CHAPTER III.

SEWAGE LIFTING.

It is not within the scope of the present work to give a complete treatise on pumping machinery, but a few words may be said on the subject to guide the sanitary engineer in selecting the type of machine most suitable for his purpose.

Broadly it may be said that almost any pump can be made to lift sewage, but those with the smallest number of joints and with the largest water-ways and most simple valves are best. It is also necessary that the pump should be capable of wide variations in rate of delivery owing to the great fluctuations of flow in the liquid to be lifted.

Provided the lift is not too great the centrifugal pump is greatly in favour. Such pumps need have only one valve, which may be made of the full water-way of the suction or delivery pipe, and as the pump is of a rotary type this valve is constantly open whilst pumping is going on, so that the wear and tear is reduced to a minimum. The only joint to be kept tight is the spindle gland, and the pump is capable of great variations of delivery with comparatively small difference in speed. The pump is also useful for thorough mixing of chemicals where these are added to aid precipitation, and tends to break up all floating matter which may have passed through the screens.

It may be objected that this form of pump does not give such a high mechanical efficiency as a reciprocating type of pump and that it is liable to be damaged by hard materials in the sewage. In practice the latter objection is found to be immaterial, and it is surprising what will pass through a centrifugal pump. Any loss of efficiency is fully compensated by the other great advantages named, and most satisfactory results are obtained by this class of pump, especially when cost of maintenance is taken into consideration.

At the same time reciprocating pumps are often used for sewage pumping, and where high lifts are required they give greater economy than rotary pumps. Pumps of the plunger type are to be preferred to piston pumps, as the grit in sewage scores the cylinders of the latter and it is difficult to keep the piston rings tight. Great care should be
SEWAGE LIFTING.

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bestowed upon the design of the valves, which should be few in number and easily got at.

One of the chief difficulties in arranging pumping machinery is the great variation of flow in the sewers. Where the sewers are upon the combined system and all rainfall has to be pumped, this variation is so great that it is impracticable to deal with it, and overflows must be provided which will relieve the pumps after a certain point is reached.

The requirement of the Local Government Board that six times the dry weather flow should be treated before being discharged into rivers has fixed the limit for pumping machinery to that amount, but when it is borne in mind that during the night the rate of flow is not more than half the normal and may be less, it will be seen that the machinery must be capable of pumping the minimum flow, or twelve times that amount.

In large works this great variation can be met by having a large number of units, and in small works it can be minimised by having reservoir accommodation for the night flow and making the pumps big enough to pump out the dry weather flow in a comparatively few hours, but this arrangement interferes with the rate of flow through the purification works, which should be kept as regular as possible. It is, therefore, a choice of evils to have a number of pumping units or excessive purification works.

Pumping machinery should always be duplicated and stand-by plant provided to deal with emergencies and break-downs, and therefore, in order to meet the great fluctuation and this requirement it may be taken as a general principle that where the sewage is to be purified the pumping plant should consist of at least three units, and these should be of such power that the best efficiency can be obtained. This will be when the capacities of the units are in the proportion of two, four, and six times the dry weather flow. Thus the small unit will be used for ordinary work and will deal with the hourly fluctuations of the dry weather flow without difficulty. When storm-water has to be dealt with the middle unit can assist the small one. When the small unit is under repair, the middle unit can take up its duty of ordinary work whilst the third unit alone can act as a stand-by for the whole plant.

The motive power may be steam engines, gas engines, oil engines, and electric motors. Since the introduction of suction producer-gas plants the gas-driven engine has become specially adaptable for sewage pumping as it can be installed at sewage works which are at a distance from the supply mains of ordinary coal gas; if, however, gas mains can be reached it is useful to have a connection laid on, as it gives greater elasticity to the plant and enables units to be started in the event of sudden rainfalls when sufficient producers are not under gas.
When designing sewerage schemes for very flat districts it frequently happens that the main trunk sewers become so flat in gradient and, through continual extensions, have come so near the surface that sufficient fall cannot be given to the branch sewers. In such cases it is a great advantage to be able to lift sewage at several separate points. Obviously the cost of establishing independent pumping stations at several places involves great cost of attendance out of all proportion to the work to be done.

