Driving Pumps by Compressed Air. —(Continued.)

Table:- giving the volume of free air, at pressures of 20 to 50 pounds, required to pump any given quantity of water to any height, with the corresponding horse-power required by the air-cylinder to do the work. *Compiled by William Cox.*

h×G	P = 20 lbs.		P = 25 lbs.		P = 30 lbs.		P = 35 lbs.		P = 40 lbs.		P = 45 lbs.		P = 50 lbs.		h×G
	V	H-P	V	H-P	V	H-P	V	H-P	V	H-P	V	H-P	V	H-P	
65000	735.8	50.70	673.4	54.6	631.8	58.50	652.2	62.4	579.8	65.65	562.9	68.90	548.6	72.8	65000
67500	764.1	52.65	699.3	56.7	656.1	60.75	626.4	64.8	602.1	68.18	584.5	71.55	569.7	75.6	67500
70000	792.4	54.60	725.2	58.8	680.4	63.00	649.6	67.2	624.4	70.70	606.2	74.20	590.8	78.4	70000
72500	820.7	56.55	751.1	60.9	704.7	65.25	672.8	69.6	646.7	73.22	627.8	76.85	611.9	81.2	72500
75000	849.0	58.50	777.0	63.0	729.0	67.50	696.0	72.0	669.0	75.75	649.5	79.50	633.0	84.0	75000
77500	877.3	60.45	802.9	65.1	753.3	69.75	719.2	74.4	691.3	78.28	671.1	82.15	654.1	86.8	77500
80000	905.6	62.40	828.8	67.2	777.6	72.00	742.4	76.8	713.6	80.80	692.8	84.80	675.2	89.6	80000
82500	933.9	64.35	854.7	69.3	801.9	74.25	765.6	79.2	735.9	83.32	714.4	87.45	696.3	92.4	82500
85000	962.2	66.30	880.6	71.4	826.2	76.50	788.8	81.6	758.2	85.85	736.1	90.10	717.4	95.2	85000
87500	990.5	68.25	906.5	73.5	850.5	78.75	812.0	84.0	780.5	88.38	757.7	92.75	738.6	98.0	87500
90000	1018.8	70.20	932.4	75.6	874.8	81.00	835.2	86.4	802.8	90.90	779.4	95.40	759.6	100.8	90000
92500	1047.1	72.15	958.3	77.7	899.1	83.25	858.4	88.8	825.1	93.42	801.0	98.05	780.7	103.6	92500
95000	1075.4	74.10	984.2	79.8	923.4	85.50	881.6	91.2	847.4	95.95	822.7	100.70	801.8	106.4	95000
97500	1103.7	76.05	1010.1	81.9	947.7	87.75	904.8	93.6	869.7	98.48	844.3	103.35	822.9	109.2	97500
100000	1132.0	78.00	1036.0	84.0	972.0	90.00	928.0	96.0	892.0	101.0	866.0	106.00	844.0	112.0	100000
125000	1415	97.5	1295.0	105.0	1215	112.5	1160.0	120.0	1115	126.2	1082.5	132.5	1055	140.0	125000
150000	1698	117.0	1554	126.0	1458	135.0	1392	144.0	1338	151.5	1299.0	159.0	1266	168.0	150000
175000	1981	136.5	1813	147.0	1701	157.5	1624	166.0	1561	176.8	1515.5	185.5	1477	196.0	175000
200000	2264	156.0	2072	168.0	1944	180.0	1856	192.0	1784	202.0	1732.0	212.0	1688	224.0	200000

Directions.- Multiply the gallons of water to be raised per minute by the height in feet to which the water is to be raised. Opposite this product in the first and last columns, headed h × G, find under the different pressures the cubic feet of free air per minute and the horse-power required. Intermediate values of h × G give directly proportionate results for the various pressures at the head of the different columns.

Note:- h = height in feet to which the water is to be raised. G = gallons of water to be pumped per minute. V = cubic feet free air required per minute. H-P = horse-power.

NORWICH SEWERAGE WORKS.

Owing to its configuration and geological conditions it has been a mattei of some difficulty to provide Norwich with an efficient system of sewerage, and some of the most eminent engineers of our time have been consulted and engaged in trying to drain the city effectually. Up to the year 1865 the city was drained by over 300 different sewers, all of which delivered their contents into the river Wensum, with the result that it was polluted to an alarming extent. At this period the late Sir Joseph Bazalgette was called in to prepare a scheme for the drainage of the city. He proposed a deep main sewer on the southern side of the river, into which all the tributary sewers from both sides of the river were to discharge by gravitation to the outlet at Trowse, where the main pumping engines, which were to be capable of lifting 2½ million gallons of sewage per day to the sewage farm at Wittingham, were to be erected. These works were carried out in 1871.

