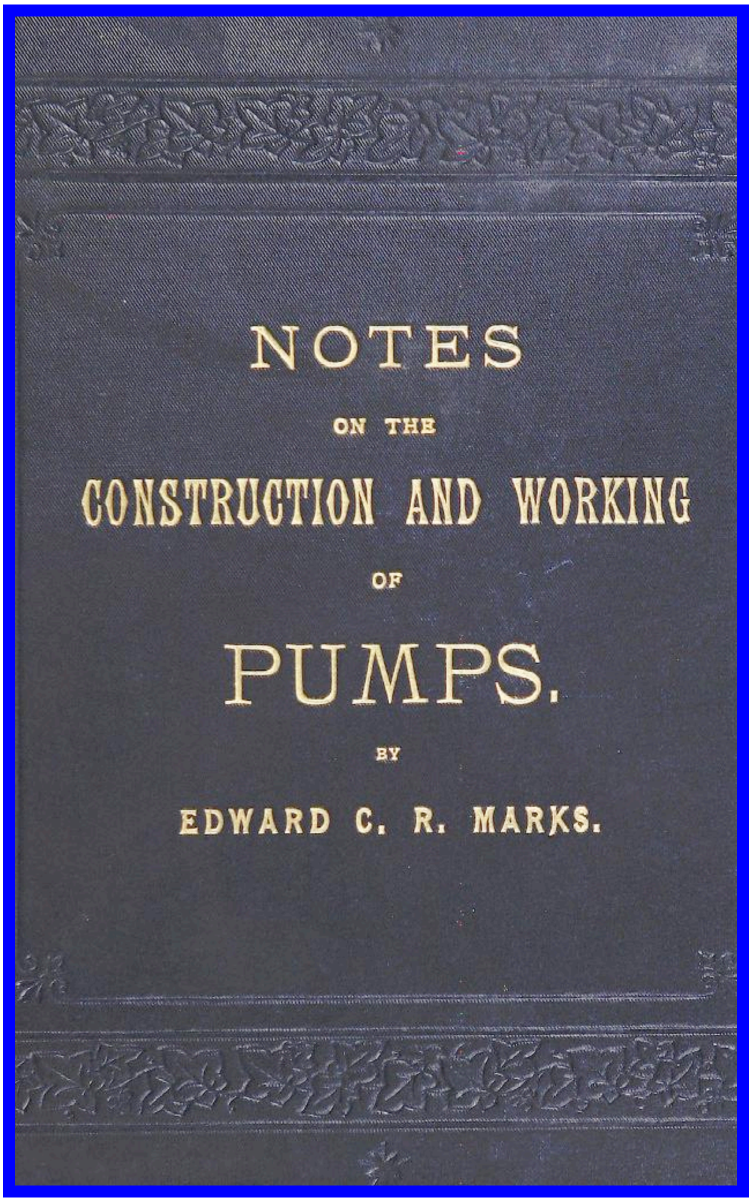
# PUMPS & PUMPING MACHINERY
# 1500 BC-1960

# *Marks on Pumps*




**1902**

# NOTES ON THE

# CONSTRUCTION AND WORKING

# OF PUMPS.


BY

EDWARD C. R. MARKS,

*Associate Member of the Institution of Civil Engineers, Member of the Institution of Mechanical Engineers, Fellow of the Chartered Institute of Patent Agents;*

*Author of "Notes on the Construction of Cranes and Lifting Machinery," "Mechanical Engineering Materials," "The Manufacture of Iron and Steel Tubes," "The Evolution of Modern Small Arms and Ammunition."*


PRICE THREE SHILLINGS AND SIXPENCE NET.


1902.

THE TECHNICAL PUBLISHING COMPANY LIMITED,

31, Whitworth Street, Manchester.

JOHN HEYWOOD,

29 and 30, Shoe Lane, London; and Ridgefield, Manchester.

*And all Booksellers.*

D. VAN NOSTRAND COMPANY,

NEW YORK.

