PUMPS & PUMPING MACHINERY 1500 BC-1960

Historical Development-4

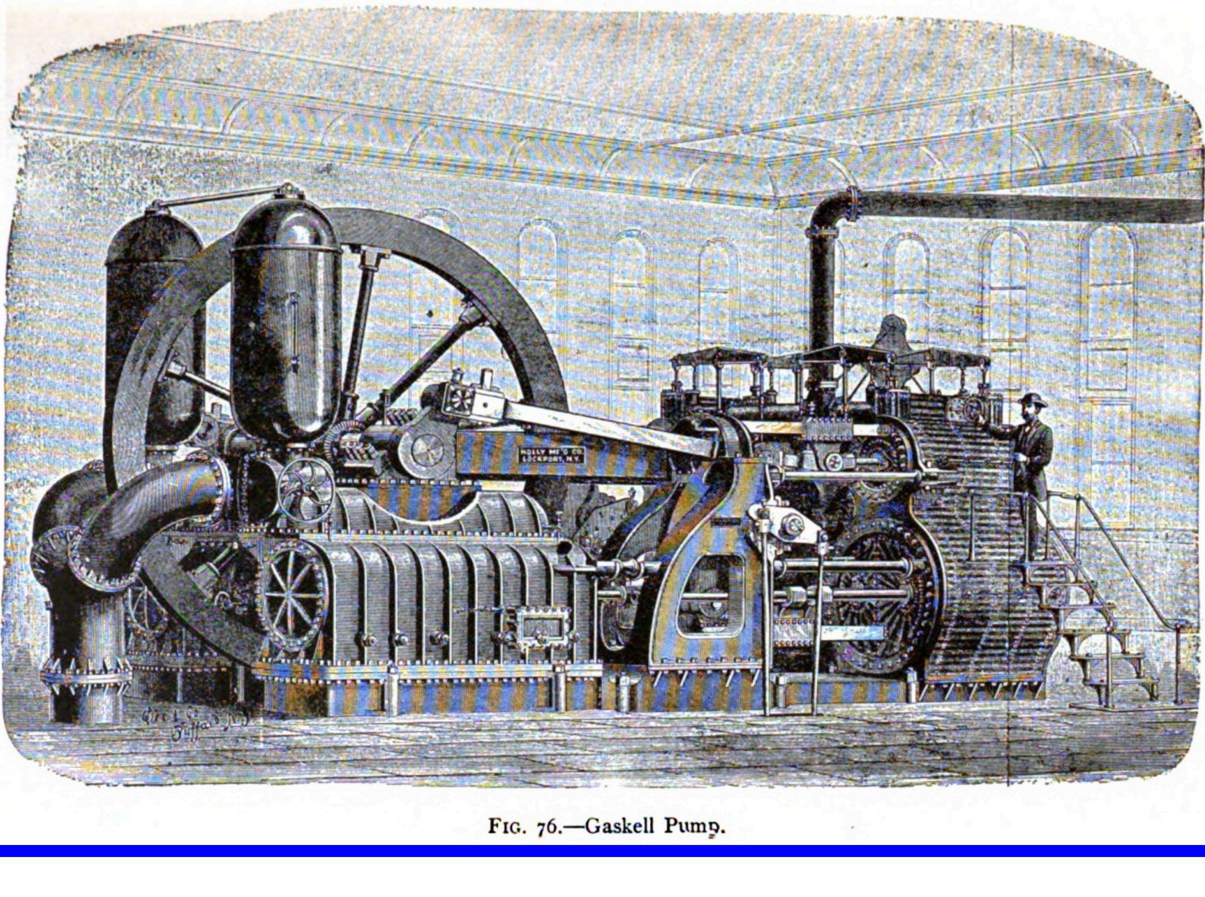

FIG. 76.—Gaskell Pump.

From PUMPING MACHINERY, 1919

PUMPING MACHINERY

A TREATISE ON THE

HISTORY, DESIGN, CONSTRUCTION AND OPERATION OF VARIOUS FORMS OF PUMPS

BY

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Continued from Part-3

was mounted on the shaft carried by the bearings, which were supported by the air chambers of the pump. A diagonal brace was carried from the bearings to the main center pedestals.

The steam cylinders were 15 and $30\frac{1}{8}$ inches in diameter, 30 inches in stroke, and were furnished with the Corliss valve gear. They were steam jacketed on the barrels, heads, and

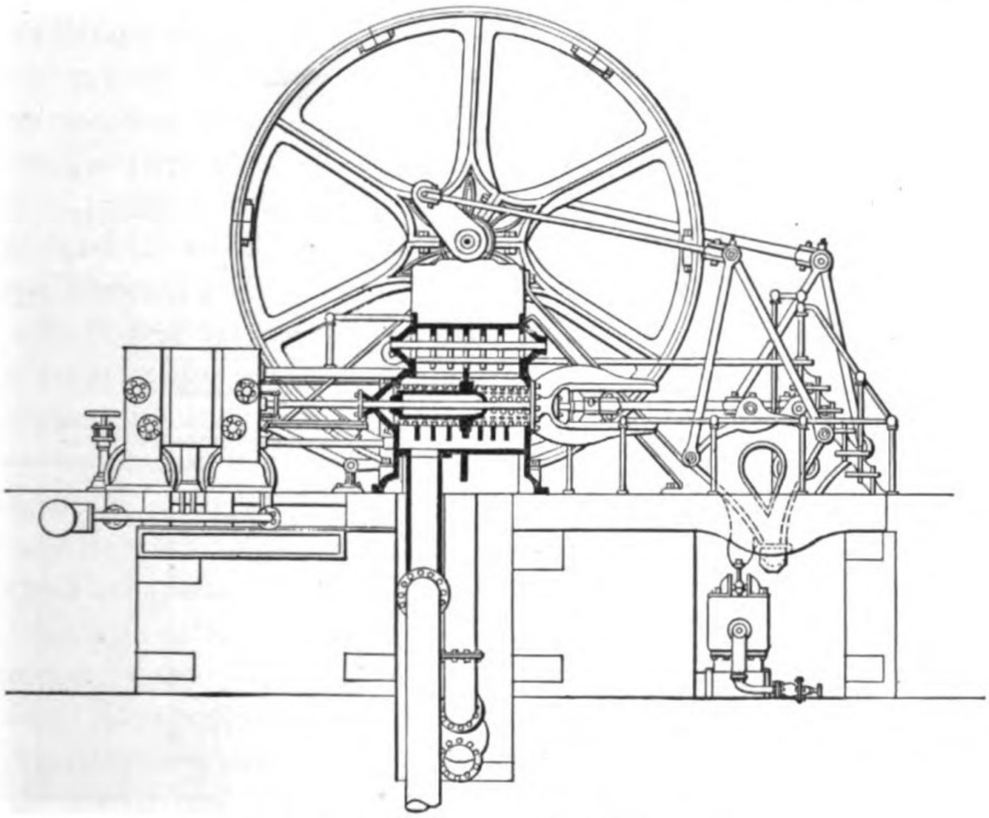

FIG. 74.—Corliss Pump for Pawtucket.

valve boxes. There was a receiver between the cylinders, the volume of which was equal to that of the low-pressure cylinder. The drips from the jackets were delivered into the boiler feed, heating it, while the drip from the receiver was passed through a coil in the boiler flue and returned to the receiver in a superheated condition. The steam throttle valves were so connected with the governor that they limited the speed to 52 revolutions.

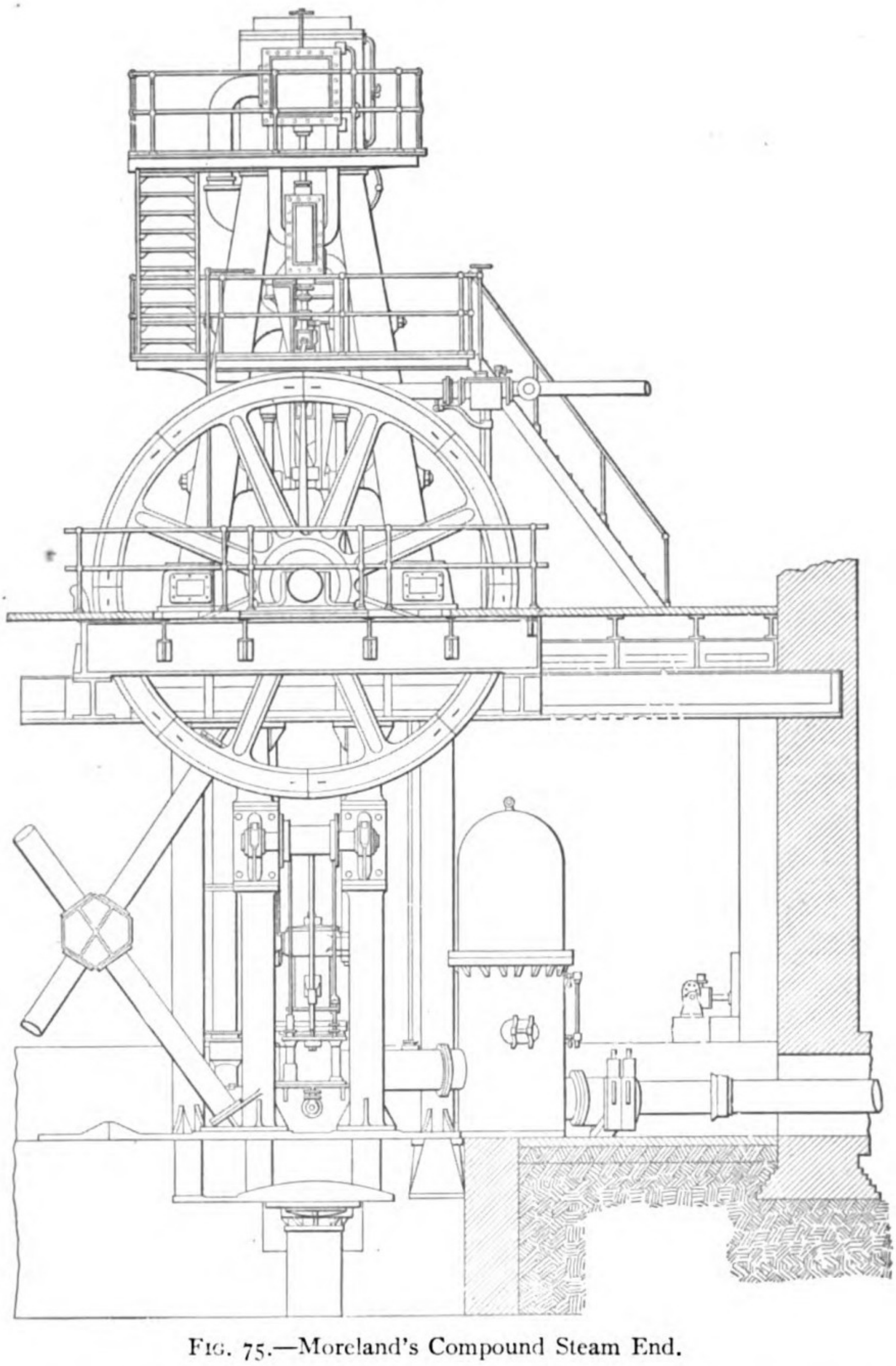

FIG. 75.—Moreland's Compound Steam End.