The difficulties in constructing the main deep outfall sewer were, however, very great, and when completed it was found to be so leaky that the quantity of water pumped at the Trowse pumping station was 5,000,000 gallons per day, or just twice the ultimate quantity provided for by Sir Joseph Bazalgette. The cost of pumping thus became very heavy, the coal consumption being about eight tons per day.

All the attempts made to render the leaky sewer water-tight by lining it with cast iron tubing, &c., proved futile, and in 1887 the Corporation, on the advice of Mr. P. P. Marshall, the then city engineer, decided on:—(1) The construction of a new main outfall sewer at a higher level than the old one, and the abandonment of the old one. (2) The adoption of the Shone system for raising

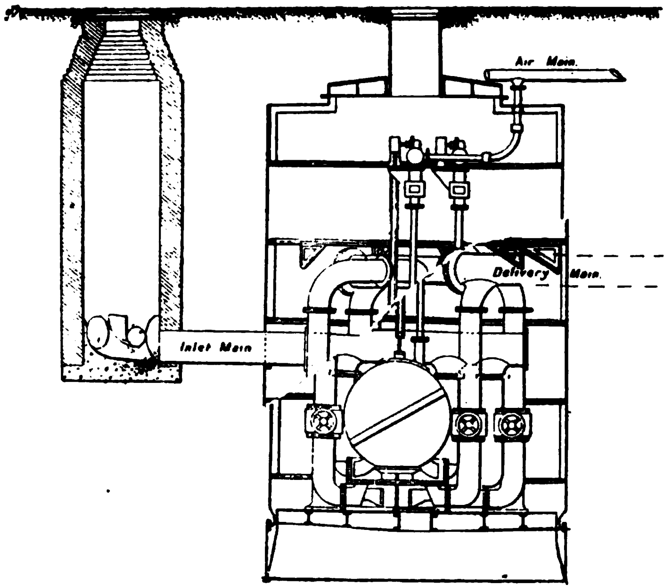

FIG. 260.

the sewage of the low-level districts into the new main outfall sewer. (3) The redrainage of the whole of the city on the separate system. The air required for working the ejectors is compressed by means of the water power which is available in the river Wensum at the New Mills, where formerly two under-shot water wheels were worked, but which only gave about five horse power each The water-power now works two Victor turbines, which give 40 to 50 brake horse-power each, one of which is sufficient to compress all the air for operating the various ejectors required to drain the low-lying parts of the city. The New Mills belong to the town, and as flour mills they were let to tenants for a mere nominal rent. By thus utilizing the Wensum river water, the working cost of the motive power for raising the sewage from the low-lying area becomes practically inappreciable. The ejectors at all the stations are in duplicate, and are placed in chambers of cast iron tubing, sunk below the level of the street surfaces. These chambers or stations were sunk in the same manner as cast iron cylinders used for bridge foundations are sunk. The bottom parts of the castings are provided with a strong cutting edge, to facilitate the work of sinking them. The soil was excavated from the inside of the pits sunk to contain them, and wherever necessary it was removed under air pressure, the entrance tube to the chamber being provided with an air lock. Heavy pumping, which might have proved destructive to adjoining properties, was thus avoided, and no difficulty was found in sinking the chambers in the water-logged subsoil to their proper depth.

The ejector stations Nos. 2, 3 and 3A discharge into one of the inverted syphons which starts in Duke of York street, just above Bishop's Bridge, goes