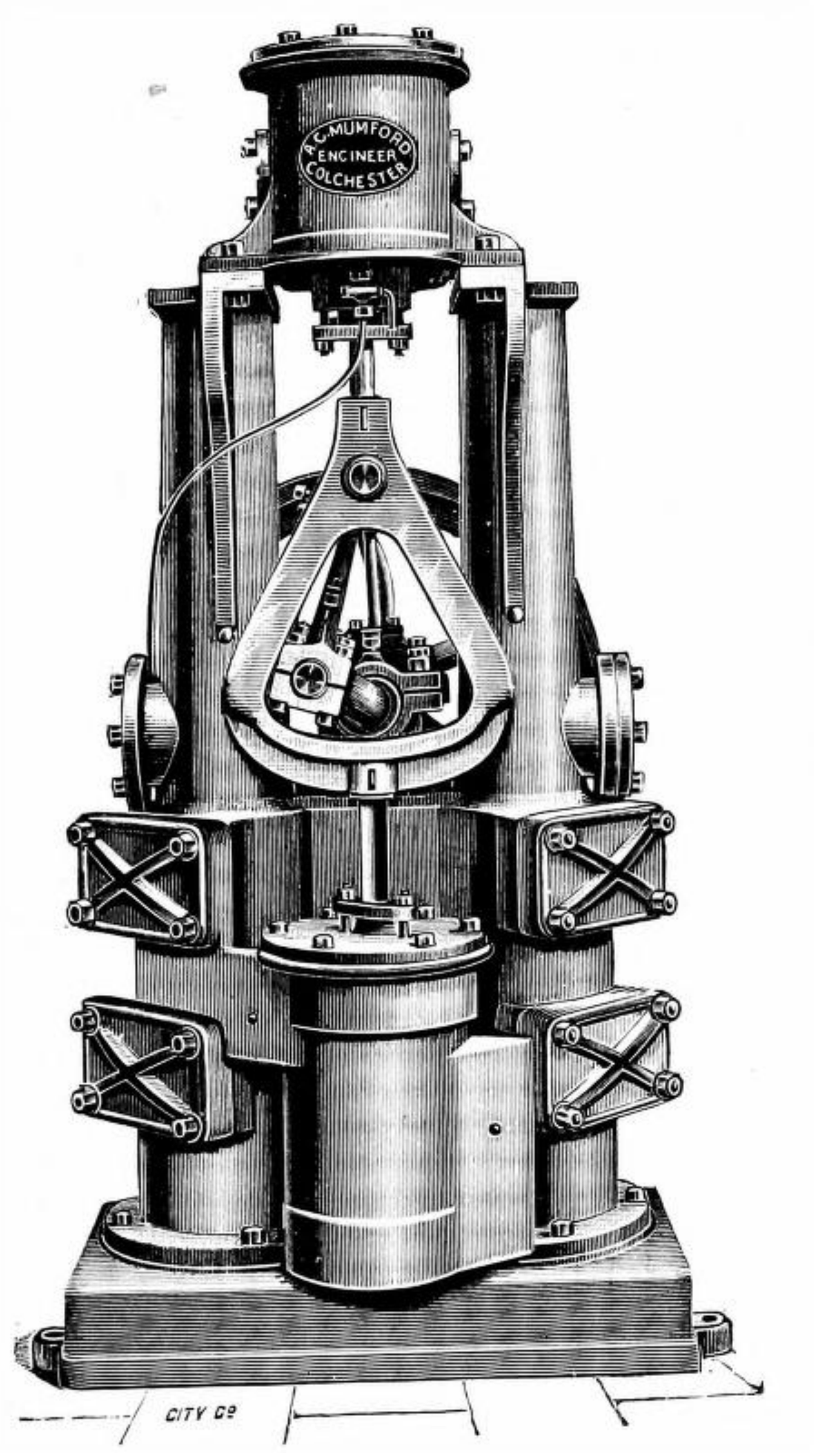



Fig. 23.

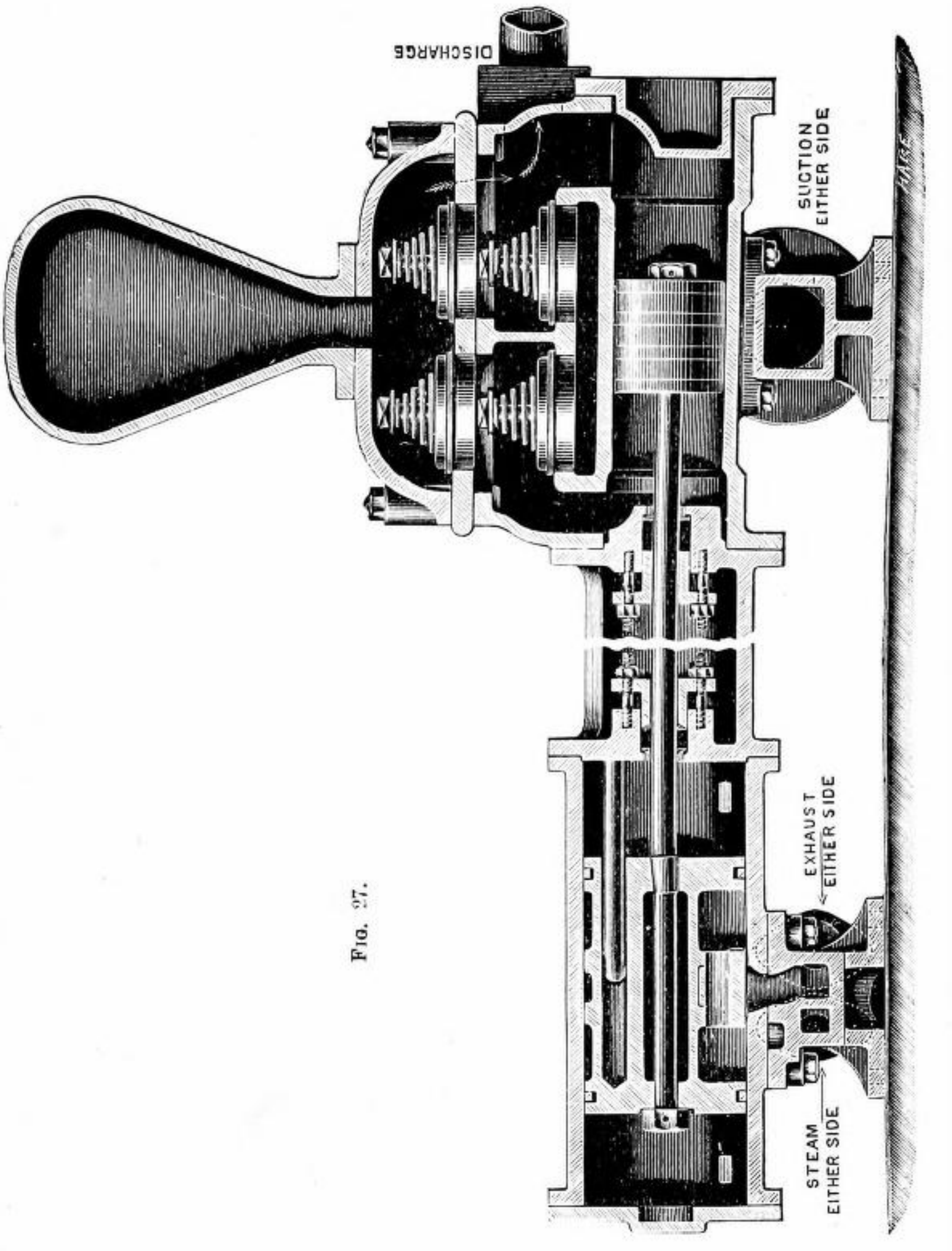

DISCHARGE
SUCTION
EITHER SIDE
EXHAUST
EITHER SIDE
STEAM
EITHER SIDE

Fig. 27.