The exhaust from the low-pressure engine was carried to a jet condenser placed beside the engine, while the air pump was placed below the main pedestal bearing. The pump was 10.52 inches in diameter with $2\frac{3}{4}$-inch rods. It was to lift 3,000,000 gallons per twenty-four hours against 270 feet head. It was of the inside-packed plunger type with 280 small valves.

In August, 1878, this engine was tested for ten hours per day for twelve days, with all coal and wood charged, and gave a duty per 100 pounds of coal of 104,357,654 when delivering 3,060,000 gallons. On October 3, 1878, a 24-hour test gave 133,522,060 foot-pounds. This was a remarkable result, but no more so than the annual duty of 123,656,000 foot-pounds for the year 1888.

In 1889 Professor Denton tested this engine and obtained a duty of 124,720,000 foot-pounds with hard coal and 127,-350,000 foot-pounds with soft coal. These results were obtained with boilers giving an equivalent evaporation of 8.88 pounds of water per pound of coal for the hard coal and 9.35 pounds for the soft coal. A higher duty could be credited to the engine if the usual amount of 10 pounds were evaporated.

The next important water-works engine was that used at the Pettaconsett Water Works of Providence, R. I. This was built by Corliss originally for Boston, but was not accepted for some reason. Its test for six days in May, 1882, gave a duty of 113,271,000 foot-pounds.

The inverted pump of Moreland and Thompson of 1868 proved to be so successful that in 1880 Moreland & Son designed a compound pump for the Eastbourne Water Works of England. This pump, Fig. 75, was of the close tandem compound steam type with a single-acting piston pump attached below. The plunger on the piston rod as shown in the earlier pump, Fig. 65, was arranged to give a discharge on each stroke. The general arrangement may be seen in the figure and reminds one of the lines of recent pumps. The valve gearing was of the Myer type and the high- and low-pressure cut off could be adjusted separately.

The general dimensions were as follows:

High-pressure diameter	20 ins.
Low-pressure diameter	38½ "
Pump-piston diameter	20 "
Plunger diameter	15 "
Stroke	40 "
Fly-wheel, 15 tons	15 ft. 7 ins. diam.

This pump was tested on February 18 and 19, 1884, by Messrs. Wallis and Borias, and showed a duty of 124,600,000 foot-pounds per 112 pounds of coal or 111,300,000 per 100 pounds of coal. It was running under a low head during this test and developed only 90.7 H.P., while it was designed to develop 160 H.P. The following data are given from the test:

Total revolutions in twelve hours	16,875
Average revolution per minute	23.44
Total amount of water, in gallons	759,456
Average total lift, in feet	243.94
" steam pressure above atmosphere	69.15
" vacuum	28.58 ins.
Horse-power water	77.97
Indicated horse power	90.70
Mechanical efficiency	86%
Coal consumed in twelve hours	1666 lbs.
Coal per horse-power hour of water	1.78
Coal per indicated horse-power hour	1.53
Duty per 112 lbs. of coal in ft. lbs	124,600,000
Duty per 100 lbs. of coal in ft. lbs	111,300,000

At this time the Holly Manufacturing Company brought out a high-duty engine to replace the quadruplex engine. This was designed by Mr. Harvey F. Gaskell, their superintendent. It was a simpler machine, and was the first standard design of high duty applicable to all forms of water works, the previous high-duty engines being of special design.

The first of these engines (Figs. 76, 77, and 78) was installed at Saratoga Springs, N. Y., in 1882.

From the figures it will be seen that the high-pressure cylinder is directly over the low-pressure cylinder and that the piston rods of these two cylinders are connected to the extreme ends of a massive walking beam by short connecting rods. This connection means that as one piston moves to the right the other moves to the left, each being at the dead

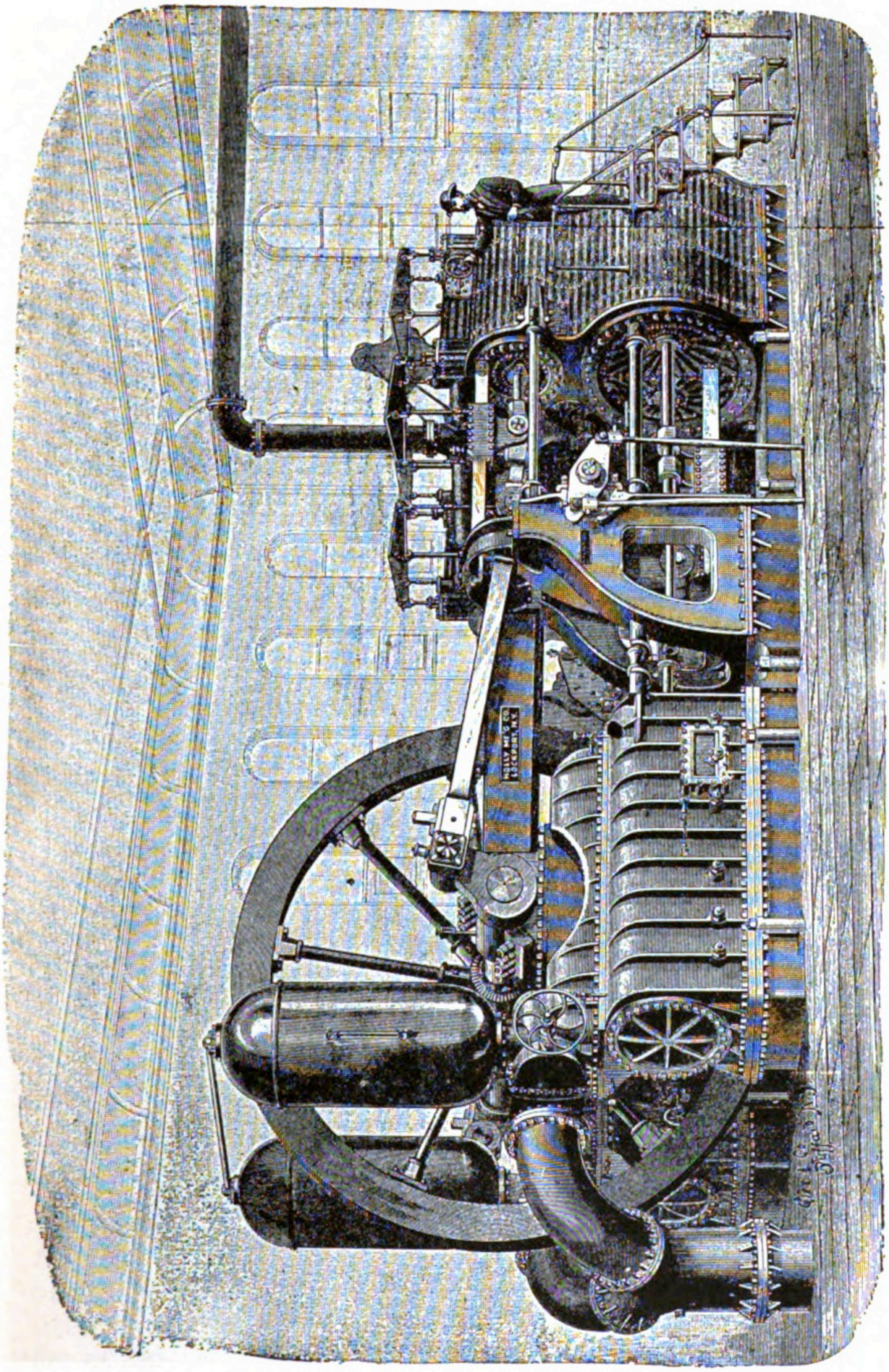

FIG. 76.—Gaskell Pump.

point at the same instant, and therefore it was of the Wolf compound type. This arrangement made it possible to dis-