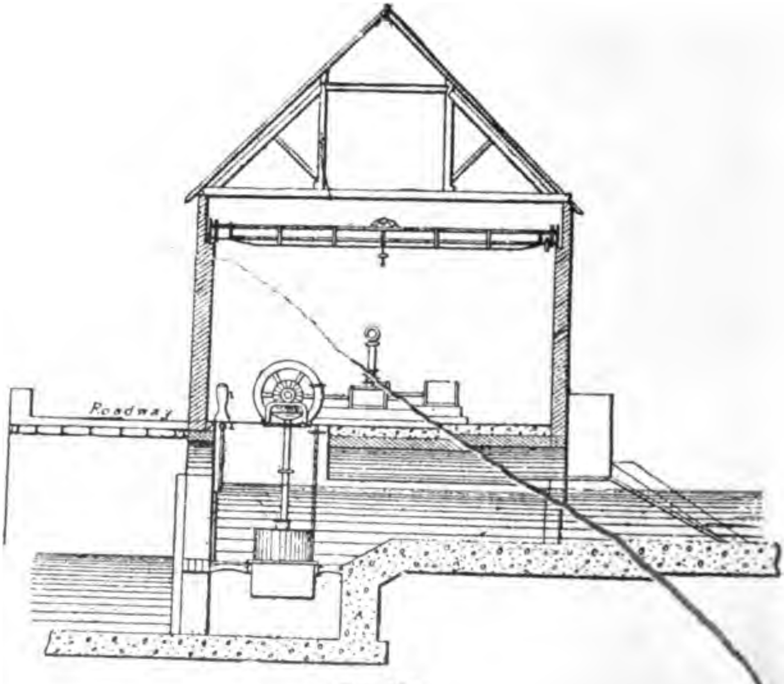

FIG. 261.

along Riverside avenue, under Foundry Bridge, along Prince of Wales street, Rosslane and Mountergate street, and finally debouches into the main outfall sewer in King street. All the sewage from the Thorpe district is discharged into this syphon through the sewers in Bishop's road, Gas Hill, Rosary road and Thorpe road. These four roads rise steeply from Duke of York street and Riverside avenue, and four cast iron branches from the syphon pipes are carried up the roads to a manhole situated above the hydraulic gradient of the syphon pipe. The population of the gravitation area discharging into this syphon is 4780, and of the ejector area 5735 inhabitants. Ejector station No. 4 discharges into a second syphon, which conveys the sewage from the northern part of the city, viz., the

Noncehold and Catton Wards, through three branches from St. Augustine street, Magdalen street and Bull Close street, meeting at Stump Cross in a 21-in. pipe, which is increased to 24-in. at the ejector station. This syphon pipe is flushed at frequent intervals from a flush tank of 3000 gallons capacity in Magdalen street, which receives the sewage from part of the Catton Ward, and discharges it through one of Shone and Ault's full-bore flushing syphons every time the tank is full, thus sending a powerful current through the syphon pipe day and night.

The population of the gravitation area draining to this syphon pipe is 25,180; that of the ejector district 12,026 inhabitants. The syphon pipe passes from Magdalen street, through Fye Bridge street, under the Fye Bridge, along

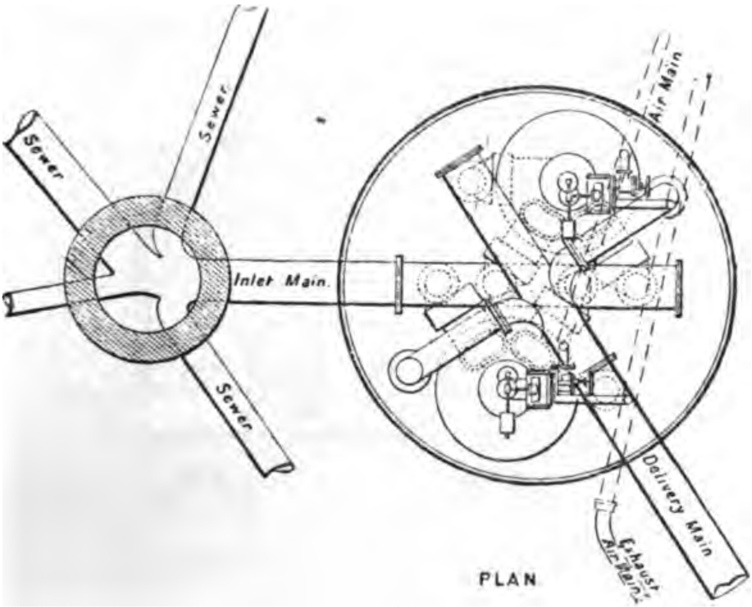

FIG. 262.

Wensum street and Tombland to the main outfall sewer in Prince's street. Ejector station No. 5 discharges direct into the outfall sewer in Benedict street, through an 18-in. main passing along Lower Westwick street and St. Margaret street. The total population of the area drained by the ejectors is thus 39,911 inhabitants, and an additional area with a population of 29,960 inhabitants is drained through the inverted syphon pipes. The whole of the sewage goes, as already stated, through the new outfall sewer to the Trowse pumping station, where it is lifted to the sewage farm by means of large beam pumping engines.