# CHAPTER XII.

## CENTRIFUGAL PUMPS.

THESE well-known machines, with which water is raised by the centrifugal force set up by a revolving disc or fan, were first brought prominently before the notice of engineers and pump users generally at the Great Exhibition of 1851.

A crude form of centrifugal pump was known as early as the middle of the 18th century. Rather more than half a century later, in the year 1818, a centrifugal pump was constructed at Massachusetts, U.S.A., and became known as the Massachusetts pump. It resembled an

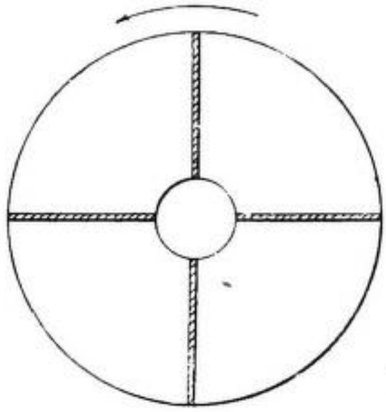


FIG. 72.

ordinary fan blower, and comprised a horizontal shaft having four straight blades enclosed within a cylindrical casing. But the pump had to be placed below the level of the water to be raised, for it is stated that "the vacuum power" was small.

At the Great Exhibition of 1851 Appold introduced his pumps having fans or impellers with curved blades or vanes (in place of vanes of the radial type shown at fig. 72), and with other improvements which enabled him to show an efficiency three times greater than could be obtained with the old machines. Appold's improvements established the position of the centrifugal pump as a most suitable machine for raising large quantities of water against a low head or pressure.

The frictional loss in the working of a reciprocating pump is practically constant, and independent of the useful head or pressure against which the water has to be delivered.

Take the case of a reciprocating pump working against a pressure of, say, 60 lb. per square inch or 139 ft. vertical head, and requiring a pressure of, say, 15 lb. per square inch to overcome the frictional resistance. Out of the total energy supplied to the machine $\frac{15}{75}$ths, or 20 per cent, will be absorbed in friction; the remaining 80 per cent represents the useful work done, or the mechanical efficiency of the machine. But if the pump is set to work against a head of but 10 lb. per square inch, the frictional resistance will still require a pressure of 15 lb. to overcome it, and thus out of the total energy supplied only $\frac{10}{25}$ths, or 40 per cent, will be accounted for in useful work done, the remaining 60 per cent being absorbed by friction.

It will thus be seen that "the efficiency of reciprocating pumps diminishes with the lift." With centrifugal pumps there is no such diminution; indeed, it has been stated, though not perhaps with strict accuracy, that they work to best advantage on services where the lift in feet can be represented by a unit figure.

An increase in the head against which the water has to be delivered by a centrifugal pump necessitates an increase in the speed of the revolving disc, fan, or impeller. The theoretical ratio between the head of water and the speed of the pump, when the revolving disc of the latter has arms or vanes which are radial at the periphery, is expressed by the formula—

$$h = \frac{V^2}{g}$$

where $h$ = head in feet (measured from the surface of the water to be raised);

$V$ = velocity of periphery of pump disc or fan in feet per second;

$g$ = accelerating force of gravity, say 32·2.

As the height through which any moving body must fall freely to attain a given velocity is expressed by the well-known formula—

$$h = \frac{v^2}{2g}$$

(of which we made use in an earlier article dealing with pipe areas), it might be erroneously concluded that the same formula would also apply here and that V represents also the velocity of the water. But on reflection it will be seen that the water in passing through the centrifugal pump receives energy which tends to propel it in two directions, viz., in an outward direction along the radial arms, and also in a direction tangential to such arms or blades of the fan, disc, or impeller. At the instant of reaching the periphery of the impeller the velocity of the water in each direction will equal the peripheral velocity, so that the water will be discharged from the periphery in a direction which is the resultant of the two directions aforesaid, and its velocity will also be a resultant of what we may term the two component velocities. Thus it is that

$$h = \frac{V^2}{2g} \times 2 = \frac{V^2}{g}.$$

As an example let us suppose that the rim velocity of a pump disc with radial arms is 36 ft. per second. The maximum theoretical head against which the water can be delivered with the pump running at the given speed will then be

$$\frac{36 \times 36}{32{\cdot}2} = 40{\cdot}2 \text{ ft.}$$

But the actual head against which the pump can deliver water will be considerably less than 40 ft., depending upon the care taken in the design and construction of the pump to prevent sudden changes in the direction and velocity of the water. With the old style of radial arms, as shown at fig. 72, there is much loss through useless churning of the water. It is, of course, also of great importance that the bearings upon which the fan shaft rotates and the means employed for driving the fan or disc be mechanically efficient.

To utilise the energy which might otherwise be spent in the formation of eddies in the discharge pipe of a centrifugal pump, Professor James Thompson suggested, subsequent to the introduction of the Appold improvements, the use of what is termed the "diffusor" or "whirlpool chamber." Such chamber surrounds the revolving disc, and the water delivered into it from the latter is allowed to continue its whirl or rotation for effecting a more gradual and efficient conversion of the kinetic energy into the pressure energy required to force the water up through the delivery pipe.

But in order to get full benefit from a diffusor or whirlpool chamber it would in most cases require to be so large as to cause more inconvenience than would be compensated for by the practical advantage obtained. Moreover, as the vanes of the disc are in British practice curved back, and not made of the radial form previously referred to, the velocity of the water on leaving the fan, and consequently its kinetic energy, is diminished; a further reduction of the kinetic energy by its conversion into pressure energy before the water leaves the disc, impeller, or fan, is also effected in some centrifugal pumps by increasing the area of the water space towards the periphery of the disc. The whirlpool chamber or diffusor may therefore be greatly reduced in dimensions, and in some cases entirely dispensed with, in the construction of the pump, without loss of efficiency in its working.