In order to meet this condition of things a system of power distribution from a central station to the pumping centre is required, and this may be done by using as the distributing medium—

1. Electricity.
2. Hydraulic power.
3. Compressed air.
4. Vacuum.

In these days of universal electric lighting and electric power schemes there are many towns where the necessary electric mains and power are already at hand, and there should be no difficulty in designing an automatic starting and stopping gear, operated by floats and relays, which would enable electric motors to be used for driving the necessary pumps of the rotary type for this purpose. Where such
electric mains are not already at hand the cost of laying them is a very important item.

Up to the present time this system has not been used to any large extent, and apparently sewage-works engineers have not thought it worth while to seriously consider this method of sewage lifting.*

A variation in the application of this source of power might be effected by using the electric motors to drive independent air compressors at isolated stations, the sewage being then lifted pneumatically.

Pumping by hydraulic power, distributed from a central station, is carried out at Esher in a scheme designed by Mr. Baldwin Latham, M.I.C.E., but so far as the author is aware this is the only installation of its kind, and as no further development of the system has been carried out it does not appear to meet with much favour.

The use of compressed air as the transmitting agent was first worked out into a practical system by Mr. Isaac Shone by ejectors worked by pneumatic power.

The ejector (Figs. 24 and 25) is simply a large iron pot or vessel placed under the roadway into which the sewage of the district flows until it is full, when compressed air is automatically admitted on top of the sewage, ejecting it in a few seconds into the main outfall sewer—the process repeating itself automatically as long as there is sewage to flow. It is the invention of this apparatus which has rendered the distributed station system practically attainable.

Fig. 26 (p. 56) gives a sectional view of a Shone pneumatic ejector of ordinary construction, suitable for raising water, sewage, sludge, chemicals, and hot fluids of all kinds. Ejectors are made of any size or shape convenient for the special circumstances for which they are required. For sewage, sludge, pail contents, preference is given to those having the lower portion of hemispherical shape.

The motive power employed is compressed air, and the action of the apparatus is as follows:—

The sewage gravitates from the sewers through the inlet pipe A into the ejector, and gradually rises therein until it reaches the underside of the bell D. The air at atmospheric pressure inside this bell is then enclosed, and the sewage continuing to rise outside and above the rim of the bell compresses the enclosed air sufficiently to lift the bell, spindle, etc., which opens the compressed air admission valve E. The compressed air thus automatically admitted into the ejector presses on the surface of the sewage, driving the whole of the contents before it through the bell-mouthed opening at the bottom, and through

* At Blackpool electric pumps are used to pump storm-water at tide time and these are automatically started by means of floats, and at Norwich the night flow of sewage is similarly dealt with.
the outlet pipe B into the iron sewage rising main or high level gravitation sewer, as the case may be. The sewage can only escape from the ejector by the outlet pipe, as the instant the air pressure is admitted on to the surface of the fluid the valve on the inlet pipe A falls on its seat and prevents the fluid escaping in that direction. The fluid passes out of the ejector until its level therein reaches the cup C, and still continuing to lower, leaves the cup full until the weight of the liquid in the portion of cup thus exposed and unsupported by the surrounding water is sufficient to pull down the bell and spindle, thereby reversing the compressed air admission valve, which first cuts off the supply of compressed air to the ejector and then allows the air within the ejector to exhaust down to atmospheric pressure. The outlet valve then falls on its seat, retaining the liquid in the
SEWAGE LIFTING.

sewage rising main; the sewage then flows into the ejector through
the inlet once more, driving the free air before it through the air-valve
as the sewage rises, and so the action goes on as long as there is sewage
to flow.

The position of the cup and bell-floats is so adjusted that the
compressed air is not admitted to the ejector until it is full of sewage,
and the air is not allowed to exhaust until the ejector is emptied down
to the discharge level.

The compressed air for actuating the ejector is produced at some
central station, and conveyed in cast or wrought-iron pipes laid under
the streets to the several ejector stations.