To ascertain the available water power at the New Mills, the water in the river Wensum was measured on May 9th, 1893, after a long period of dry weather. The mean sectional area of the river just above the Mills was found to be 0·80 per cent. of this, and the velocity 0·05256 ft. per second. The quantity of water per minute was therefore 57,700 gallons. The fall at the Mills is 6 ft. 6 in, and the total power of the water is therefore 113:6 horse power. The old wheels barely gave out 10 per cent. of this power, and the engineers therefore proposed to have them removed, and to put down a pair of 48-in. Victor turbines. These turbines have been used extensively in the United States and Canada, and they have recently been used for a large electric installation at Worcester, where they have given excellent results.

The Victor turbine is very simple in construction, strong and easily regulated. It gives nearly as high an efficiency with a greatly reduced gate opening as when working full power, and all the various parts are made to standard gauges, so as to be interchangeable and easily replaced.

Each turbine drives a set of horizontal air-compressing engines, each set having two air cylinders 15-in. diameter, 18-in. stroke, and able to compress 650

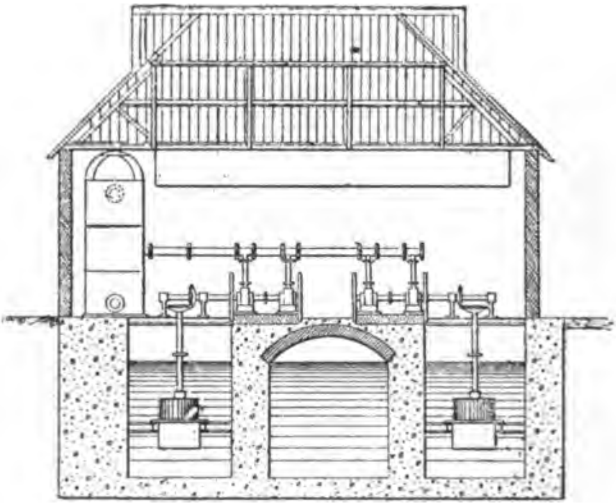

FIG. 263.

cubic feet of free air per minute to a pressure of 18 lb. per square inch, when the turbine is using 30,000 gallons of water per minute.

During heavy floods in the river, the total water below the mill rises to the level of the ordinary head water above, and then all the sluices must be opened to avoid the flooding of the upper parts of the town and the western suburbs. On such occasions there is no available water head for working the turbines. Provision has therefore been made for driving the air compressors by steam by attaching compound steam cylinders to the tail rods of the air-compressing cylinders. The steam cylinders are 9½ in. and 14½ in. diameter, and arranged in such a manner that they can be readily connected up when a flood occurs. Steam is supplied to work the compressors from a Babcock and Wilcox boiler, heated with town refuse burnt in two furnaces constructed by the Horsfall Refuse Furnace Syndicate. These works adjoin the air-compressing station, and form part of the New Mills property. Before the Victor turbine was substituted for the old water wheel, nine sluices were provided, the largest being 6 ft. by 4 ft. 6 in. deep, with a combined area of 182.5 square feet. They were, however, very difficult to open, and when heavy floods occurred some of the smaller openings became choked by *debris*. Sir John Hawkshaw recommended, in 1879, that they should be enlarged, and in the new works connected with the Victor turbines care was taken to provide large sluices of modern design. The waste water sluice is of the well-known Stoney type, 14 ft. 3 in. wide, 8 ft. deep, and in addition to this two sluices have been provided behind each of the turbines, 12 ft. 6 in.

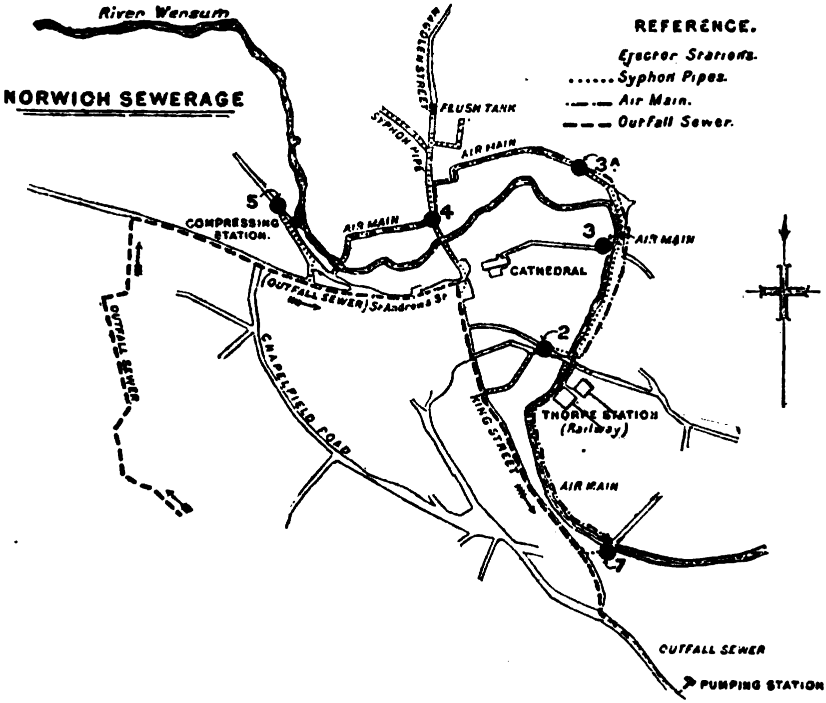

FIG. 264.