From the whirlpool chamber, or directly from the periphery of the disc, the water passes into the volute or spiral chamber, having a section uniformly increasing as it approaches the discharge or delivery pipe to receive the increasing volume of water from the disc. Conical suction and discharge pipes are sometimes employed with advantage.

Figs. 73 to 76 represent four types of discs or impellers, as adopted by different makers. Figs. 73, 74, and 75 show (in side elevaton) three curved or sloping vane types by three different English makers, whilst fig. 76 represents (in plan) the modified radial vanes of a horizontal type centrifugal pump by French makers.

Unless a centrifugal pump can be fixed below the surface of the water to be raised, it is necessary to charge the casing

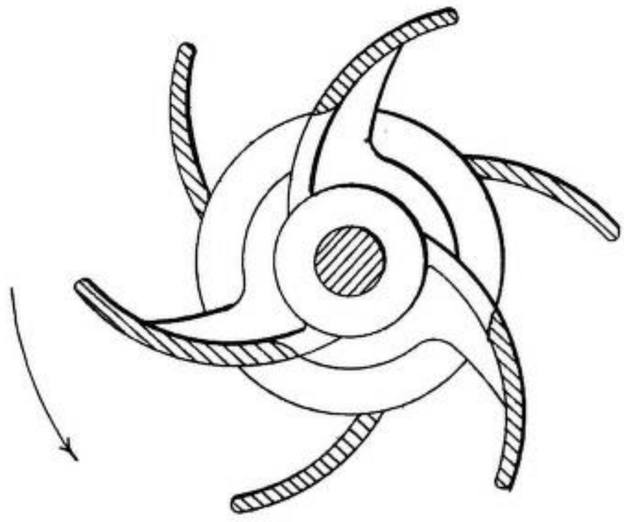


Fig. 74.

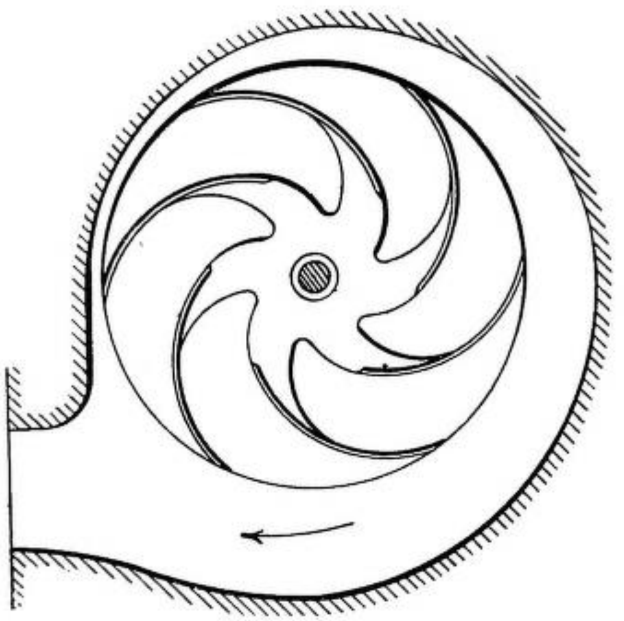


Fig. 73.

with water before starting. For this purpose a steam ejector can be employed to exhaust the air from the pump casing and pipes.

Fig. 77 is an illustration of a centrifugal pump, for belt driving, by Messrs. Drysdale and Co., of Bon-Accord Works,

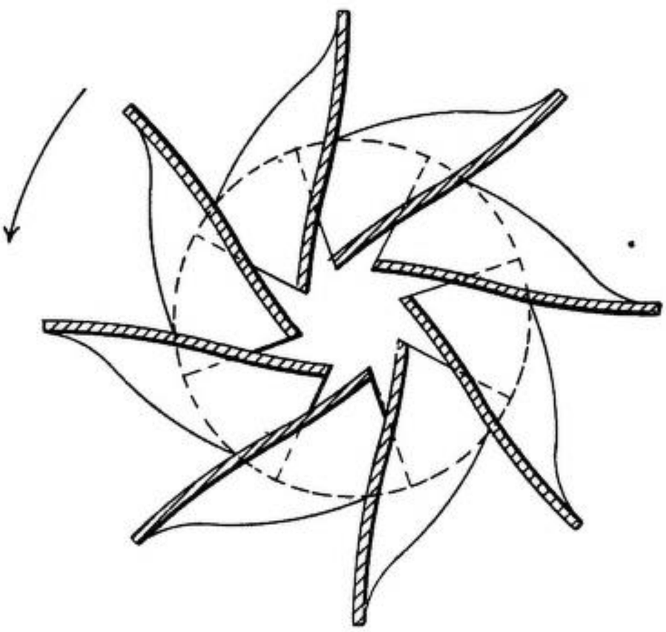


FIG. 76.

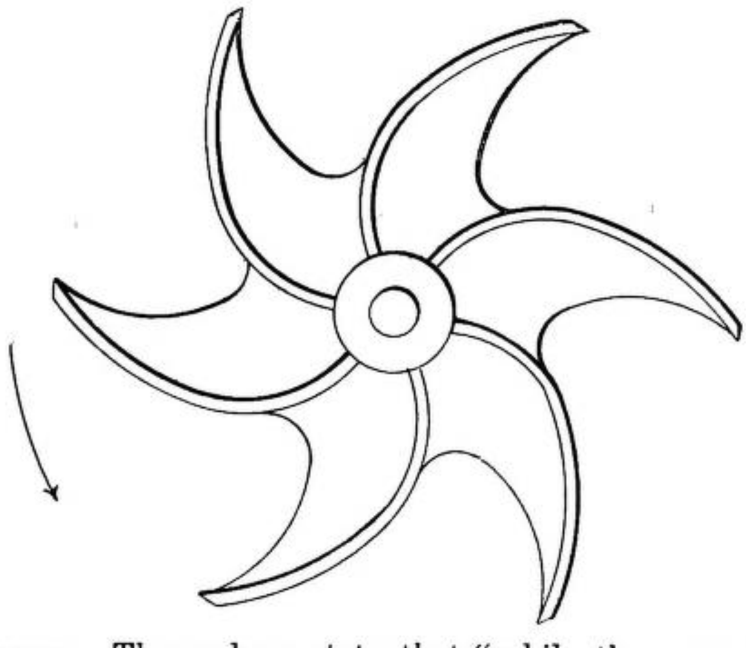


FIG. 75.