In this apparatus, the working parts are reduced to a minimum,
and those of a kind not likely to get out of order. The parts into
which the sewage enters contain no tooled surfaces, such as are
unavoidable in pumps, and get rapidly destroyed by the action of the
sewage sludge and grit from road detritus, etc. In the ejector there
is nothing but the hard skin of the castings, coated with Dr. Angus
Smith's composition, upon which the sewage can produce no detrimental
effect. The apparatus is therefore very durable.

The friction of a pump piston and other working parts is
avoided, the compressed air itself acting direct upon the fluid, without
the intervention of any machinery, and forming an almost absolutely
frictionless and perfect air piston, past which there can be no slip or
leakage whatever.

The cup and bell-float arrangement is one that cannot get out of
order, as an ordinary rising and falling float would be liable to do.

The only tooled parts are those in connection with the small
automatic air-valve, which makes only one movement, of two or three
inches, for each discharge of the ejector (according to the size of the
ejector), and is only in contact with the compressed air, and out of
reach of the sewage.

The sewage inlet and outlet valves are so arranged as to give a
passage-way of the full area of the pipe, allowing a free passage to all
the solids that the pipe itself can carry.

The outlet is from the bottom of the ejector, so that the whole
of the sewage, including solids, sludge, grit, and everything brought
down the sewer, is discharged out of the ejector.

For these reasons, no screening or straining of the sewage is
necessary, as is the case with pumps, and the great nuisance caused
by the cleaning of pump gratings and sump wells is avoided.

The sudden rush of the whole contents of the ejector, when the
discharge is into a main gravitating sewer, forms a most effective flush.

The ejectors are in successful use at Warrington for the transmission
of pail contents from central depots in the town, through 2½ miles of cast-iron main, to the works at Longford, saving the Corporation over £1,200 per annum in cartage alone; and at Southampton for transmission of sludge through a length of 1,500 yards of 4-inch cast-iron main. They are also in use at Eastbourne, Southampton, Warrington, Norwich, Ipswich, Felixstowe, Staines, Henley-on-Thames, Bombay, Karachi, Cape Town, Wellington (N.Z.), Arad (Hungary), and many other places in this country and abroad.

In towns where the solid refuse—ashes from private house bins, etc.—is destroyed by fire in specially constructed furnaces, the resulting heat may be utilised for generating steam to work air compressors, and the site of the refuse destructors may be used for the compressing station, as has been done at Southampton and other places; or the compressors may be placed at the gas or waterworks, or other site where steam or water power is available.

Shone's hydro-pneumatic ejectors have also been applied at Rangoon, and the following is a description of the system as there carried out (Plate XIV., p. 60):—

A gravitation system of sewage per se for a perfectly flat and tide-locked city like Rangoon was naturally found impracticable, and could not, under any circumstances, be recommended on sanitary grounds. After considerable inquiry by the municipality, it was decided, with the approval of the Government of India, to adopt the Shone system as being the only known system by which the city could be properly drained on sound sanitary principles.

The works were commenced in February, 1888, and completed by March, 1890.

The city proper is divided into 22 sub-sections, or ejector districts, and within each of these districts is placed, in as convenient and suitable a position as possible, an ejector station, in which are placed two ejectors, each of 200 gallons capacity; one ejector in each station being capable of doing the maximum work, the other being in reserve in case of accident.

All gravitating sewers converging and discharging to the several ejectors are of 6 inches diameter, cast-iron spigot and socket connections, and are laid throughout with steep gradients, none being flatter than 1 in 200; the total length of gravitating sewers being about 22 miles.

The junctions for connection to the houses are 5 inches diameter, and have been carried in all cases above the water level in the subsoil.

For the purpose of temporarily disposing of the excreta from the houses not yet connected with the gravitating sewers, 130 night soil
SEWAGE LIFTING.

Depôts have been erected and connected with the sewers in the back drainage spaces, to which depôts the excreta is carried in ordinary pails by the conservancy, and there discharged into a large trough, from whence it flows into the sewers and gravitates to the ejector stations.