wide by 5 ft. high, giving a total sluice area of 239 square feet, without reckoning the port area of the turbines themselves.

As the new buildings fronting the direction of the flow of the river are narrower in their width than the old buildings, there remains ample room for further extension of the sluices hereafter, if those now provided should prove to be inadequate during periods of heavy floods.

The compressed air is conveyed from the compressors in the air-compressing station to Lower Westwick street through a 9-in. cast iron socket pipe, and from that point the air pipes are gradually reduced in size to correspond to the volumes of air to be conveyed by them to the various ejector stations.

Two air receivers, 7 ft. diameter, 20 ft. high, are provided in the engine-house, and all the compressed air passes through these, being thereby cooled and dried before it enters the air mains. It is estimated that the cost of the whole scheme will be £164,000, and the works are being carried out by Mr. A. E. Collins, the city engineer, Messrs. Shone and Ault, of Westminster, being the consulting engineers for the Shone ejectors and machinery in connection therewith. The contractors for the Shone ejectors, air-compressing machinery and turbines, air and sealed sewage mains, were Messrs. Hughes and Lancaster, of Westminster and Ruabon. Contracts for the sewers in the various districts have been placed with Messrs. Monk and Newell, of Liverpool, and Messrs. B. Cooke & Co., of London.

TABLE 66.

Tabular Statement Showing Detailed Particulars Relating to Ejector Stations, Norwich Sewerage.

Ejector Station.	No. 2. Foundry Bridge.	No. 3. Bishops Bridge.	No. 3a. Barrack Street	No. 4. Fye Bridge.	No. Westwick Street, near New Mills.	No. 7. Carrow Bridge, Colemans' Works.	Total.
a. Population of district, present	2910	1425	1400	12,026	18,150	4000	39,911
b. Population of district, future	4110	2165	2160	12,026	23,550	8000	52,011
c. Number and size of ejectors	Two of 250 gals.	Two of 150 gals.	Two of 150 gals.	Two of 500 gals.	Two of 1000 gals.	Two of 300 gals.	—
d. Quantity of sewage discharged per minute, present	196 gals.	89 gals.	88 gals.	780 gals.	1184 gals.	250 gals.	2587 gals.
e. Quantity of sewage discharged per minute, future	271 gals.	136 gals.	135 gals.	780 gals.	1521 gals.	500 gals.	3243 gals.
f. Ground level at ejector stations	9·00	10·19	9·00	10·00	12·40	14·7	—
g. Invert of lowest sewer at station manhole	—5·50	—2·60	—4·00	—4·25	—4·86	—12·16	—
h. Delivery levels of sewage mains (centre of pipe)	+5·75	+5·75	5·75	+8·00	+10·93	0·91	—
i. Total dead lift	15·77	11·27	12·67	18·00	21·53	18·26	—
k Total pipe friction in feet	2·91	11·26	17·54	1·38	1·97	0·93	—
l. Total dynamic head	18 68	22·53	30·19	19·38	23·50	19·19	—
m. Air pressure required	9·00	10·00	14·00	9·00	11·00	9·00	—

The particulars of the various ejector stations, with the population of the ejector districts, are shown in the table above.

Our illustrations, taken with the preceding article, are self-explanatory.—*The Engineer.*

PNEUMATIC CESSPOOL EXCAVATOR.

A pneumatic apparatus for emptying cesspools has been invented by English manufacturers and is now in use at Pokesdown, England. It consists of a tank for sewage and a dome and connecting pipe for producing a vacuum in the tank. The tank is mounted upon an ordinary four-wheel truck and can be drawn by a horse. A smaller portable truck supports a vacuum pump. Two men can work it and produce enough power to create a vacuum in the tank. The pump is connected to the dome by means of flexible pipe, and the gases arising by the exhaust of the air are forced to an upright boiler shaped stove and burned. The vacuum, of course, causes the material to rise from the cesspool and the tank is filled and carried away. None of the material is brought to view or comes in contact with any of the machinery.