Glasgow. The makers state that "while these pumps will meet the requirements of all users for ordinary low lifts, they will be found specially advantageous for irrigation, drainage, and similar work. The impellers or discs are specially wide to permit of the passage of any solid matter likely to be allowed inside, and a cleaning door is provided to meet the case of any special obstruction." In their lists, published with the pump as illustrated, the makers give the speeds necessary for lifts of 10 ft. and 18 ft. respectively. Thus a small pump, to deliver from 60 to 80 gallons per minute, must be run at about 1,000 revolutions per minute

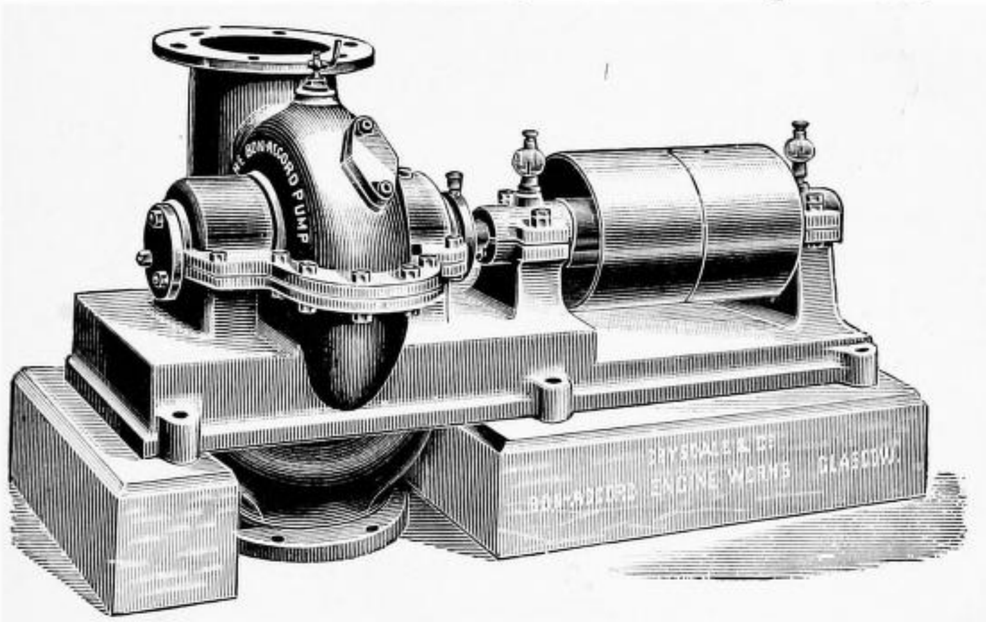



FIG. 77.

when working against a 10 ft. head, and 1,350 revolutions for a head of 18 ft. A larger pump, to deliver from 2,200 to 2,700 gallons per minute, is run at 345 revolutions per minute when working against a head of 10 ft., and 490 revolutions when working against an 18 ft. head. Pumps designed for high lifts (from 25 ft. to 50 ft. or more) are provided with fans of larger diameter than the low-lift types, in order to obtain the required peripheral velocity of the impellers or discs without driving the same at such a high rate of rotation as to cause inconvenience.

Fig. 78 is an illustration of a combined centrifugal pump and electric motor, also by Messrs. Drysdale and Co.; whilst fig. 79 represents a combined pump and vertical steam engine by the same makers, as employed for the circulation

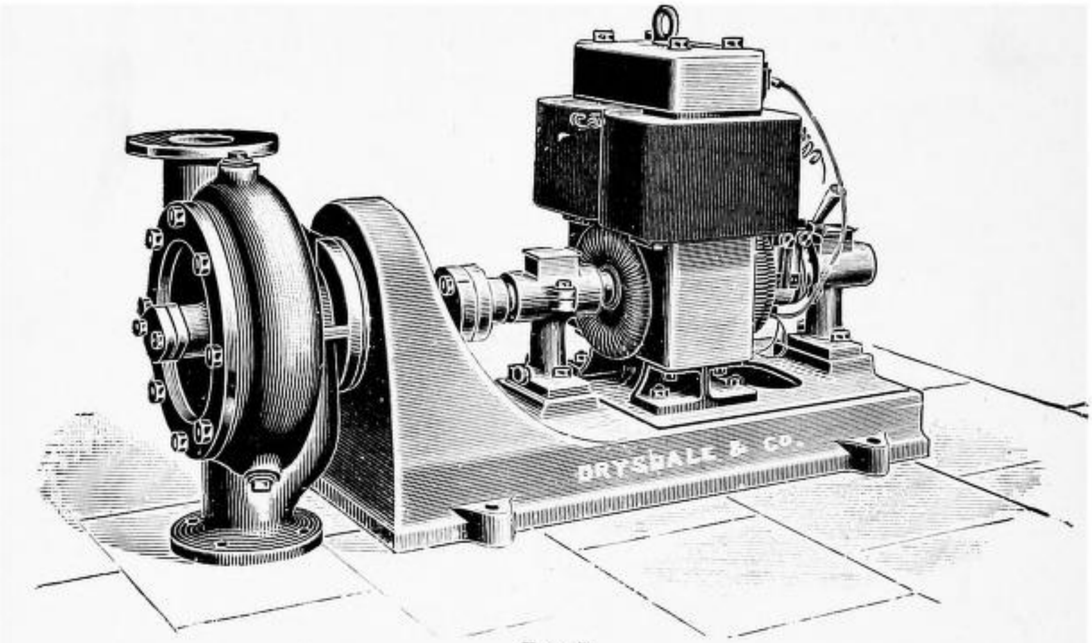



FIG. 78.