At the head of each length of gravitating sewer is placed a 200-gallon flushing tank, regulated to discharge automatically once or twice a day, or as often as experience shows it to be necessary, to keep the sewers perfectly clean and free from deposit.

The sewage is discharged to the outfall at a level of three feet below the lowest tide through cast-iron sewage mains of various sizes, commencing at 6 inches diameter at No. 1 ejector station, and gradually increasing in size until they are finally 21 inches diameter from No. 20 ejector station to the outfall.

The total length of sewage rising main is nearly six miles.

The Supplementary High-pressure Water Supply forms a portion of the combined scheme carried out in Rangoon. The water gravitates from the Royal Lake into twelve of Shone's 500-gallon ejectors, from whence it is ejected by pneumatic pressure of 27 lbs. per square inch into the 27-inch water main, thus giving an additional head of 62 feet to the water delivered in the city.

The whole of the sewage and water ejectors are worked by compressed air, produced at the compressing station, situated in Dalhousie Street, nearly opposite the New Government Offices. The compressing machinery consists of—

Three complete sets of triple expansion steam engines, each engine having three air compressing cylinders 16 inches diameter, 24 inches stroke. The steam cylinders of each engine are of the following dimensions:

- High-pressure cylinder ... 12 in. diameter, 24 in. stroke.
- Middle " " ... 16\(\frac{1}{2}\) " 24 "
- Low " " ... 21\(\frac{1}{2}\) " 24 "

and are arranged in front of the compressing cylinders, so that each steam cylinder drives a compressing cylinder direct.

Each engine is able to work up to 150 indicated horse-power.

There are five Lancashire steam boilers, each 22 feet 6 inches long, 6 feet 6 inches diameter, with two internal flues 2 feet 6 inches diameter, fitted with three Galloway tubes in each boiler, and standing a working pressure of 150 lbs. per square inch.

Two air receivers, 24 feet long by 8 feet diameter.

Two Atkinson's feed water heaters.

Two donkey feed pumps.

The cast-iron air mains for sewage and water ejectors commence
at 10 inches at the compressing station, and are ultimately reduced to 8 inches diameter, with a total length of about six miles.

Gasport Sewerage Works.—In a paper presented to the Institution of Civil Engineers by Mr. C. L. Cox,* particulars are given of a series of tests made with the object of ascertaining the efficiency of the Shone system of pumping in actual working conditions at the Gasport Sewerage Works.

The system of sewerage there was designed to utilise the Shone system of lifting in a very complete manner, there being 18 ejector stations and the whole of the sewage being dealt with by this means.

The air mains varied from 2½ inches to 12 inches diameter and were 11 miles in length; they were tested in sections with a pressure of 40 lbs. per square inch, the working pressure being 22½ lbs. per square inch.

There must always be some leakage of air in its transmission to the ejectors, and a test was made to ascertain what this loss would amount to. It was found that the loss of air in the mains and also in the automatic alternating and stop valves at the ejectors was equivalent to 12½ per cent of the total power developed and that for the mains alone the leakage was about half the above figure.

The tests made showed that the total sewage lifted during a six hours test on May 3, 1906, was 351,300 gallons, the average lift being 38'34 feet and the actual pump horse-power 11'34.

The power developed by the steam engine driving the air compressors during the same period was 29'50 indicated horse-power.

The actual efficiency of the system from steam cylinder to ejector was therefore \( \frac{11'34}{29'50} = 0'384 \), which for such a system must be regarded as a satisfactory result.

The computation of the subdivision of the losses is given in the following tabular statement and is of interest.