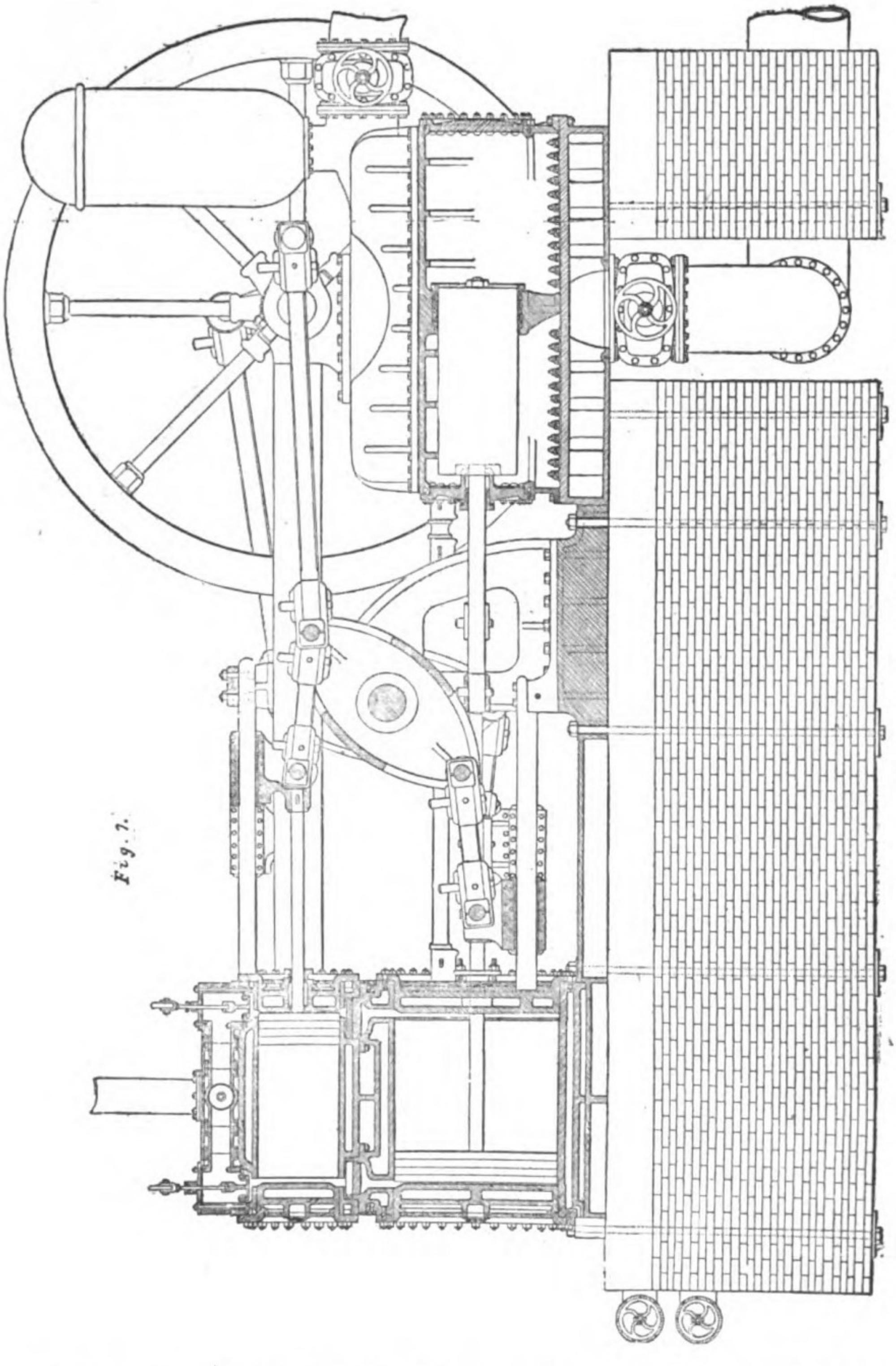

FIG. 77.—Gaskell Pump.

charge directly from the high-pressure cylinder to the low-pressure through the gridiron valve seen in Fig. 78.

A connecting rod from the upper end of the beam joined it to the crank of the fly-wheel shaft and by connecting the two sides or engines by cranks at right angles the motion of

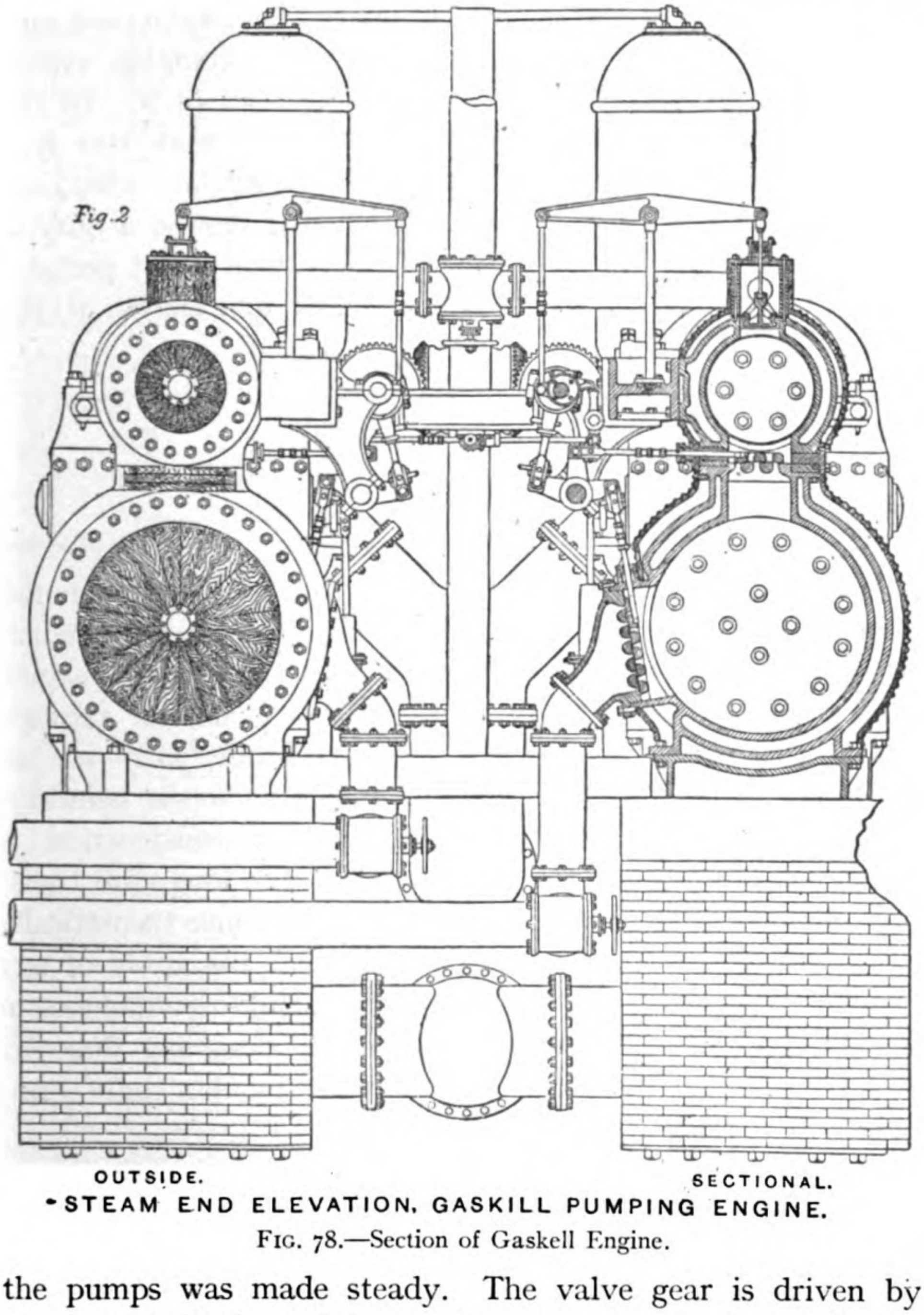

FIG. 78.—Section of Gaskell Engine.

the pumps was made steady. The valve gear is driven by two longitudinal revolving shafts driven by bevel wheels, the high-pressure steam valve being of the poppet type with an automatic relief while the other valves are of the gridiron type. The condenser can be driven from a lever attached to the trunnions of the walking beam, although in the Saratoga engine a Buckley condenser was used. The water end consisted of an inside packed plunger, the Worthington system of a large number of small valves being used in it. In this engine there were 672 water valves. There were two tests made on this pumping engine; one in November, 1882, and the other in June, 1883; both of the results showed a duty of about 113,000,000 foot-pounds, although for a short period a duty of 127,000,000 was obtained. The dimensions of this engine were:

Diameter high-pressure cylinder	21 ins.
" low-pressure cylinder	42 "
" pump plunger	20 "
" " rods	4 "
Stroke	36 "
Capacity	5,000,000 gals.

There were subsequently many changes made in the details of this engine, but the general plan was unaltered. Charles T. Porter in his report of 1883 on the Saratoga engine makes the following statement: "In the details through which this general plan has been carried out, there are no features which seem open to criticism, but, on the contrary, all seem entitled to commendation. The construction is thoroughly mechanical in every respect. The forces are transmitted and the strains are resisted in the manner theoretically the most correct. . . . I do not think that the study of any machine has ever given me a stronger feeling of confidence in its durability." This shows the kind of designing done by Mr. Gaskell and the kind of work done by the Holly company.

While these pumps were being built in America, the European practice seemed to hold to the Cornish steam pump (Fig. 79), although in many cases horizontal fly-wheel engines were connected through other rods or gears to horizontal or vertical pump cylinders (Figs. 80 and 81), and in certain cases the beam engine was built with a fly wheel (Figs. 82 and 83).