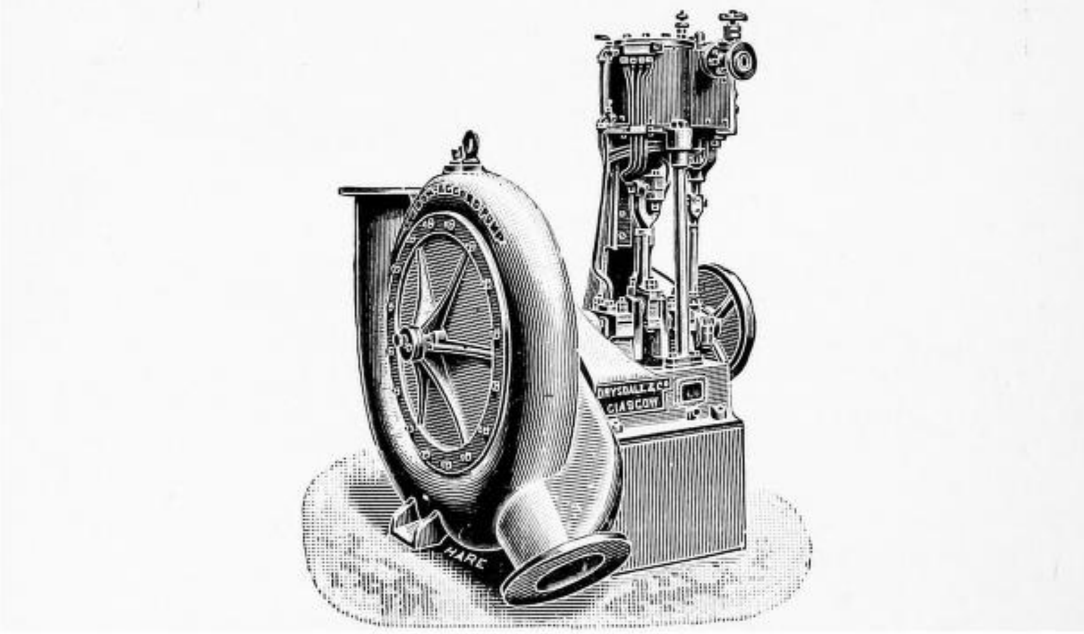


FIG. 79.

of surface condensing water in the mercantile marine and for other services.

Messrs. Gwynne and Company, of Brooke Street Works, Holborn, London, E.C., who have manufactured such machinery for half a century, give the following terse summary of some advantages possessed by a centrifugal pump:—

"It can be erected with ease and celerity.

"It works with an easy rotary motion, without valves, eccentrics, or other contrivances which consume power in friction.

"It is economical in use, simple in construction, and of very great durability.

"It discharges a continuous and steady stream without air vessels.

"It is little affected by sand, mud, grit, or other foreign matter in the water; in the larger sizes it will admit the passage of solid bodies 6 in. diameter, and the smaller sizes in proportion, without injury."

As compared with the full theoretical efficiency of 100 per cent, Messrs. Gwynne give the average efficiency of their centrifugal pumps as 75 per cent, and claim that so far back as 1862 a centrifugal pump of their manufacture gave, at the International Exhibition of that year, an efficiency of 83 per cent.

As an example of the very accurate balancing of their machines, Messrs. Gwynne instance the experimental running with an empty pump of one of their centrifugal pumping engines, or centrifugal pump coupled direct to a vertical steam engine, at 550 revolutions per minute, when not fastened down but merely resting on timbers. The makers state that no vibration was experienced during such test.

For emptying graving docks, and for other services where enormous quantities of water have to be rapidly discharged against a low head, the centrifugal pump is unrivalled. Messrs. Gwynne construct centrifugal pumps for such services with discharge pipes or branches as large as five feet in diameter, and which on official trial have delivered over 82,000 gallons or 366 tons of water per minute.

Fig. 80 represents one of Messrs. Gwynne and Company's centrifugal pumps coupled direct to one of their enclosed silent high speed engines.

Messrs. Gwynne and Company give the following particulars respecting their combined centrifugal pumping engine, as employed with surface condensers and for similar