<table>
<thead>
<tr>
<th>Date</th>
<th>Mechanism E₁</th>
<th>Compressed Air E₂</th>
<th>( E₂ - E₁ \times E₂ )</th>
<th>Loss by Leakage E₄</th>
<th>Loss of Efficiency of Air in passing through Mains E₅</th>
<th>Efficiency of Air at Ejectors E₆</th>
<th>Computed Efficiency P.H.P. E₇</th>
<th>Actual Efficiency P.H.P. E₈</th>
</tr>
</thead>
<tbody>
<tr>
<td>May 1st</td>
<td>0'930</td>
<td>0'838</td>
<td>0'900</td>
<td>0'875</td>
<td>0'953</td>
<td>0'754</td>
<td>0'407</td>
<td>0'384</td>
</tr>
<tr>
<td>May 10th</td>
<td>0'971</td>
<td>0'902</td>
<td>0'900</td>
<td>0'875</td>
<td>0'953</td>
<td>0'754</td>
<td>0'407</td>
<td>0'385</td>
</tr>
</tbody>
</table>

When designing works upon this system it would appear that the most economical air pressure to work to is 15 to 20 lbs. per square inch and

SEWAGE LIFTING.

that it is cheaper to introduce a second lift rather than to work to a higher pressure.

As an example of a town where the Shone system is carried out and deals with the whole sewage of the town, Karachi may be mentioned. The number of ejector stations installed was six, dealing with a population of 30,000 persons. Each station contains duplicate ejectors 200 gallon capacity, and they deliver against a total head of from 65 feet to 70 feet.

The air mains are from 6 inches to 5 inches diameter ordinary cast-iron pipes laid with lead joints, and they were tested at 60 lbs. per square inch pressure, the working pressure being an average of 37 lbs. per square inch. The delivery pipes were cast-iron turned and bored jointed pipes varying from 7 inches to 12 inches diameter.

The sewers were designed on the separate system and take sewage only, 15 gallons per head being the quantity estimated for and they are partly cast iron and partly earthenware pipes of 5 inches to 9 inches diameter.

Tests made at the completion of the works showed a net efficiency between indicated horse-power of compressor engines and water lifted of 0.9257; the efficiency of the engine and compressor was 0.819 and of the air mains 0.984.

Mr. J. F. Brunton, the municipal engineer of Karachi, communicated some notes on the working of the system to the Institution of Civil Engineers* from which these particulars are taken.

The works were in operation early in 1885 and trials made in August and September, 1901, showed that the efficiency of the mechanism was 0.820, but that of the whole system it had fallen to 0.185.

The sources of unavoidable loss between engine and ejectors in the Shone system of working are:—

1. Friction of the mechanism of engine and compressors.
2. Heating of air during compression.
3. Slip and clearance in the compressor.
4. Leakage in air mains and in the automatic valves controlling the air supply to the ejectors.
5. Slip and clearance in the ejectors.
6. Impossibility of working air expansively in the ejectors.

Mr. Brunton found that the loss under the first two heads combined was 28 per cent. giving an efficiency of 0.72, and the loss in the air mains was over 5 per cent.

He estimated the losses under heads 3, 4, and 5 at 7 per cent., if the plant were working properly, which would give an efficiency up to the ejectors of 0.650, whereas the tests of 1901 showed an efficiency of 0.335 only.

Efforts were then made to stop the waste of air with the result that

considerable improvement took place in the working of the installation, the efficiency up to the ejectors rising to 0.439 and that of the whole process from steam cylinder to water lifted being 0.323.

From a table attached to the paper it appears that in 1903-4 the cost per 1,000 gallons of sewage lifted was about 1.63d.; this figure did not apparently include anything for capital charges.

The coal consumption was 7.28 lbs. per 1,000 gallons, costing 0.81d.; the coal used was Yorkshire coal of fair quality.

When comparing these figures with other methods of pumping the cost of coal and the local conditions of labour must be borne in mind.

During the discussion on this paper it was stated that at Bombay, where four ejectors are at work with an air pressure of 22 lbs. per square inch, the efficiency of the system varied from 0.21 to 0.24.

The advantages of having a means of raising sewage at several points widely distributed are obvious when dealing with the sewerage of a town built upon flat ground such as is often found in a wide estuary at the mouth of a large river.

Where such a system can be made available it is possible to divide the town into separate drainage districts each with its pumping station raising the sewage either to a separate outfall or to a combined outfall.

By this means small pipes can be used and they can be laid at good gradients without making deep cuttings, the quantity of water required for flushing purposes can be reduced to a minimum, and new areas can be added as they become populated.

