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SYDNEY AND SUBURBS LOW LEVEL SEWERAGE.

(By A. E. CUTLER).

Although the greater portion of the City of Sydney and its surrounding suburbs is drained by gravitation sewers, flowing direct either into the sea, or to a sewage farm or outfall treatment works, there are some large areas having so little elevation above the sea that special methods must be provided to intercept the sewage therefrom and prevent it flowing into the waters of the harbour as would otherwise be the case.

The total area of these low-lying districts is 2900 acres and the estimated future population thereon is 116,000, which would mean a daily flow of 5,800,000 gallons.

The first of these low-lying areas to be dealt with was the Double Bay Valley.

This valley has an area of 78 acres and the prospective population thereon is 2323, and with a sewage allowance per head of 50 gallons the average dry weather flow would amount to 80.62 gallons per minute.

The proportion of rain water admitted is estimated as being equal to that falling on an area of 200 square feet per head of the population, and the assumed maximum rainfall was taken as equal to 2in. per 24 hours.

It was also assumed that half the total daily sewage would flow off in 4 hours.

Therefore, the maximum combined flow would amount to 577.8 gallons per minute.

The first thing to be decided was whether it would be advisable to concentrate the sewage from this area to one point and there erect a pumping station to lift the sewage to the gravitation sewers, or have several small stations.

Before this point can be decided, the natural slope of the ground, the nature of the sub-soil, and the amount of water likely to be met with in the excavations must be known.

In the case of Double Bay, the land for the most part is situated about 7 feet above high water, and the sub-soil is peat and sand very heavily water-charged. Therefore, it was decided to construct four stations to which the sewage could be fairly easily lead, and to lift the sewage from these stations by means of Shone's automatic hydro-pneumatic ejectors.

Thus, comparatively shallow sewers could be constructed having good gradients, and the depth of the collecting wells at the stations would be moderate. Whereas, had it been decided to put down one pumping plant, the sewers must have been of much greater depth with a correspondingly deeper pump well.

In carrying out the work it was very soon seen that to have attempted to drain this valley to one point would have much increased the cost, as even at the moderate depths that the present sewers are laid very great difficulties were met during construction.

The total length of the sewers laid is 8117ft., comprising 7829ft. of 6in. and 288ft. or 9in. pipes. The grades vary from 1 in 200 on the level ground to 1 in 100 on the slopes abounding the area, while the velocities range from 1½ to 2ft. per second with the sewage flow. Automatic flushing stations are provided in suitable positions, which will have the effect of increasing the velocities to about 5ft. per second—a sufficient rate to cause thorough flushing. Ejector station No. 1 is at the intersection of Pelham and Cross streets; No. 2, at the corner of Cross and Bay streets; No. 3, in William-street, near Double Bay; and No. 4, on the Marine Parade, near Ocean-street. At each station the Shone's hydro-pneumatic ejectors are in duplicate, one ejector being ample to deal with the maximum sewage flow, while the pair working together are capable of discharging the maximum combined flow of rainfall and sewage. At stations Nos. 1, 3, and 4 the ejectors are each 50 gallons capacity, and at station No. 2 150 gallons. The ejector's stations and collecting wells alongside are of cast-iron. The collecting wells are 4ft. diameter of ¾in. metal, and receive the sewage from the different collecting sewers. The ejector chambers are 10ft. diameter, except No. 2, which is 12ft. They are constructed of cast-iron segmental plates 1in. thick, bolted together through vertical and horizontal flanges, strengthened by gussets. The bottom section is strengthened by cross girders of H. section, bolted to a wider flange running round the cylinder 12in. from the bottom. After the cylinders were sunk to the required depth, the bottom was filled in with concrete between the H. girders. To these the ejectors are secured. The upper portion of the chamber, being above the water level, is composed of concrete, which sits on the top flange of the cylinder. It is built with a decrasing diameter, finishing at 4ft. 6in. at the surface. This allows sufficient room to remove the ejectors, if required for repairs. The opening is closed with a cast-iron manhole door. Ventilating shafts are provided near each collecting well to carry off the sewer gas. The ventilation at these shafts is naturally assisted by the discharge of the exhaust air from the ejectors through a nozzle into the shafts. The air and delivery mains are of cast-iron, the Normandy joint being used in the air mains, and ordinary spigot and faucet in the delivery mains. The Normandy joints have proved to be highly satisfactory; no leaks were discovered when these mains were tested. Both the air and delivery mains are in sections, so that any branch can be cut out in case of an accident. Means are provided for emptying the delivery mains into the sewers when repairs have to be effected.