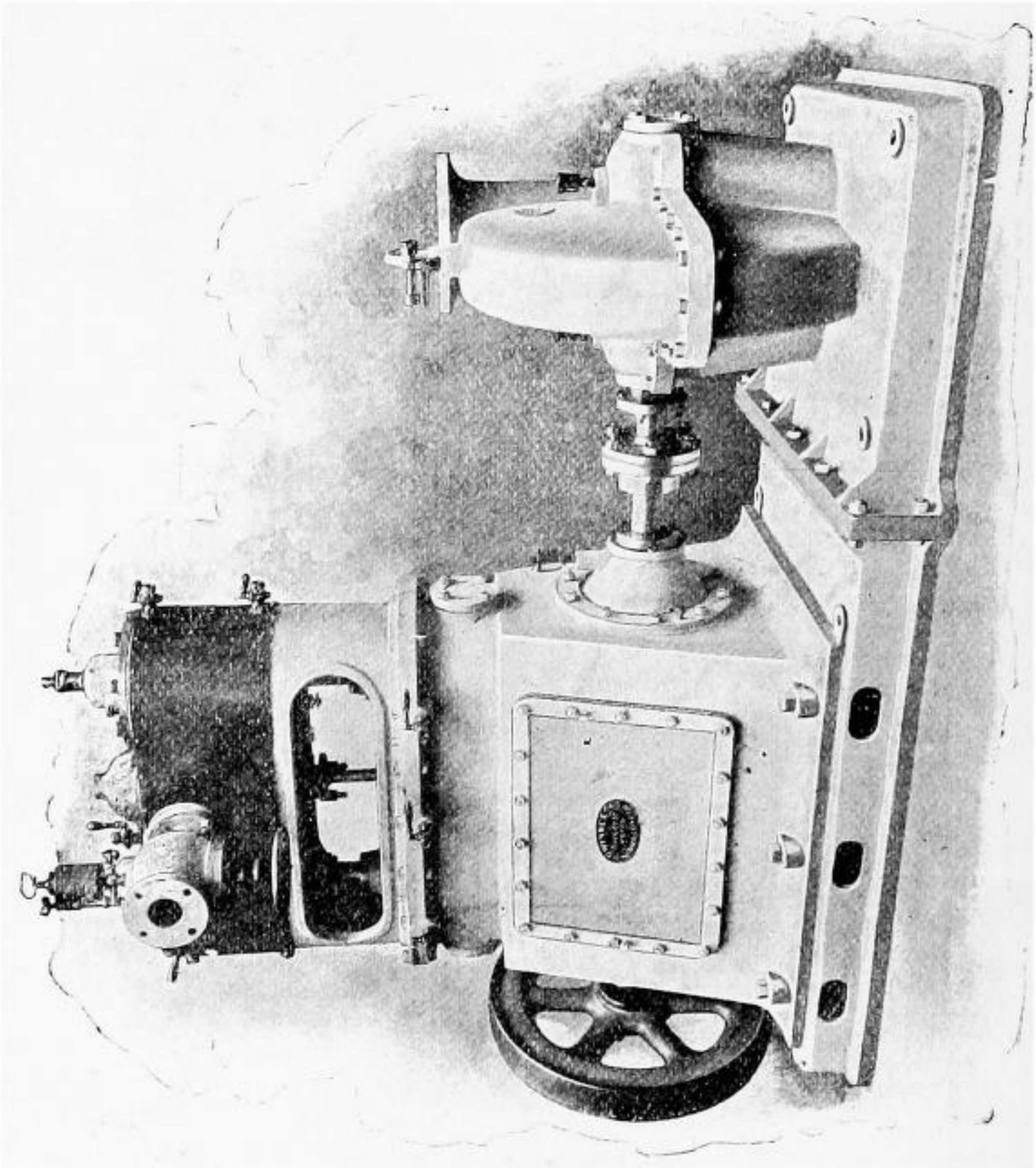


FIG. 80.

services, consisting of a vertical engine of the ordinary or open type having its crank shaft directly coupled to the spindle of the pump which is mounted on the engine bed :—

"The pump disc is of gun-metal and the spindle of steel, coated with gun-metal. All the bearings are of manganese bronze and have large wearing surfaces carefully adjusted. In many cases, especially for the Admiralty, the pump casing,

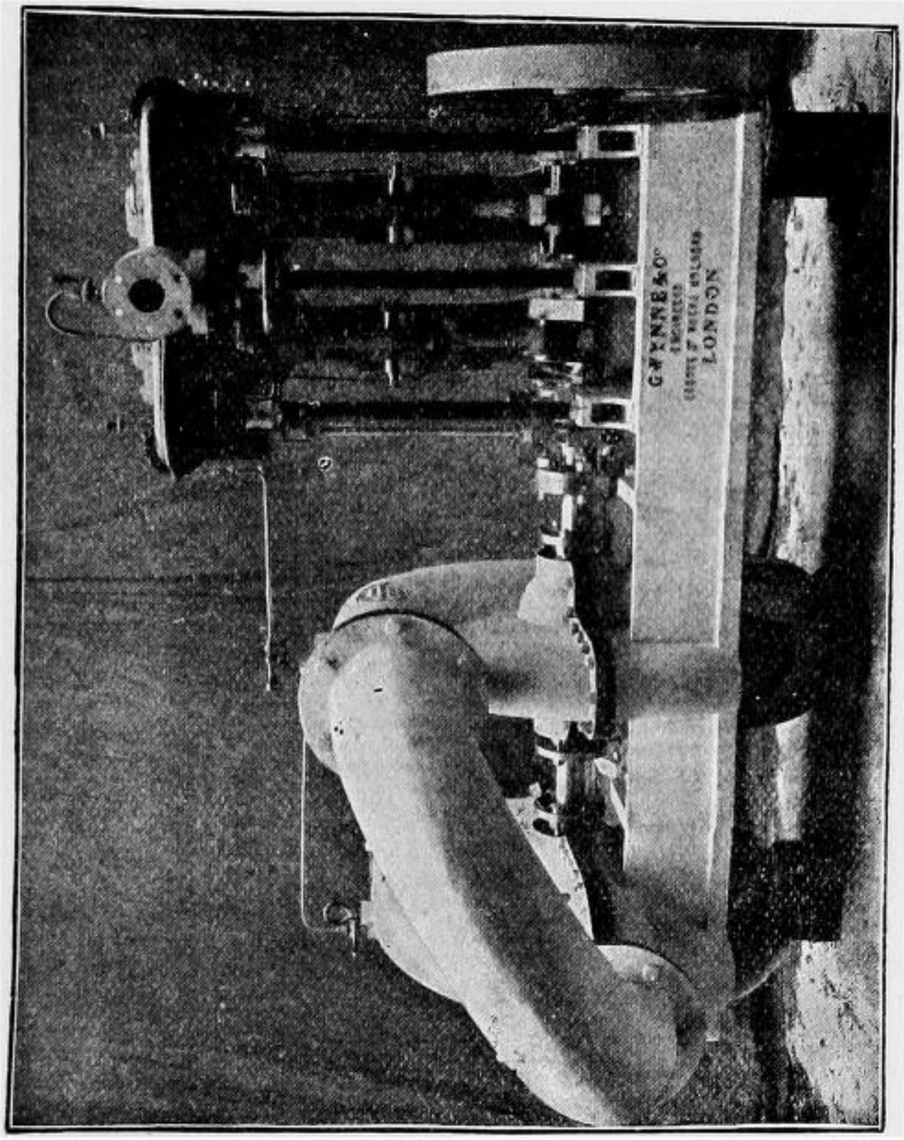


Fig. 81.

the disc, and the spindle are all of gun-metal. The pump disc and spindle can be removed and replaced without disturbing any pipe joint."