The pneumatic system of sewage lifting has now been in use at a large number of towns for a great many years, and may be regarded as the most satisfactory method of pumping at different points from a central station.

The system when first introduced by Mr. Shone was covered by patents which have now run out, and the necessary plant which was at one time only made by Messrs. Hughes and Lancaster is now manufactured by Messrs. Manlove and Alliott, Messrs. Goddard, Massey, and Warner, and by Messrs. Adamson and Son.

Adams' Air Lift.—Cases often occur in practice where small areas in the drainage system are below the general level of the sewers, or when designing new works where it could be possible to gravitate the sewage to a certain site were it not for a few isolated houses which are at too low a level.

In such cases it is a great advantage to have an automatic method of

* Owing to improvements in the mechanism and extensions of the system the coal consumption for 1905 was reduced to 4.33 lbs. per 1,000 gallons lifted, costing 0.727d.
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Fig. 27.
Air Chamber or Power Station. High Level.

Fig. 28.
Sewage Ejecting or Forcing Chamber. Low Level.

Figs. 27, 28.—High Level Sewage raising Low Level Sewage to Intercepting Sewer by means of Adams' Sewage Lift.
sewage lifting, and when the higher parts of the drainage area are steep
this can be done by utilising the high level sewage to compress air,
which is then transmitted to the low level area and then utilised to lift
the sewage.

Adams' Patent "Autaram" or Sewage Lift on this principle is shown
in Figs. 27, 28.

The sewage lift is actuated by air compressed by a column of sewage
or water. In effect it is an automatic engine, compressor and pumps
combined; but the only moving parts required are the plain inlet flap
valves. Its use (where the conditions are favourable) means the sub-
stitution of a self-acting lift—worked by waste liquid—entailing
practically no annual expense, for the engines and pumping plant
usually employed. The distance between the "air" and "forcing
cylinders" is immaterial. The greater this distance, however, the
greater will be the volume required at the high level.

In all cases the sewage, etc., to be raised gravitates to the "forcing
cylinder" or ejector, entering it through a plain, non-return flap valve.
Liquid is fed to a flush tank in the "air chamber" and discharged
through its pressure pipe to the "air cylinder," displacing the air
therein, which passes by an air pipe to the "forcing cylinder," exerting
there its pressure upon the sewage to be raised, the latter being dis-
charged through the rising main. The "air cylinder," when full, is
emptied by means of a syphon. The sectional drawing shows the lift
entirely below ground. It will be seen that sewage enters the flush
tank, that this tank discharges its contents to the "air cylinder"
beneath it, and that the air-pipe extending from the "air cylinder" to the
"forcing cylinder" will deliver air to the latter, and that this air
will drive out the liquid contents of the "forcing cylinder," and that
after this operation the contents of the "air cylinder" will be with-
drawn by the syphon shown in order that this cylinder may be
emptied in readiness for the next discharge of the flush tank. The
withdrawing syphon from the "air cylinder" and the rising main from
the "forcing cylinder" both deliver their contents to the intercepting
sewer.

Where local conditions do not allow of the flush tank being placed
beneath the ground this may be supported upon a column or placed
within a tower—the supply being led under pressure to it. Where
sewage is not available the town's water supply may be often advan-
tageously used. The wisdom or otherwise of thus operating the lifts
will depend upon the cost of the water.

The amount of liquid expended to raise a given volume will vary
with local conditions—the height of lift, etc.—from 60 per cent. up to 400
or 500 per cent. for excessive lifts.
SEWAGE LIFTING.

Where it is desired to construct underground urinals in positions where the sewer is not of sufficient depth, the Adams' Patent Automatic Sewage Lift may be used with advantage. The drawing (Fig. 29) shows an installation, and the manner in which it is discharged to the sewer above by the pressure of air from the "air cylinder." The apparatus is entirely automatic, coming into operation only when there is liquid to be raised.

