a common point.

The pumping stations themselves are situated below the level of the ground, being built of concrete where the nature of the ground would permit, but in many cases cast-iron caissons have had to be sunk, on account of the bad ground and the excessive amount of water that would be encountered during construction.

These caissons are elliptical in plan, being 27 feet long by 20 feet broad, and 24 feet deep, weighing in all 80 tons each. They were erected above the ground, and then slung from a scaffold and lowered into position, the ground being excavated from the interior as the cylinders were lowered.

Over some of the pumping stations a small building will be erected, allowing light and air to the station below, but in some cases the stations have had to be constructed under the roads, and then the buildings could not be erected, and other provision has been made for ventilation.

The two largest stations are those situated at the intersection of William Henry-street and Pyrmont-street, and at Wentworth Park. These pumps are capable of raising 3200 gallons per minute. The pumps are of a very simple design, having hollow differential plungers, the sewage flows through the plungers, the area of the lower plunger being double that of the upper. Between the upper and lower plunger is cast an enlargement forming a valve chamber, in which is fixed a simple form of clack valve.

The foot valve is situated in the bottom of the casing in which the lower plunger works. By this arrangement the sewage traverses the pump continuously in the same direction, and the likelihood of any deposit taking place is reduced to a minimum. The dimensions of the pumps for the dfferent stations is shown in table "G."

The pumps are designed to make 48 revs. per minute, giving a plunger speed of 120 feet, but when running light the speed would beincreased to 180 feet per minute. The pumps are fitted with a double reductoin spur gearing with machine-cut teeth.

The pinions on the motor and intermediate shafts are made of compressed green-hide, with steel shrouds, the teeth being machine-cut.

These pumps are being manufactured by the Clyde Engineering Company under a guaranteed efficiency. The motors driving the pumps are being supplied by the Westinghouse Company.

They are of very substantial make, the armatures being of the slotted drum type, the cores being built up of laminated steel.

The field coils are compound wound, so as to give an almost constant speed under the variation of head that the pumps have to work against.

By reference to table "C" you will observe that there is a very considerable difference in the head when collecting tanks are either full or empty.

When the tanks are standing full, the head being very materially reduced, and the pump will then have a tendency to run slightly faster, but as the tanks are emptied the head will be increased and the speed of the pump reduced.

The electrical mains are partly underground and partly above. Where they are laid below the surface, Dalton conduits will be used, the cables being insulated witn paper and lead covered. Table "H" gives the approximate sizes of the cables, but they have been slightly modified, due to the alteration in the market value.

You will observe that there are three classes of cable, the heavily-insulated underground cable, the weatherproof cable for overhead work, and the bare copper returns.

You will also see by reference to table "F" that a constant drop of 10 per cent. is allowed in the line, whether the station is near the controlling station or some miles away. Now, this drop should be proportioned in such a way, between the three descriptions of cable, so that the cheapest possible combination may be arrived at, the more expensive cable being reduced in size and the cheaper increased.

Every precaution has been taken to ensure the safety of the underground and overhead mains.

The Dalton conduits will be laid to manholes having a maximum distance of 100 yards apart. The conduits will have a fall to the manholes and the manholes themselves will be properly ventilated.

In the construction of the sewers on the foreshores of Darling Harbour very great difficulties have been encountered. The subsoil is little better than silt, and much of the excavation had to be baled out with buckets. Moreover, provision had to be made for the interception of numerous old city sewers. Most of these sewers carry so much rain water that means had to be adopted to intercept the dry weather flow, and allow of the wet weather flow being discharged into the harbour. Specially-designed jumping weirs were introduced. These weirs consist of a pipe laid across the invert of the sewer, about $\frac{1}{3}$ of the pipe is cut away, so that during the dry weather flow the sewage is intercepted by the slot thus formed, but during the wet weather the water will jump this narrow opening. Means are provided so that elevation of the lip formed by this slotted pipe can be adjusted by turning the pipe around on its axis. Thus the weir can be altered to suit the grades of the various sewers that have to be intercepted. One of the largest of these sewers is known as the Lackey-street sewer. It commences near Liverpool-street, passes through the Belmore Park, and discharges into the head of Darling Harbour. This sewer carries an enormous amount of rainwater as well as sewage matter. It is 10 feet wide and 7 feet high. To pump the water flowing down this during wet weather would be out of the question, so that provision has to be made to intercept the dry weather flow and carry it to No. 1 pumping station.

Now, as the invert of this sewer is some 6 feet below high water it is obvious that means must be introduced to exclude tidal waters.

It, therefore, became necessary that tidal gates should be constructed across the lower portion of this sewer.

As it would have been impracticable on account of the size to have one gate, it was decided to put in three, elliptical in form, each being 5ft. 3in. high by 4ft. 3in. wide. The combined capacity of these three being equal to that of the sewer.

In order to ensure these gates not leaking and allowing the tidal waters to reach the pumping station, each gate is forced on to its seat by means of a hydraulic cylinder, worked from the ordinary pressure main.

But, as previously pointed out, it being impossible to cope with the wet weather flow, special provision had to be mode for releasing these gates during heavy rain. The cylinders are controlled by small piston valves, the valves being connected to levers which are regulated by floats. You will observe by reference to the drawings of this work that there are in all three floats, two being placed at a lower lever than the third one. Each of the two lower floats acts on a different piston valve, and either acting release the water pressure from the cylinders, but if from some unforeseen causes these should fail to release the gate, and the water continues to back up in the sewer, the third float will come into operation and release the doors. If, again, this float fails to act and the water rises still higher, the pressure on the gates will be increased due to the extra head, and this pressure will be transferred by the chain to the water in the hydraulic cylinders; this in its turn acts on an equilibrium valve and opens the exhaust from the cylinders, thus releasing the gates.

There are, therefore, four distinct methods of opening these gates, and as there are three gates there can be little risk of the water in the sewer not having a clear get-away. It may seem that unnecessary precautions have been taken, but it must be remembered that if these gates failed to act, in a very few minutes, during heavy rain, all the lower portion of Ultimo would be flooded.

It can be understood the great trouble involved in the construction of this valve chamber. Provision has to be made for getting rid of the dry weather flow, and also keeping the tidal waters out; some 40 feet of the existing sewer has to be bodily cut away. The contractors had to construct special temporary tidal gates to carry this work to a successful issue.

At the present time the frames of the flaps have been built in, and, therefore, the work involving the greatest risk of construction is completed.

Another sewer having a large dry weather flow discharging into the head of Darling Harbour has also to be intercepted and taken to the No. 1 pumping station.

This sewer commences in Devonshire-street, runs past the Ultimo Power-house, and discharges into Darling Harbour below the William Henry-street over Bridge.

It is 4ft. 6in. by 3ft. 6in., and during wet weather flows full. There is a third section of sewers flowing to No. 1 station; this latter section starts from near the Darling Harbour Meatworks, and intercepts all the sewers on the eastern slopes of Pyrmont.

These three sections are lead by separate sewers to the pumping station, and each section can be cut out by a hydraulic penstock. In the controlling station is placed