The ejector is a simple form of pump for crude, unstrained sewage. It is a closed, cast-iron vessel, with inlet pipe and inlet valve, and outlet pipe and outlet valve. There is also an air valve worked by a float. The sewage flows in by gravitation until the ejector is full. At that moment a bell-shaped float, contained within the vessel, rises and opens the air valve. The compressed air supplied from the central station entering the ejector, the pressure of this on the surface of the liquid in the tank closes the inlet valve, and forces the sewage through the outlet valve up to the high-level sewer. When the level of the sewage in the vessel falls, it leaves unsupported a float placed near the bottom; this float acts upon the air valve, closing it, and allows the ejector to again fill. The whole operation takes about half a minute.

The ejectors discharge the sewage into a branch of the main northern sewer, the total lift amounting to about 56ft.

The central station, from which the compressed air for working the ejectors is provided, is situated off Bay-street, near Swamp-street, and consists of a one-storey brick building with sandstone facings.

The estimated maximum h.p. required is 8.83, and, assuming the efficiency of the whole system at 35 per cent., the indicating h.p. at the generating station would be $25\frac{1}{2}$.

The air compressing plant consists of two Parker continuous current shunt wound motors actuating two air compressors. Space has been left for the duplication of this machinery when an extension of the sewerage system requires it. The motors are each capable of developing 25 h.p., at a speed of 470 to 500 revs. per minute, when supplied with a current pressure of 500 volts. One motor is, therefore, when running at full speed capable of performing the whole work. By arrangement with the Railway Commissioners, the electrical energy is supplied through a 19/16in. cable from the power-house at Rushcutters' Bay at a cost of one and one-third pence per B.T. unit.

The air compressors have 11in. cylinders and 18in. stroke, the cylinders are water jacketted, and sprays are also provided.

The inlet valves are opened and the outlet valves closed mechanically.

The air receivers are of mild steel with segmental ends 4ft. 6in. internal diameter and 9ft. high. They are fitted with manholes, and dead weight safety valves regulated to blow off at 35lbs. pressure. The inlet and outlet pipes are 6in. diameter, the former extending upward in the centre of the vessel about 5ft., and the latter has its mouth protected by a cast-iron baffle. The spray water by these means is separated from the air and discharged by a trapped drain pipe in the usual way. The motors and compressors, by working in parallel or series, can be run at half or full speed. To acomplish this, and also to ensure the safe starting of the motors against a maximum load, a series parallel controller has been designed which allows the current at starting to pass through a series of resistances which are cut out step by step. As the work to be performed is so variable, necessitating the air compressor being run to suit the flow of sewage, means have been provided by which, when the pressure has either risen or fallen between certain fixed limits, the machinery will be automatically stopped or started. The maximum pressure decided on was 28lbs., and the minimum 20lbs., the latter being the smallest pressure which would lift the sewage from the ejector stations to the gravitation main, and the former being as high as the pressure could be economically used. It became necessary, therefore, that the series-parallel controller should be automatically governed so that the pressure should be maintained between these two limits.

Placed on the wall of the engine-room is a small air cylinder fixed horizontally. About 4 feet away, and standing vertically one above the other about 3 feet apart, are two small hydraulic cylinders, also secured to the wall. They are so placed that a prolongation of the bore of the air cylinder would exactly fall midway between the two hydraulic cylinders. Each hydraulic cylinder contains a plunger, and secured to and connecting the plungers is a die-plate. Thus, if the lower plunger was being forced out of its cylinder, the upper one, of a necessity, would be forced in.

The pressure for working these hydraulic cylinders is obtained from the ordinary water main.

In the small air cylinder before mentioned is a piston, the rod of which passes through the cylinder cover. To the end of the piston rod is secured a toothed rack, which gears with a toothed wheel or pinion on the head of the controller spindle.

On the upper side of the rack is fixed a square bar, having square stops or projectors standing out from both sides; these stops correspond with the different points that the controller must pause at whilst cutting the resistances out.

In the die-plate fixed to the hydraulic cylinders are teeth cut, and the square bar carrying the stops passes through the die-plate. The teeth in the die-plate are arranged in such relation to the stops on the bar that if the die-plate is made to move either up or down by putting pressure on to one or the other of the hydraulic cylinders, and the compressed air is allowed to act on the piston of the air cylinder, one stop on the bar will be forced between two of the teeth on the die-plate, the next stop hitting the die-plate and thereby checking the movement of the rack, and, therefore, also the controller spindle; when, however, the die-plate is moved a little further, this stop passes through, and the next will hit the die-plate. Thus, an intermittent motion is given to the controller spindle and the pauses attained, which are required in cutting out the resistances.