An important installation on this system was carried out at Douglas, S.E.
I. O. M., and was described by Messrs. Stevenson and Burstal in a paper read before the Institution of Civil Engineers.*

In this case the low lying part of the district consisted of a strip about 1½ miles in length but somewhat narrow on the north side of the harbour and a similar strip about ¾ of a mile in length on the south side. Taking into consideration the contours of the district and the quantity of high level sewage which could be utilised from the existing sewers for power purposes at any particular spot it was found that four lifts would be required in order to obtain a reasonable maximum lift at each point whilst at the same time keeping the low level sewers at a moderate depth below the surface of the ground.

The sewage was discharged from the lifts into new high level sewers which have nearly always a free outlet into the outfall manhole.

The apparatus used consisted of a series of automatic syphons and cylinders and had only one moving part, namely, the inlet valve to the sewage pressure cylinder.

The sewage from the upper district is delivered into an air-pressure chamber in which is placed a screen for the removal of rags, brushes and other large articles, and these are periodically flushed out through a wash-out valve and pipe to the tail drain.

After passing through this screening chamber the sewage is collected in a tank in which is situated an automatic syphon. This tank is provided with a sludge valve for discharging any sludge which may collect.

When the flushing chamber is filled to its proper level the sewage is automatically syphoned out into a cylinder, the air of which it compresses and forces along an air pipe to the low-level forcing-chamber and delivers to the forcing-cylinder in which the sewage of the low level district has been collected. Sewage in this cylinder is then forced out into the outfall sewer. The sewer which was filling the first cylinder continues to rise until a second automatic syphon is brought into operation emptying the cylinder into the tail drain, leaving the cylinder empty and thus completing the cycle of operations, which occupies about five minutes when the lifts are in full work.

Practically no repair is required with this apparatus, for with the exception of one valve there are no moving parts, nor is there any expenditure on power. The cost of attendance is small and generally would occupy only a portion of the time of one man to inspect twice a day the screening chamber and the inlet to the forcing cylinder.

The following table gives the particulars of the sewage lifts at Douglas:—

* Proceedings Inst. C.E., Vol. CLX., p. 239.
SEWAGE LIFTING.

TABLE 12.—PARTICULARS OF SEWAGE LIFTS AT DOUGLAS.

<table>
<thead>
<tr>
<th></th>
<th>Winter.</th>
<th>Summer.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total population</td>
<td>19,000</td>
<td>60,000</td>
</tr>
<tr>
<td>Population in low level area</td>
<td>2,500</td>
<td>12,000</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Details of lifts.</th>
<th>Broadway</th>
<th>Granville Street</th>
<th>Ridgeway Street*</th>
<th>Walpole Avenue*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capacity in per cylinder ...Galls.</td>
<td>400</td>
<td>500</td>
<td>500</td>
<td>500</td>
</tr>
<tr>
<td>Height of lift from invert of cylinder to invert of discharge pipe ...Feet</td>
<td>11·75</td>
<td>13·25</td>
<td>17·25</td>
<td>15·77</td>
</tr>
<tr>
<td>Volume of high level sewage required per cylinder ...Galls.</td>
<td>600</td>
<td>600</td>
<td>970</td>
<td>1074</td>
</tr>
<tr>
<td>Fall utilised for high level sewage from invert of head sewer to invert of tail sewer ...Feet</td>
<td>21·00</td>
<td>24·28</td>
<td>31·00</td>
<td>30·30</td>
</tr>
<tr>
<td>Effective fall of high level sewage from invert of cylinder to invert of tail sewer ...Feet</td>
<td>15·75</td>
<td>18·00</td>
<td>25·5</td>
<td>25·00</td>
</tr>
<tr>
<td>Efficiency (per cent) of lifts calculated as follows:—</td>
<td>400</td>
<td>1000</td>
<td>754</td>
<td>1990</td>
</tr>
<tr>
<td>Quantity of low-level sewage x by height of lifts x 100.</td>
<td>49·73</td>
<td>45</td>
<td>84·87</td>
<td>29</td>
</tr>
</tbody>
</table>

A vacuum system of lifting sewage is the Liernur system.

Liernur’s Improved Pneumatic System.—This system of sewerage was introduced by Captain Liernur, a Dutch Engineer, in 1868, and has been considerably improved by his sons, Messrs. F. and W. Liernur.