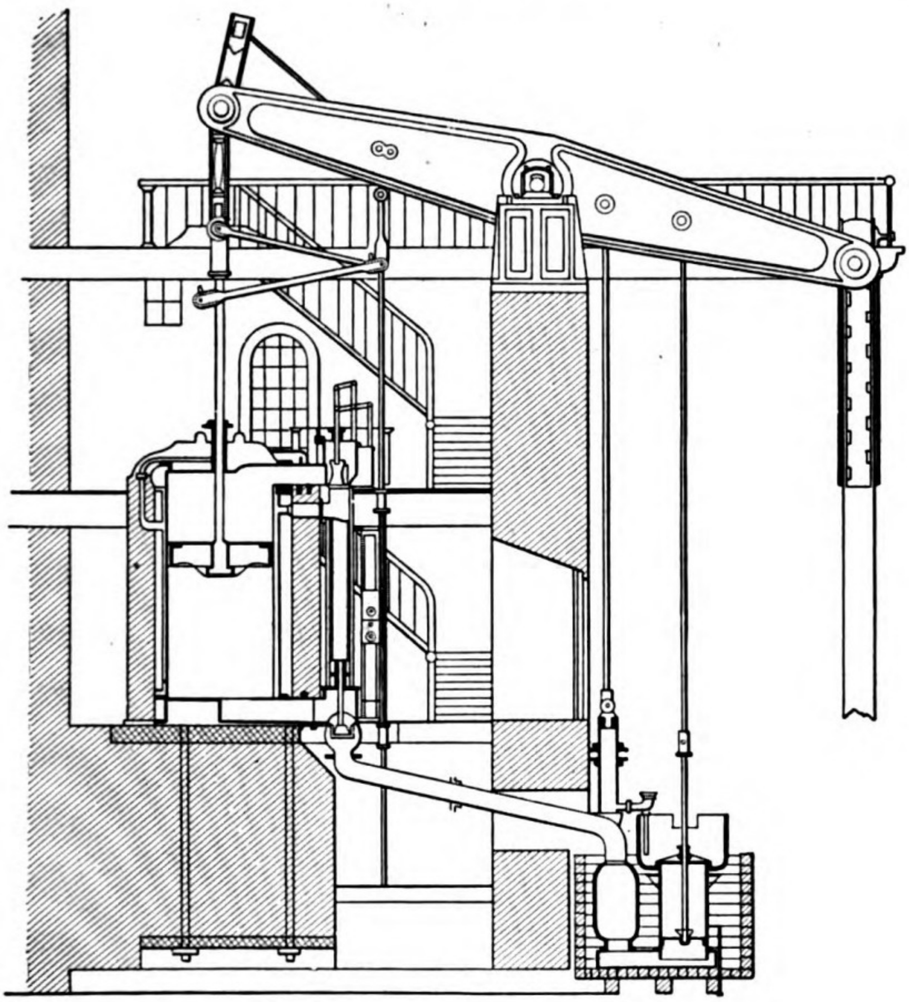

FIG. 79.—Cornish Engine of 1878.

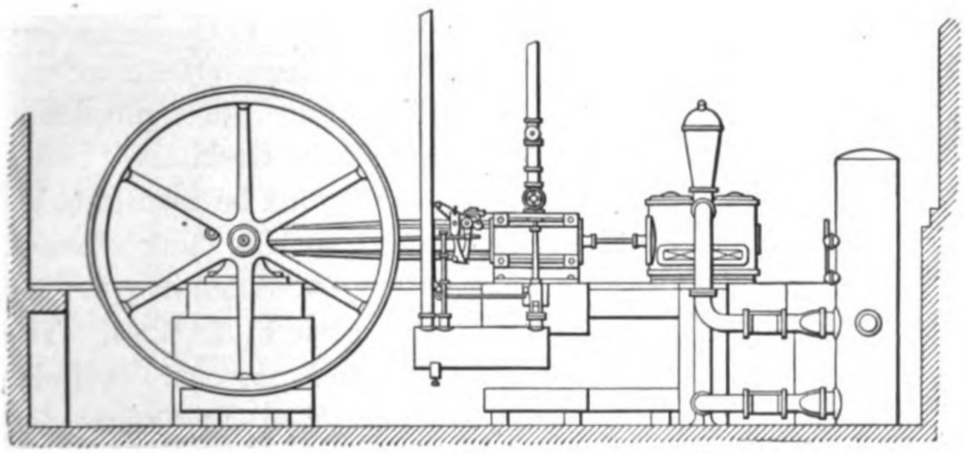

FIG. 80.—Horizontal Fly Wheel Pumping Engine.

The pump shown in Fig. 83 was one constructed by Simpson & Co., for the Lambeth Water Works of London. This pump was of the type used for many years by this company and gave unusually good results. The steam end consists of a compound engine connected to the beam by a Watt parallel motion. A fly wheel was used to replace the heavy bob weight.

The technical press of that time does not record any remark-

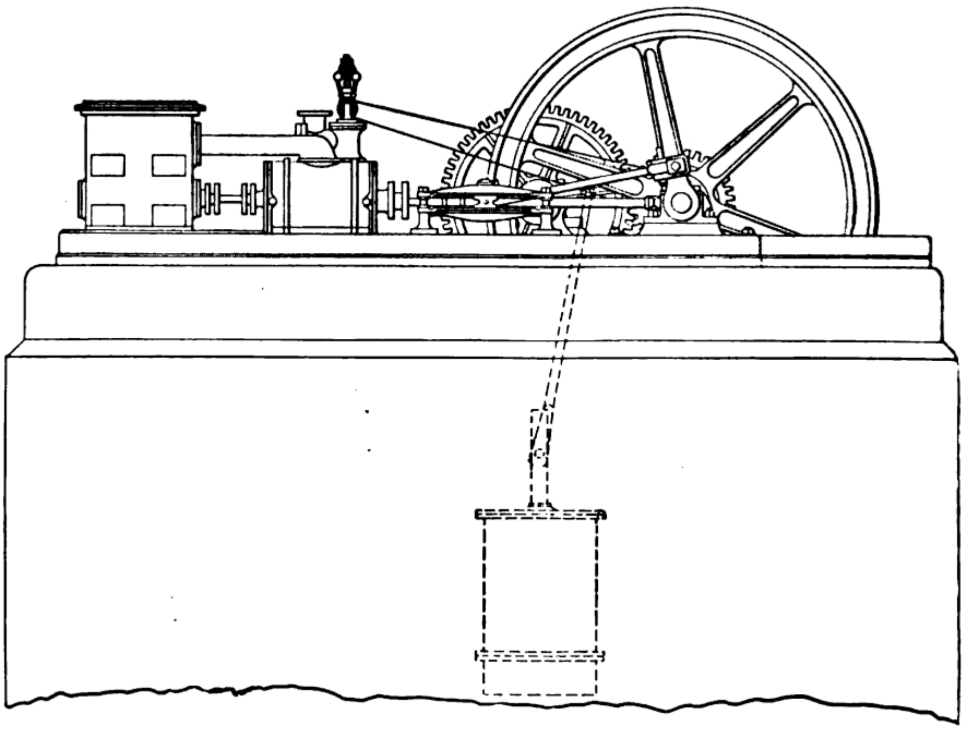

FIG. 81.—1874 Fly Wheel Pump.

able duties for these machines, and for that reason these are not described here, although the student who cares for examples is referred to the bibliography at the end of the book.

An exception to the statement above must be mentioned—the pump used for the city of Paris at the St. Maur station. Although installed in 1876, it was somewhat similar to one installed in 1871. They were built by Farcot & Sons. The steam cylinder was 39.4×70.8 inches, and the water cylinder was 14.2×70.8 inches. The distance from the center of the shaft to the center of the water cylinder was 50 feet 8 inches. The pump had a piston speed of 350 feet per

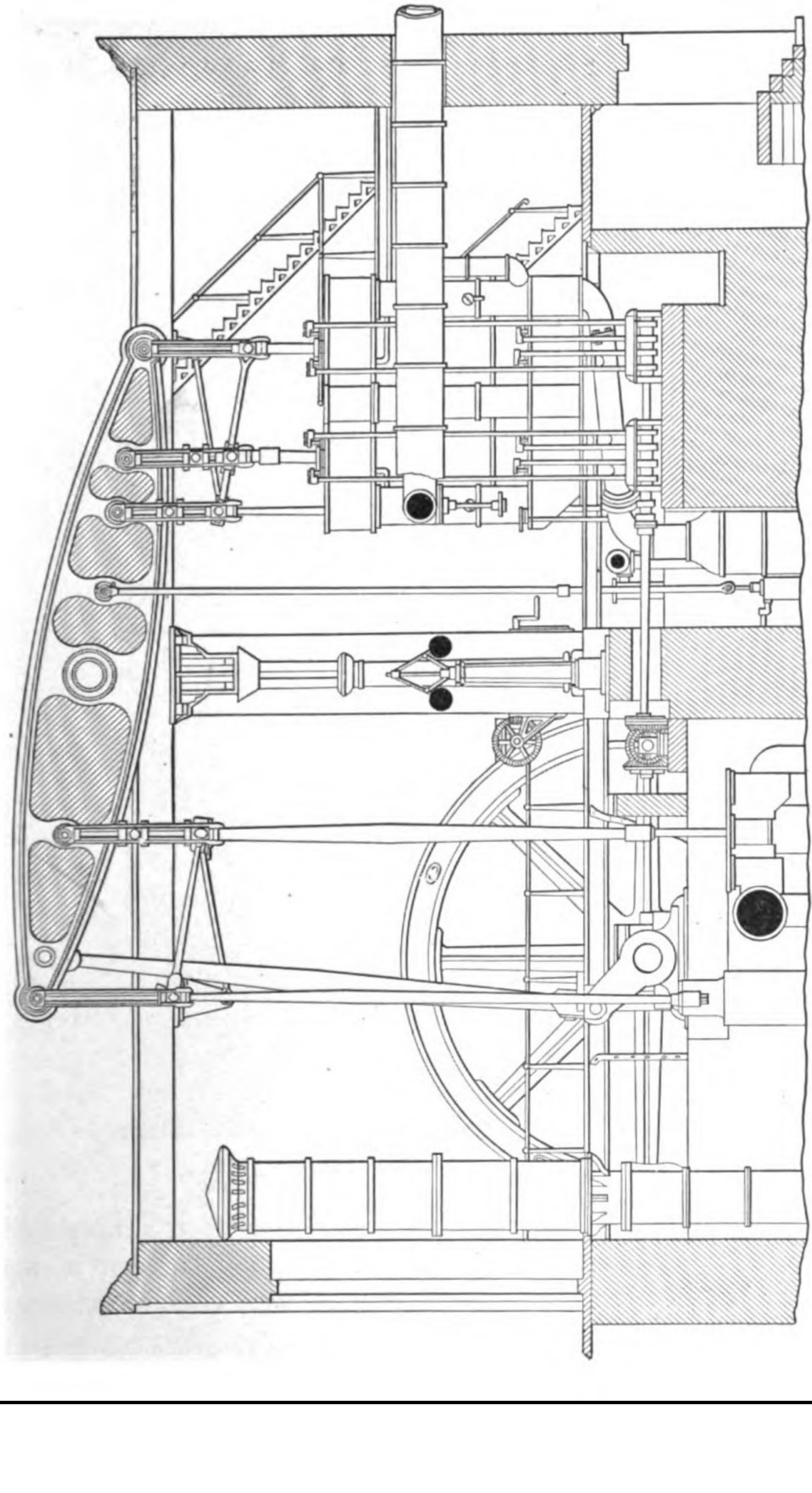

FIG. 82.—Berlin Water Works Engine.