The whole of this mechanism is in its turn controlled from a central valve, so constructed that it will rise at 28lb. pressure, and not fall until the pressure has been reduced to 22lb. The rising and falling of this valve turns the air pressure to one or the other side of piston, and at the same time the water pressure on to the upper or lower hydraulic cylinder. Thus, the whole process of stopping and starting this plant is automatically carried out.

The central valve also controls a small hydraulic cylinder which opens and closes the compressor jacket circulating water supply valve.

The general arrangement of the machinery is such that either of the motors, compressors, or receivers can be cut out, or both the motors can be run in series, driving either one or both of the compressors at half speed.

The air delivery pipes are in duplicate throughout, so that it is almost impossible for a breakdown to occur which would seriously affect the supply of compressed air.

The spur wheel on the counter shaft driving the compressor gears into a green-hide pinion placed on the motor shaft, and although the teeth on the spur wheels are not machine cut, these pinions have run constantly for the last 18 months, showing practically no signs of wear, and the gear is almost noiseless. When the plant was first started phosphor bronze pinions were used, but the wear was very considerable, and they made so much noise that green-hide pinions were substituted with complete success.

A storage battery has been installed, consisting of 230 Epstein cells. The primary duty of this is to provide power to run the plant at night when the tramway plant is not available, and, secondary, during ordinary running to reduce the drop in the line between Rushcutters' Bay and Double Bay. The battery is always switched on, so that when the machinery is running the motors obtain their energy partly from that and partly from the line. As soon as the motors are stopped the batteries start charging, making up for what has been used whilst running. In addition to the advantages derived in this way from the battery, it was possible to materially reduce the areas of the cable.

A switchboard is provided with all the necessary fittings, including recording ammeter, voltmeter (with connections to line or battery), ammeter to each motor, polaised battery ammeter, and all the necessary quick break switches, cut-out plug fuses, and electric light circuit connections.

Taking the average annual rainfall at 51,522 inches, the quantity of sewage and rainfall to be pumped would amount to 54,846,137 gallons per annum, and the h.p. hours expended, taking the efficiency of the whole plant as 34.8 per cent., would be 35,371. The cost of electrical energy would, therefore, be £147 7s. 6d. per annum, and the cost (including energy, wages, and 6 per cent. per annum on capital cost for repairs and renewals) of lifting 1000 gallons would amount to 5688 pence with present population, and 3991 pence with future population.

EFFICIENCY TESTS OF PLANTS.

In order to obtain efficiencies of the plant, tests were made under ordinary working conditions on February 13th, 14, 15th, and 16th, with one air compressor and all the ejector stations working. Each day before starting a man was placed at each ejector station to count and keep tally of the number of times the ejector discharged, from the time of starting to the finish of each trial, and the capacity of ejectors being known, the number of gallons of sewage discharged by each station could be readily computed. From this, and the total lift, the work performed was obtained. The compressor was kept going at a uniform speed of 50 revolutions per minute, which maintained an average air pressure of 20lb. per square inch in the receivers. Indicator diagrams were taken off the compressor at intervals in order to obtain the average i.h.p. developed. On starting the plant each day the reading off the Watt meter at Double Bay station was taken when the air pressure had risen to 15lb. per square inch, and simultaneously a reading was taken off the Watt meter at Rushcutters' Bay generating station. Readings were also taken off both Watt meters at the end of the day's trial. By this means a record was obtained of (a) the electrical energy which left the generating station at Rushcutters' Bay; (b) the loss of energy in the line; and (c) the energy used by the motor at the Double Bay power station. The loss of efficiency due to drop in the temperature was obtained under normal working conditions by taking the temperature of air leaving the compressor and at each ejector station. On the first day the trial was taken for a period of two hours; and the second day two hours; and on the third day one hour and twenty-five minutes. On each of these days it was found that Nos. 3 and 4 stations were pumped out shortly after starting, as tnere was not sufficient sewage flowing into them to keep them working continuously for the same period as the other ejectors. On the following day the flushing stations and a couple of hydrants were turned into the sewers, and by that means a constant flow was maintained, enabling all the ejectors to work continuously during the two hours and twenty minutes. The conditions, therefore, under which the latter test was made were more satisfactory than the first three, and the efficiencies which are given in the table A below, were based upon this day's results. It may be mentioned that when taking these tests with one compressor at fifty revolutions per minute the plant was practically developing only one quarter of its full power. With the maximum quantity of sewage to be lifted the plant might reasonably be expected to give a slightly higher efficiency.

Table A gives particulars of the work to be performed and table B the results of the tests.

The whole of this plant was designed in the Sewerage Construction Branch, and, with the exception of the motors, manufactured in the colony.

As previously stated, the plant has been running 18 months, without any repairs having been found necessary, and the automatic controlling gear has worked with clock-like precision.