The system was employed in the first instance in Amsterdam in 1871. The town allowed a trial to be made in a small quarter of about 15,000 inhabitants, but the town would only allow the system to be applied simply for conveying the fecal matter and closet water, including a small quantity of toilet water, omitting the household slops, which had to be thrown into the next open canal as had hitherto been the custom. The result of this experiment showed vacuum might be relied on as a motive power. Since this the system has been extended, so that it now embraces a population of about 200,000 inhabitants, and several small installations have been made in Leiden, Riga, Kœrtingsdorf, Ferreira Mines (South Africa), etc., and in Trouville-sur-Mer, in 1897.

The Liernur method of sewerage is based on what is known as the separate system, the polluted liquids, including fecal matter,

* The same high level sewage actuates both Ridgeway Street and Walpole Avenue lifts.
sink slops, soapy and dirty water, being conveyed away in one set of pipes to a central pumping station, at which it is dealt with by works of special construction, and the storm and surface waters by a second set, which would discharge into the nearest natural water-course.

The system works on the principle of a large pump, the whole of the sewers and house drains being submitted to a powerful suction (only a vacuum of half an atmosphere is used) from air-pumps fixed and worked at the central station. On the vacuum being applied to the street sewers the air rushes down the soil pipe (which also acts as ventilator at the head of each house drain) and drives everything before it. The only liquid required is that which gains admission from the w.c.'s, sinks, baths, etc., so that the diameters of the pipes can be considerably reduced, and the pressure exercised by the air-pumps is sufficient to draw the sewage through the pipes with a velocity of from 10 to 20 feet per second.

It has been found that the traps in conjunction with the w.c.'s, baths, etc., are not unsealed by the action of the vacuum, which is confined to the soil pipes.

This system is equally adapted for hilly districts, and where there is little or no fall, as the pipes are laid at a uniform depth under the ground, in the same way that gas and water mains may be laid, no down-grade being necessary, although at the same time it is always taken advantage of where it can be obtained. The pipes employed are made of iron in place of the ordinary glazed stoneware, they thus require fewer joints, and less jointing material; extra water flushing is not required. The difficulties of sewer ventilation are overcome, as the gas generated in the pipes is drawn off to the central station and there destroyed; the drain pipes also being composed of cast iron with carefully made joints, leakage of sewer-gas is precluded, and this is further provided against by the suction in the pipes. The disposal of the sewage and collection at the central station is an integral part of this system.

The average cost of the installation of this system is stated by the company to be about £2 per yard, including everything, street sewers, reservoirs, outfall works, pumping station, and complete plant for sewage treatment.

The annual cost of the conveyance of the sewage by vacuum suction is also stated to be about 10d. to 1s. per head.

In designing sewage lifting machinery the variations in the rate of flow in the sewers must be provided for.

The provision necessary to deal with the storm-water flowing into the sewers has already been dealt with, and the hourly fluctuations in
the rate of flow in dry weather are shown by the curves in Fig. 16, p. 30.

It is often desirable, for the purpose of estimating the annual cost of pumping, to know what addition must be made to the cost of pumping the dry weather flow to cover the extra expense of lifting the stormwater at various degrees of dilution.

The curve given in Fig. 30 has been compiled from information supplied by Mr. J. D. Watson, M.Inst.C.E., of observations made at the Birmingham Sewage Works.

The dry weather flow of sewage there is at the rate of 30 gallons per head per day, and the vertical ordinates of the curve give a measure of the quantity of sewage and stormwater combined which has to be dealt with at the Birmingham works at varying degrees of dilution, assuming that the rainfall is distributed equally throughout the whole year.

Taking as an example a case where it is desired that sewage and rainfall up to four times the dry weather flow shall be admitted to the sewers, it will be seen from the diagram that with a dry weather flow of 30 gallons per head the average annual quantity of water flowing to the sewers would be 43 gallons per head, and if six times the dry weather flow of 30 gallons per head be admitted, the extra quantity to be pumped would be only about 1 gallon per head per day as an average more than with four dilutions.