minute, which meant about 30 R.P.M., a high speed for that day. At this speed it pumped 3,000,000 gallons in twenty-four hours. To get such a high speed the valves on the suc-

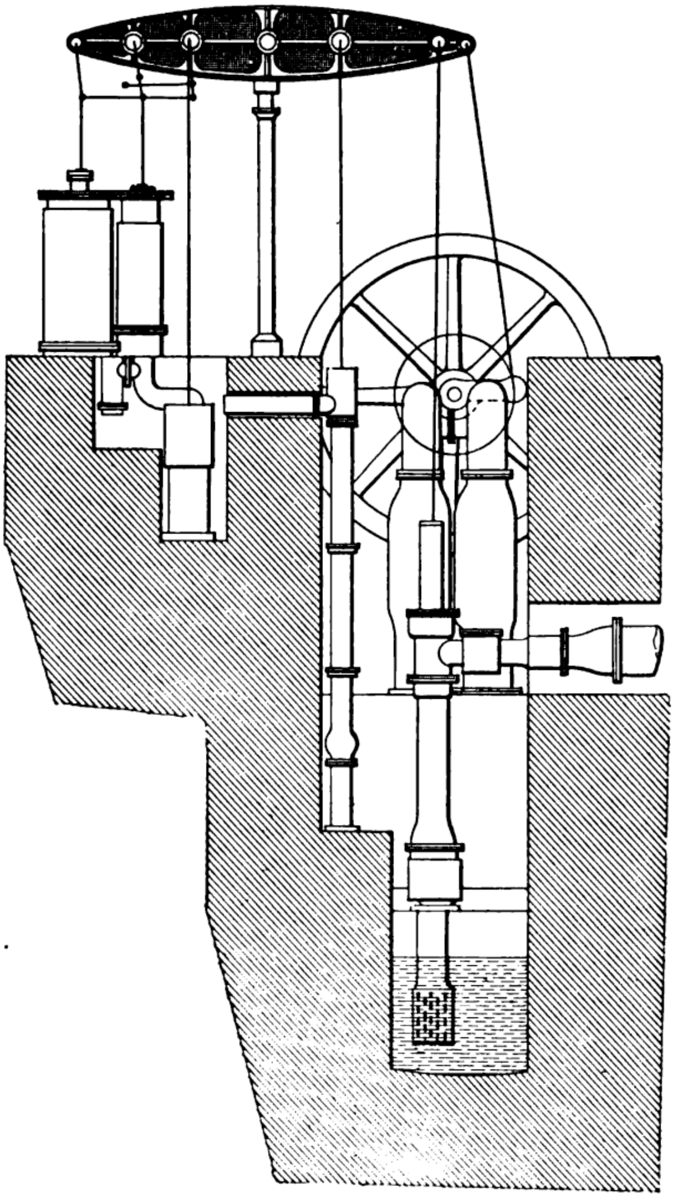

FIG. 83.—Simpson's Pumping Engine.

tion and discharge side were made so as to open simply and give a free passage to the water. This may be seen in the figure. The passages through the pump were made quite large so that the water would have a free path.

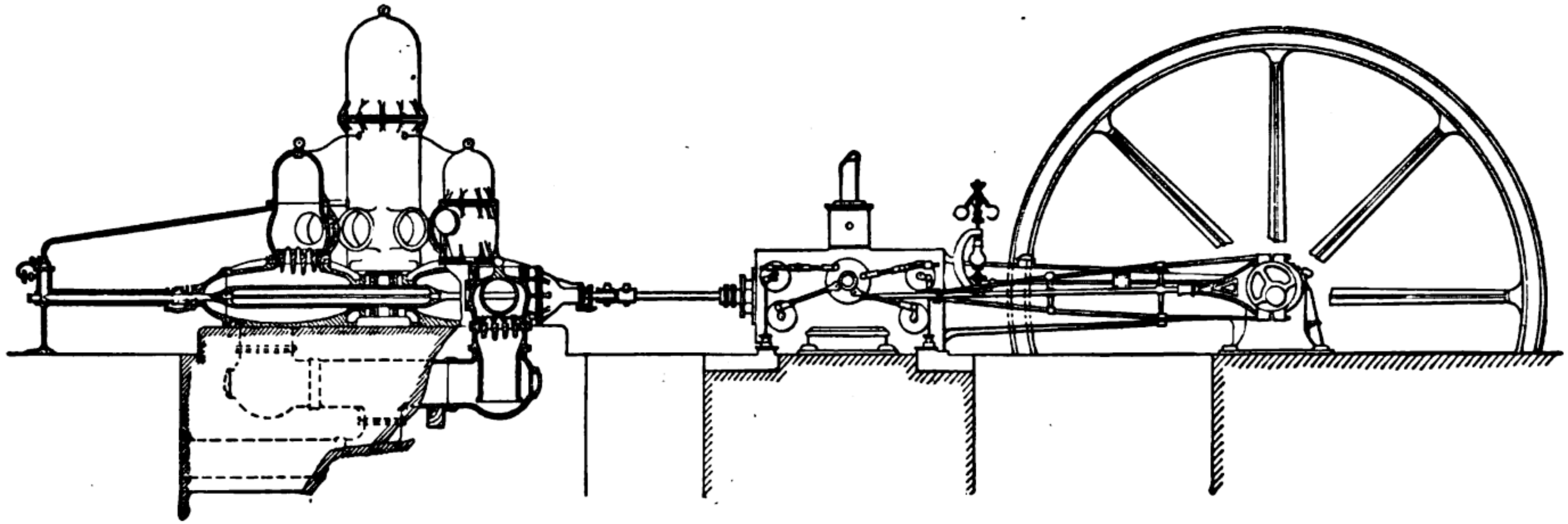

Fig. 84.—St. Maur Pump of Farcot & Sons.

The extended tail rod on the pump plunger was used to pump air into the air chambers to keep them charged.

The pump was driven by a single-cylinder condensing engine, with the air pump driven by a lever connected to the

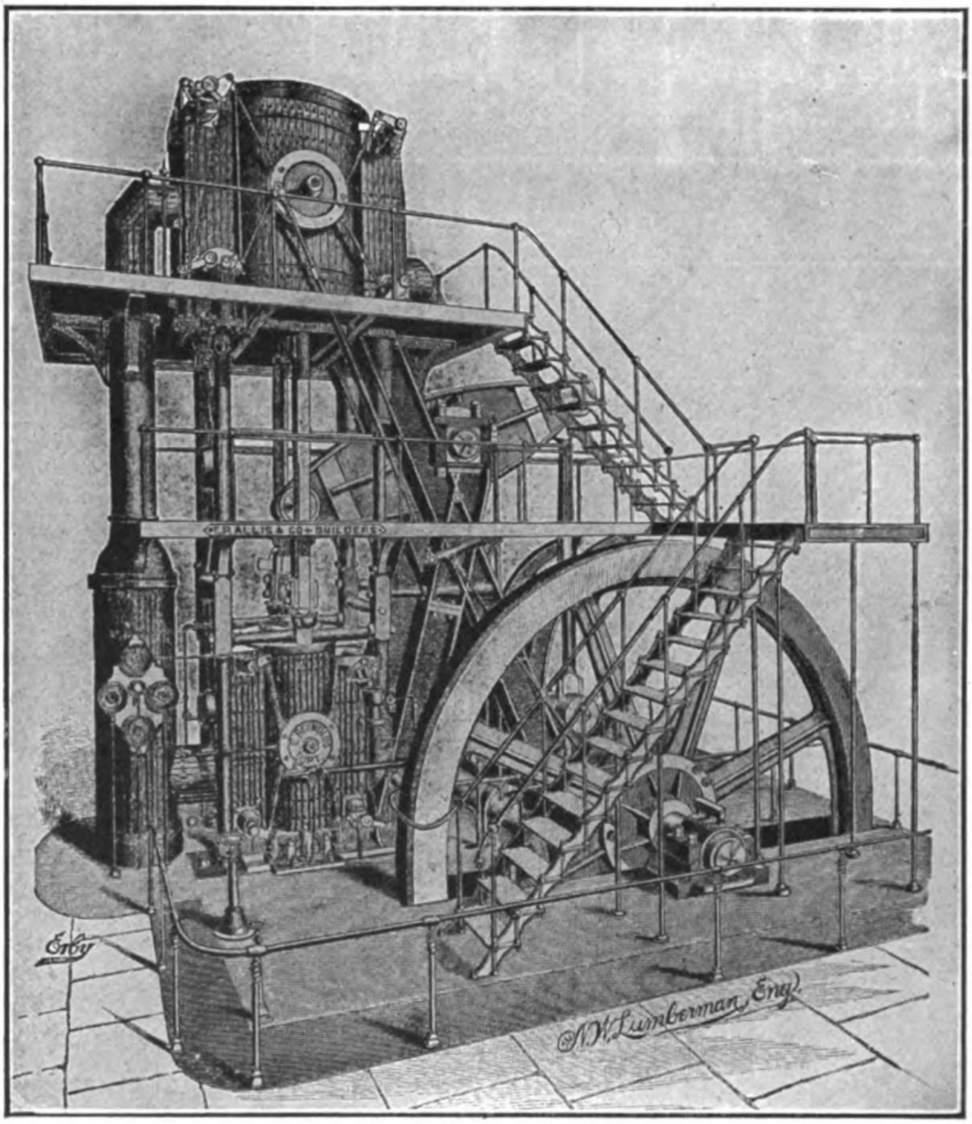

FIG. 85.

cross-head, and so well was the machine designed that the makers reported the development of an indicated horse power on 12.1 pounds of steam per hour or 1.54 pounds of ordinary coal while 2.03 pounds of coal were used per pump horse power per hour. This would mean a duty of 78,000,000 foot-pounds per 100 pounds of coal.