The low-level scheme which I will now describe is of very much greater extent than that of Double Bay, embracing, as it does, all the low-level areas from Rushcutters' Bay to Balmain.

There will be in all 20 pumping stations, and the total amount of sewage to be dealt w... will be 6675 gallnos per minute, the combined areas drained amounting to upward of 1700 acres, carrying a prospective population of 70,000 persons.

The localities fixed for the pumping stations are as follows:—

No. 1. Intersection of Pyrmont and William Henry streets.
,, 2. Wentworth Park.
,, 3. Johnstone's Creek, near Booth-street.
,, 4. Johnstone's Creek, near Piper-street.
,, 5. White's Creek, near Brennan-street.
,, 6. Abattoir-road, Balmain.
,, 7. Roberts-street, Balmain.
,, 8. Reynold-street, Balmain.
,, 9. Stephen-street, Balmain.
,, 10. Mort's Bay, Balmain.
,, 11. Snail's Bay, Balmain.
,, 12. Washington-street, Darling Harbour.
,, 13. Sewerage Reserve, Darling Harbour.
,, 14. Hume-street, Darling Harbour.
,, 15. Pottinger-street, Dawes' Point.
,, 16. Circular Quay.
,, 17. Nicholson-street, Woolloomooloo.
,, 18. Rushcutters' Bay.
,, 19. Elizabeth Bay.
,, 20. Darling Island, Pyrmont.

Before this work was initiated very careful consideration was given to the possible means of raising this sewage from these low-level areas, as it was seen that the annual cost must of a necessity be high, and the scheme to be adopted should be the one that reduced this to a minimum. After very careful calculations had been made, it was finally decided to adopt double-acting differential plunger pumps driven by electric motors.

Table "C" gives the actual work to be performed at each station. Column 10 shows the amount to be pumped, and column 11 the amount that will have to be pumped per minute to produce 4ft. vel. in the rising main, as it was decided that the velocity in the rising mains should not be less than 4ft. per second in order to prevent the possibility of any silting taking place.

And in order to arrive at the most economical method of dealing with the sewage of the above-mentioned localities, calculations and estimates of the different methods thta might be employed were made. The methods considered were as follows:—Hydraulic pumps, Shone's hydro-pneumatic ejectors, pumps driven by means of electric motors (the power being supplied by the Railway Commissioners at a cost not to exceed ¾d. per h.p. hour).

He would give a short abstract of these calculations to show on what basis the decision of the Department was arrived at.

For purposes of comparison, we may assume that the actual cost of istalling the machinery in the 20 sub-stations will not materially differ whether Shone's ejector hydraulic pumps or electrically-driven pumps are used, and, therefore, the capital cost of this portion of the work will not be considered at present, although later on an allowance will be made for the Shone's ejectors, which would cost slightly less than the other methods.

Also, no notice has been taken of the supervision at the sub-stations, as it is considered that this item will be very nearly the same for either method, all three methods being automatic.

In fact, any method that could not be automatically controlled was not considered, as the staff required to keep each sub-station running night and day would be very large, and the anual cost for wages would amount to about £10,000.

COMPRESSED AIR.

The losses in the compressed air plant would be as follows:—Loss by friction in main engines and compressors; loss by drop into the ejector; loss in ejector, air not being used expansively; loss through heating air during compression; loss by friction in air mains; loss through leakage.

Of all these losses only two can be caluclated with any degree of accuracy.

The loss due to the compression of the air in the compressors (the air being assumed to be compressed isothermally) and the loss through using the air non-expansively in the ejectors expressed by the formula—

where P a equals atmospheric pressure
in lbs.
P I equals absolute pressure in lbs.
and Z equals resulting efficeincy.

$$Z = \frac{1 \quad \frac{P\,a}{P\,1}}{\log.\ E\ \frac{P1}{Pa}}$$

where P a equals atmospheric pressure
in lbs.
P 1 equals absolute pressure in lbs.
and Z equals resulting efficiency.

Also the loss through friction in the airmains expressed by the formula—

$$Pia \text{ equals } Pa \frac{2/VWL}{222900a}$$

Pi and Pa being as before.

V if a co-efficient arrived at by experiment, which for the size pipes under consideration would be .0045.

W the velocity of the air in feet per sec.

L the length of the pipe in feet.

By reference to table "C," columns eight and nine, it will be seen that the heads vary from 93 to 37 feet, but we will assume that if compressed air was to be used Station 11 can be modified so that a pressure equal to a 80ft. head will be sufficient to lift the sewage and give the required velocity in the rising main. One objection, therefore, to the use of compressed air and Shone's ejectors is that as the pressure must be sufficient for the