The 6,000,000-gallon Reynolds pump of 1881 (Figs. 85 and 86) for Milwaukee shows a type similar to many of the European pumps of this period in its general arrangement of cylinders, except that there was an additional low-pressure cylinder

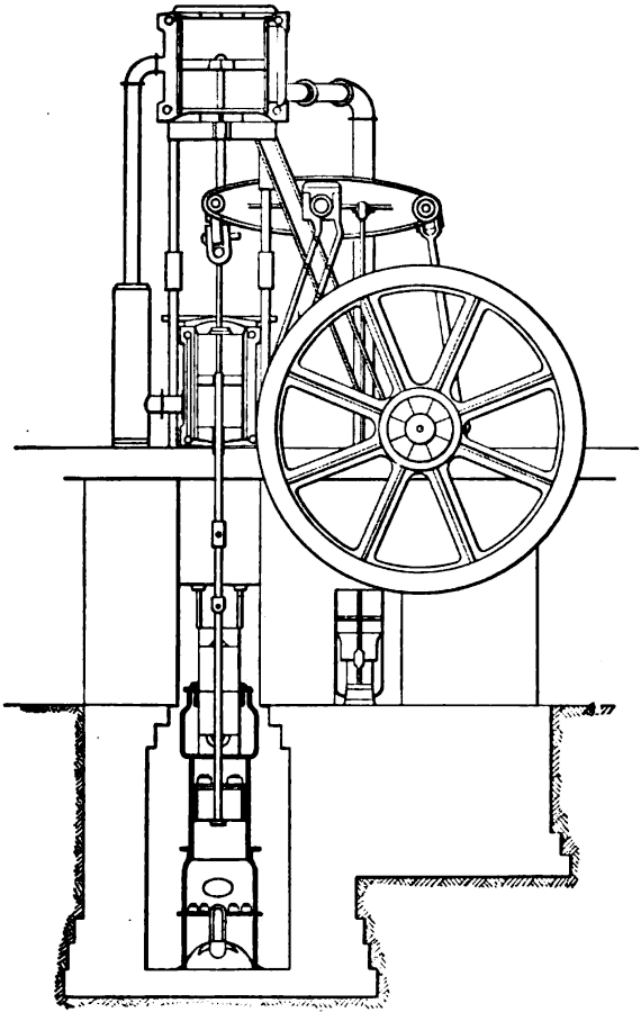

FIG. 86.—Reynolds Milwaukee Engine.

added above the beam. The duty of this engine was 104,000,000 foot-pounds per 100 pounds coal. Following this came the two 12,000,000 gallon Allegheny pumps of 1883 (Fig. 87), in which there were three cylinders to each pump—one high pressure and two low pressure. The engine was an entirely new design for large engines, although small pumps had been arranged in this general manner much earlier. The cranks were placed at 120° and the number of working steam cylin-

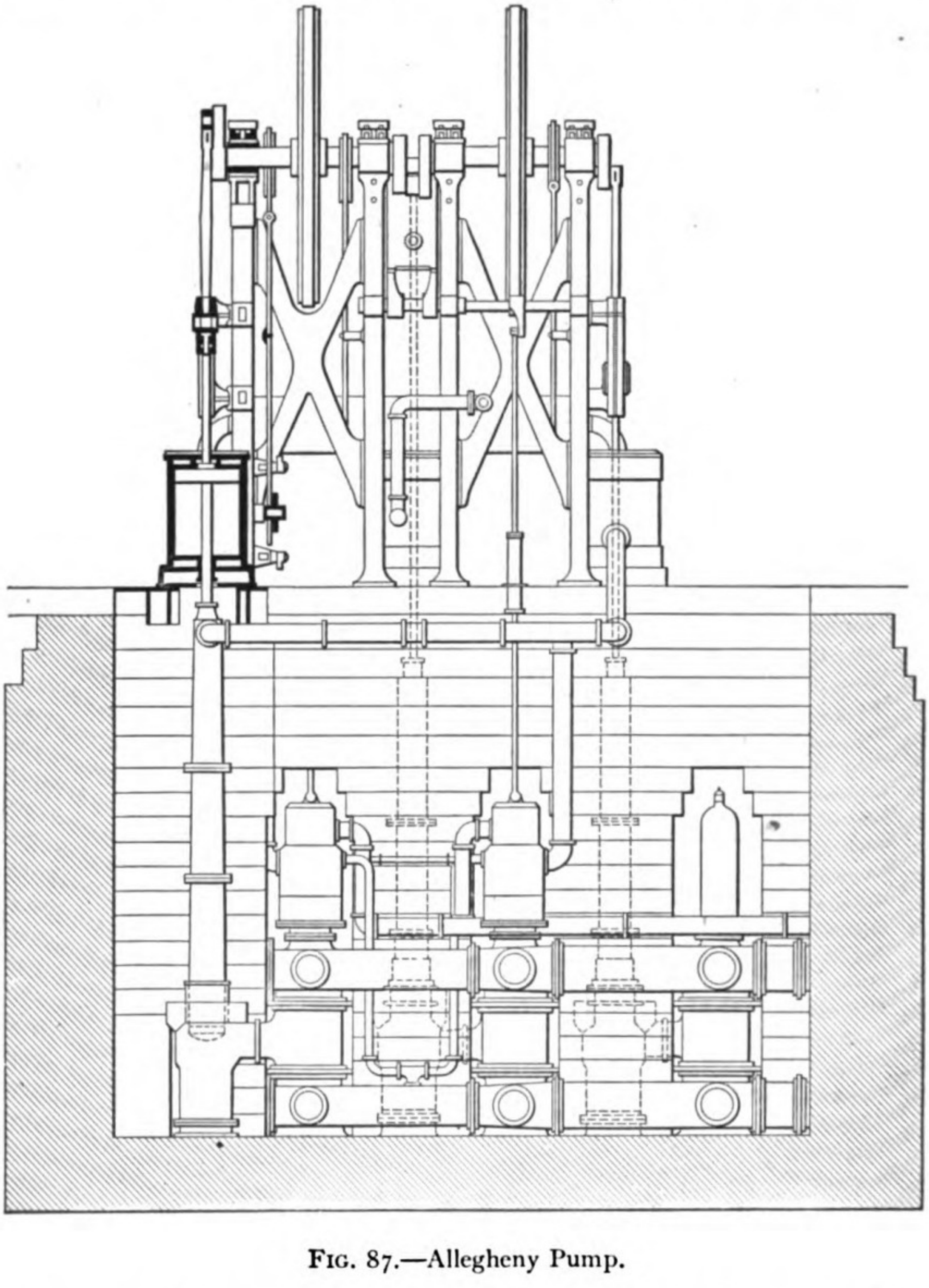

FIG. 87.—Allegheny Pump.

ders was reduced to three in place of four, so common in the standard type of pump of the day. The arrangement of the pump and steam cylinders is clear from the figure. The valve gear was of the Corliss type with fly ball and hand governing and receivers were used between the cylinders. The

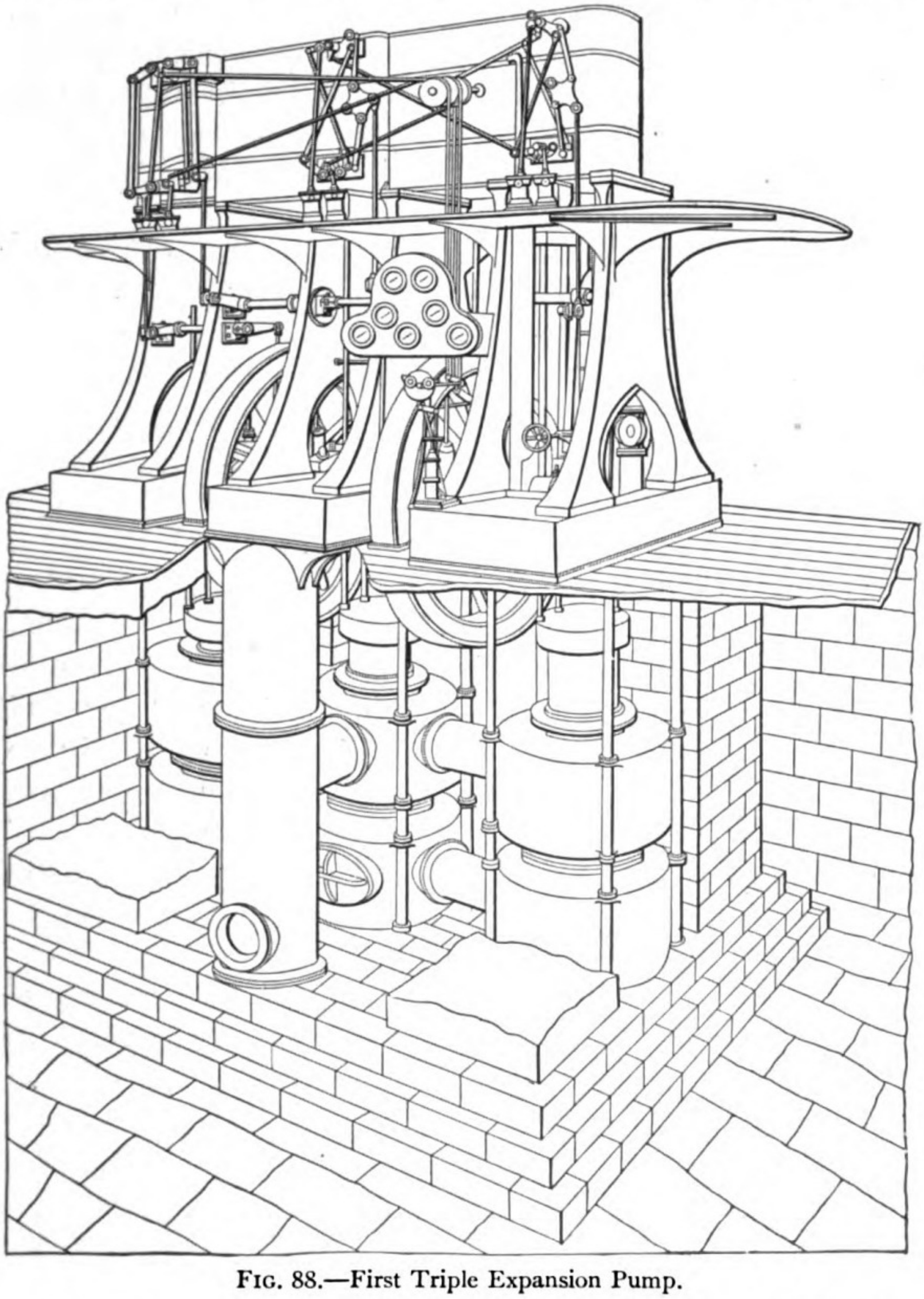

FIG. 88.—First Triple Expansion Pump.

cylinders were jacketed, but there was no heating coil in the receiver.

The valves of the pumps were originally of the Cornish double-beat design, but these were later changed to small valves supported on a cage or basket placed over the opening for the Cornish valves.

The test of this engine gave 107,000,000 foot-pounds per 1000 pounds of steam when tested in 1884 by Mr. C. A. Hague and Professor David M. Green. It represented a type of engine of great value for small floor space, as was the case of the Eastbourne engine of 1880.

After the Allegheny engine of 1883 Allis built several compound-beam fly-wheel engines of about 2,500,000 gallons, and in one of them for Hannibal, Mo., the clearance was reduced by putting the Corliss valves in the head of the cylinder. This engine on test in November, 1885, by Mr. C. A. Hague, gave a duty of 118,327,025 foot-pounds per 100 pounds coal at a gauge pressure of 79 pounds. This engine then led to the design of the triple-expansion engine.

The triple-expansion engine (Fig. 88) is the first of the most popular type of large pumping engine, although many other forms have been suggested and used. This pump was built for the city of Milwaukee. The figure shows clearly the arrangement of the pump and engine. This resembles, to some extent, the design of frame used by Moreland in England. It is in reality the same arrangement as that used for marine engines with pumps added below the bed plate of the engine.

The engine gave the high duty of 122,483,204 foot-pounds per 100 pounds of coal with 80 pounds steam pressure. The dimensions of the engine were as follows:

High-pressure cylinder diameter	21	ins.
Intermediate-pressure cylinder diameter	36	"
Low-pressure cylinder diameter	51	"
Pump plunger	23½	"
Stroke	36	"
Capacity per twenty-four hours	6,000,000	gals.

The first triple-expansion pump in England (Fig. 89) was introduced in 1891 by S. Richardson & Sons, and gave a steam consumption of 13.53 pounds per I.H.P. hour. The use of triple-expansion for direct-acting pumps was also introduced at this time by Davison in his water-works pumps. These gave good results and increased the duty of direct-acting pumps.

In 1885 Worthington brought out his high-duty engine,

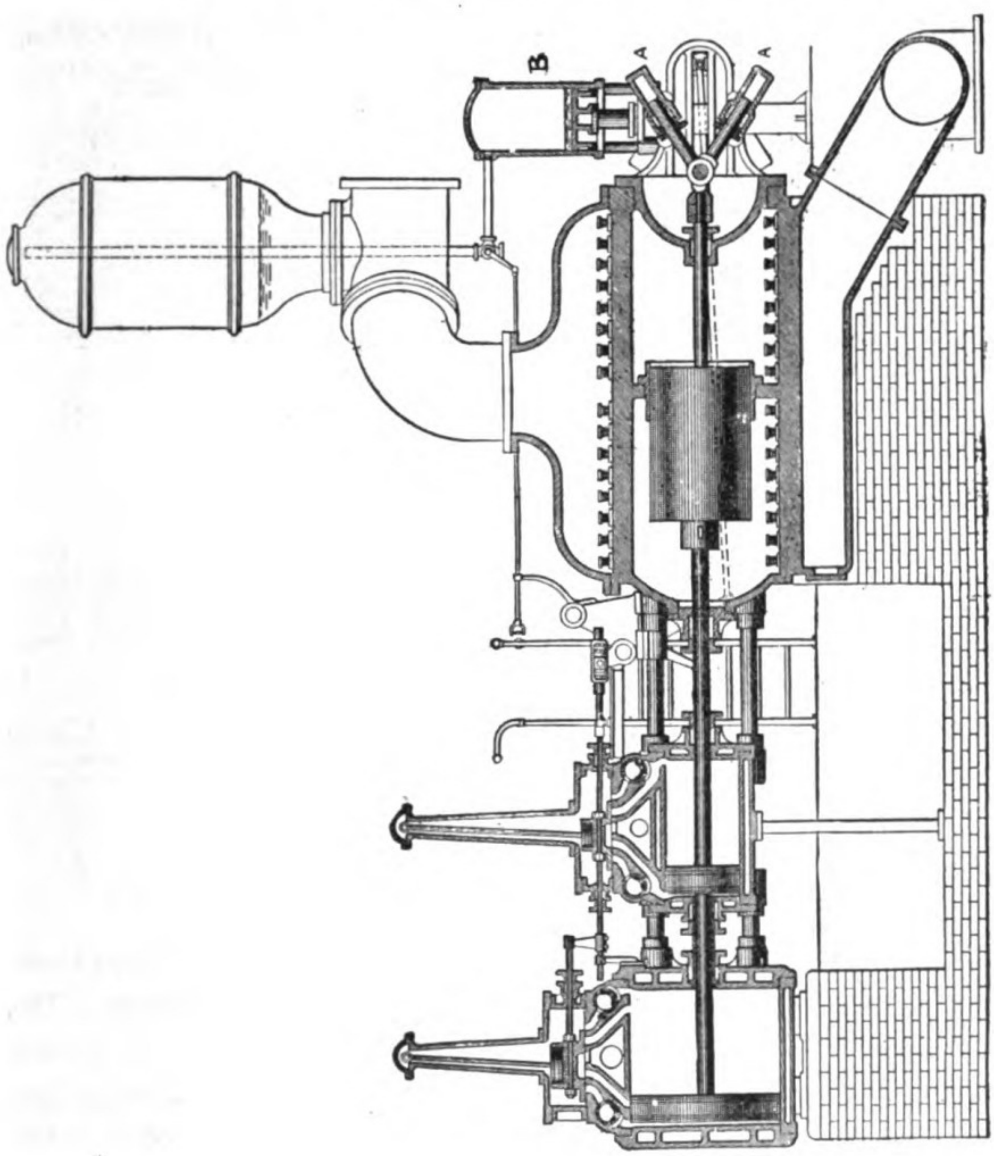

FIG. 90.—Worthington High Duty Pump.

built exactly as the duplex engines, but with the addition of compensating cylinders so as to use steam expansively. It was not possible to obtain the high duties of the expansive fly-wheel pumps with the ordinary duplex pump, and although these could be sold much cheaper, their duty was so low as to

Fig. 99 is the Snow type of horizontal pump designed to take up little floor space and yet have the cylinders for the

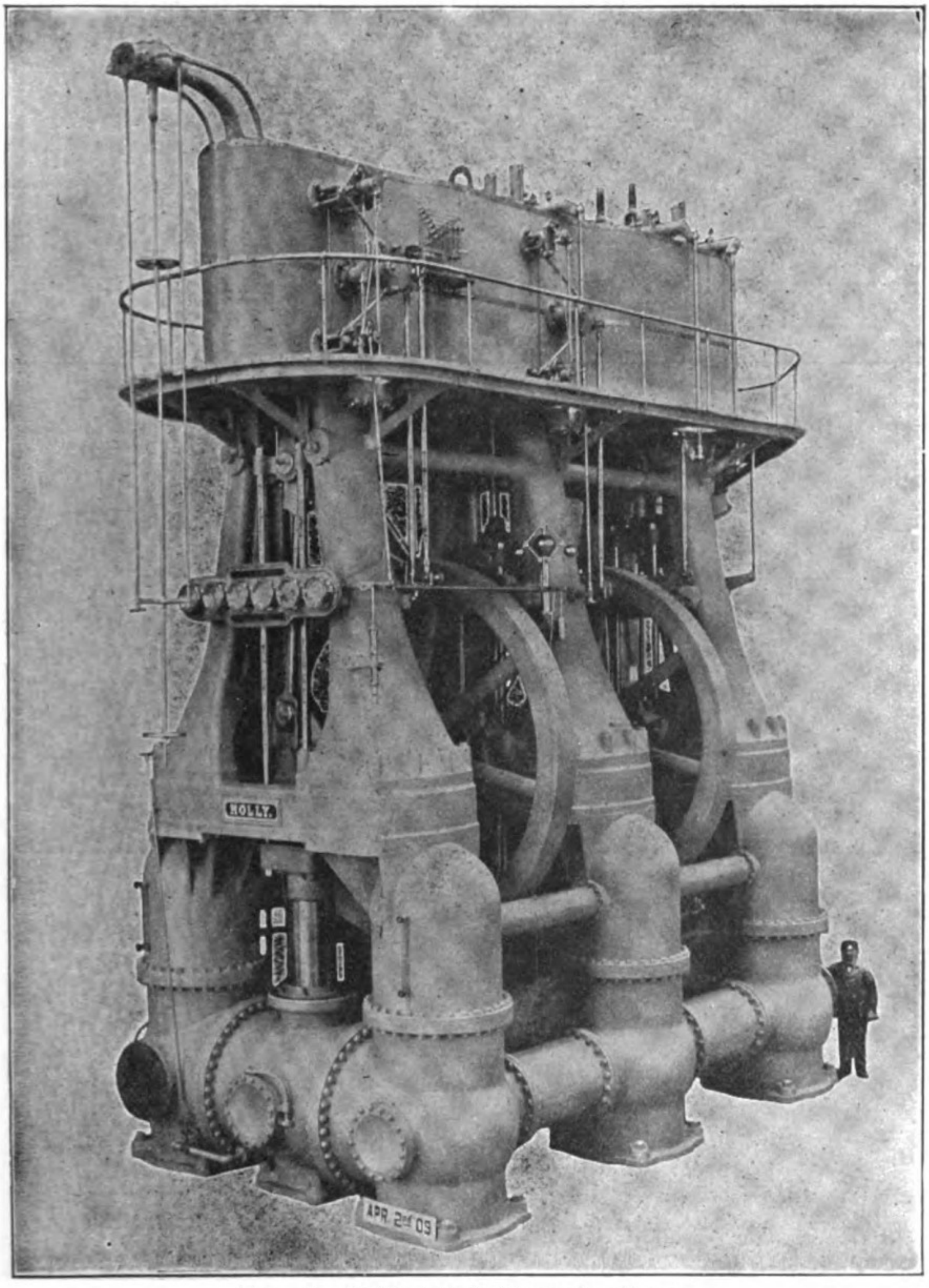

FIG. 98.—Holly Triple Expansion Pump.

water and steam ends in such a position that they may be easily examined and repaired. The method of clearing the plete pipe on account of the opening from the filling ring, and for that reason the bending action on the casting requires additional ribs.

It is the object of the whirlpool chamber to reduce the absolute velocity of discharge, changing it into pressure. It does not accomplish this efficiently, as there is shock here and a sudden change in velocity which means a loss. By having this chamber gradually increase in area the velocity of the water decreases as it passes through, and with this action the

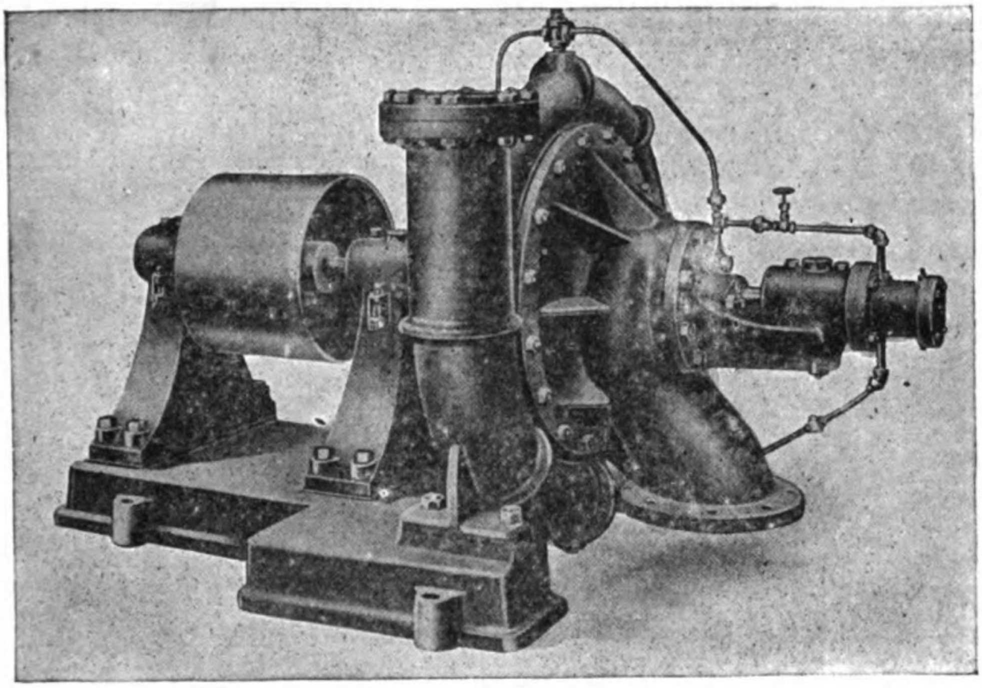

FIG. 425.—Worthington Belted Volute Pump.

pressure increases. To make this change in an effective manner, however, the diffuser is used, in which there is no shock, and the velocity head is changed into pressure.

Fig. 425 illustrates one of the Worthington single-flow volute pumps for a belt drive, while Fig. 426 illustrates a double-flow volute pump, motor driven. These figures show the external appearance of the pumps; the pipes for water circulation in the stuffing boxes and thrust bearing; the stiffening webs; the method of supporting the casing and the method of attaching the heads to the casing. The double-flow pump of Fig. 426 is not equipped with a thrust bearing, as in this type of pump there should be no end thrust.

These pumps are intended primarily for heads up to 65 feet, and in most cases when this head is exceeded the turbine type of pump with a set of diffuser vanes would be used. The impellers built by Worthington are specially designed to suit the conditions of the particular service required by the purchaser, and this should always be done, as each speed and head

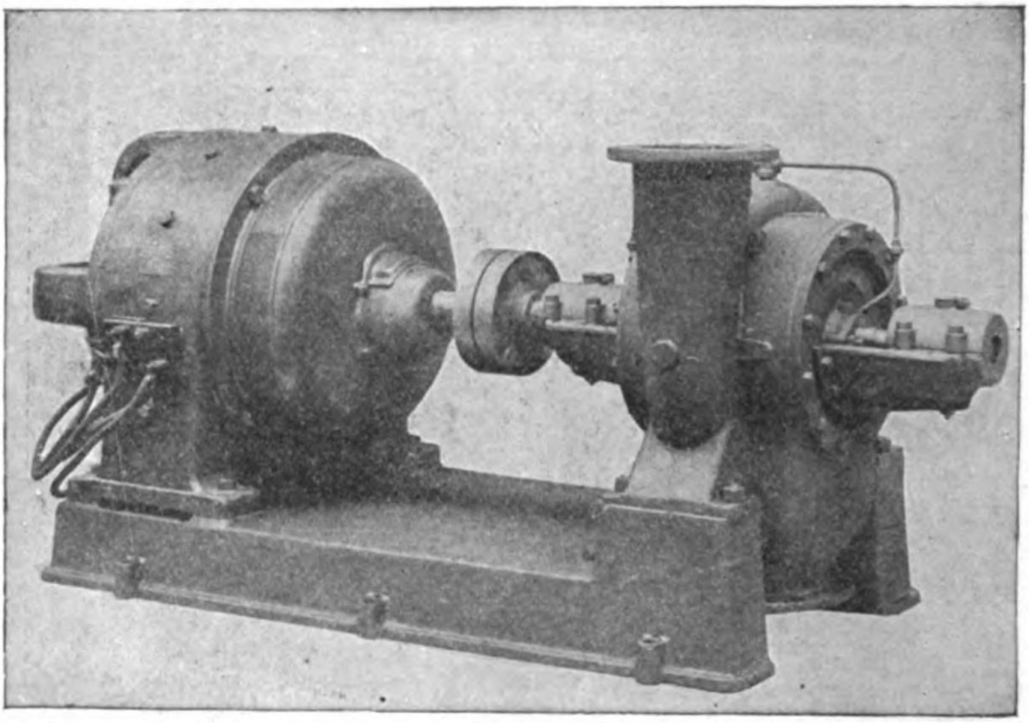

FIG. 426.—Motor Driven Worthington Double Flow Volute Pump.

requires a definite form of impeller. The suction head shown in Fig. 423 is so arranged that water may enter from all parts, giving an adequate supply to the impeller.

These pumps are built in different sizes, as shown by the tables below; the first table giving the capacities, speeds, heads and power; the second, the dimensions of the casing.

The pumps shown so far have been arranged with the suction below, while the discharge has been taken off vertically. This arrangement may be changed to suit as shown in Fig. 427, which illustrates a few of the different arrangements possible with their designating numbers.

A recent design of volute pump for a low head but large capacity is shown in Fig. 428. This pump is known as a **tri-rotor volute pump.** It was installed in the Interborough Rapid Transit Station for circulating the water through the surface condensers. It is in reality three double-flow volute pumps with four vertical suction pipes rising to the center of the casing and threading among the three horizontal discharge pipes which unite and discharge from one large opening at the front of the bed plate. The head being small, there are no stiffening ribs found on the exterior of the casing. The ring oil bearings, thrust bearing, water-supply pipes for stuffing boxes

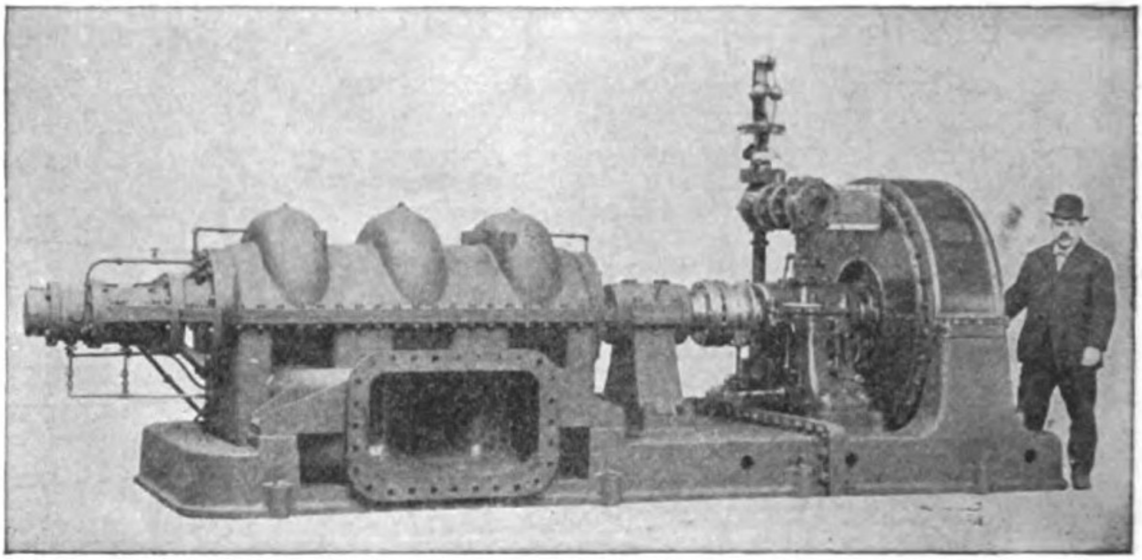

FIG. 428.—Worthington Turbine Driven Tri-rotor Volute Pump.

and thrust bearing as well as the general arrangements for casting the casing and heads are clearly seen. The figure also illustrates the method of driving the pump by a steam turbine.