Fig. 81 represents a centrifugal pump plant for high lifts, by the same makers. A pair of pumps arranged in series are driven direct by a double-cylinder steam engine. The delivery from the one pump flows to the suction inlet of the other pump, which imparts more energy to the water to enable it to overcome a greater delivery head.

This method of imparting the required energy to the water by means of two or more moderately sized pumps, arranged in series and rotating at the same speed, rather than by a single pump very large in diameter and running at a high velocity, may be sometimes adopted with advantage. In general, however, a reciprocating type pump would be employed for lifts above the economical capacity of ordinary centrifugal pumps.

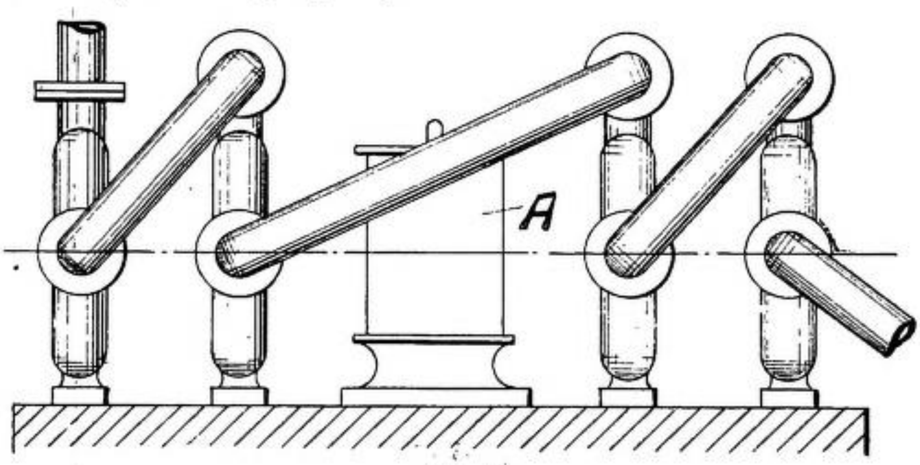



Fig. 82.

Fig. 82 is a sketch diagram representing an arrangement, recorded by *Cassier's Magazine*, in which four pumps are coupled by a French maker (whose name is not given) direct to an electric motor A, all being arranged on the one bed plate, as indicated. It is stated that the plant was employed to raise water through a height of about 157 ft. No statement is made as to the efficiency of the arrangement, but in view of the many necessary changes in the direction of flow of the water, in passing from the suction pipe of the first pump to the discharge pipe of the last pump of the series, no great efficiency could be anticipated.

Fig. 83 is an illustration of a centrifugal pumping engine for circulating purposes, having twin delivery branches.

The makers, Messrs. W. H. Allen, Son, and Company, of Queen's Engineeering Works, Bedford, supply the following particulars :—

"The twin circulating pumping engine, patented by us, is of novel design, and is used for the purpose of limiting the machinery in the engine room of a twin-screw vessel, where every corner of the room is already filled up. The object is

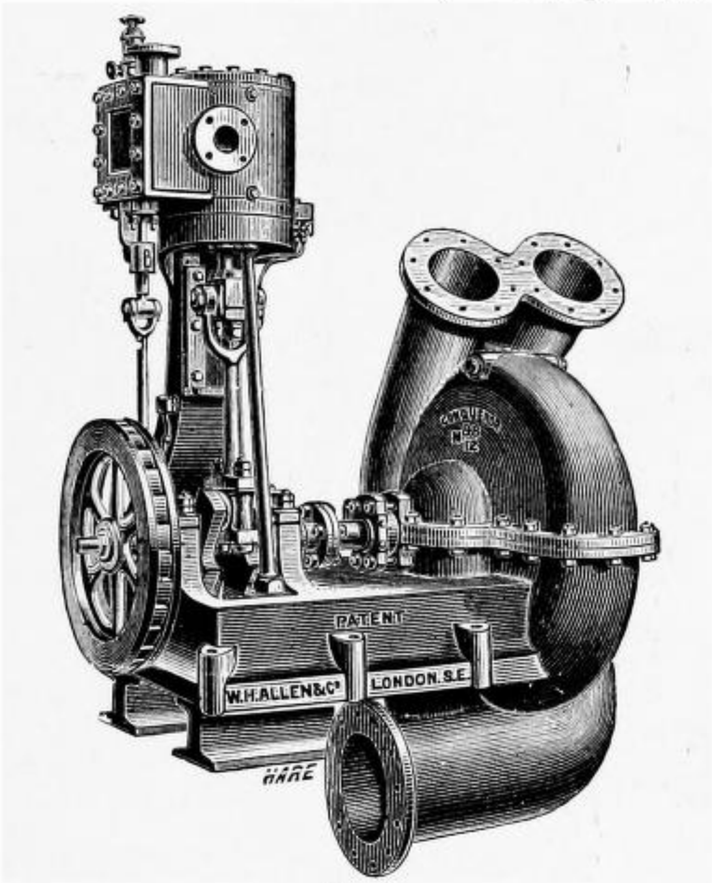



Fig. 83.

to have one circulating engine for two condensers, having a common suction pipe to the sea in the usual way, but a double-delivery one to each condenser. The pump is divided by a central diaphragm and the disc is made of a new form in order to take the water from both sides and discharge equally from each of two distinct pipes. These pumps accomplish this work in an admirable way, discharging from each delivery pipe a solid body of water into each condenser.

In many cases, where duplicate engines cannot be got in, this will be found an advantageous method of applying circulating engines to twin screws."

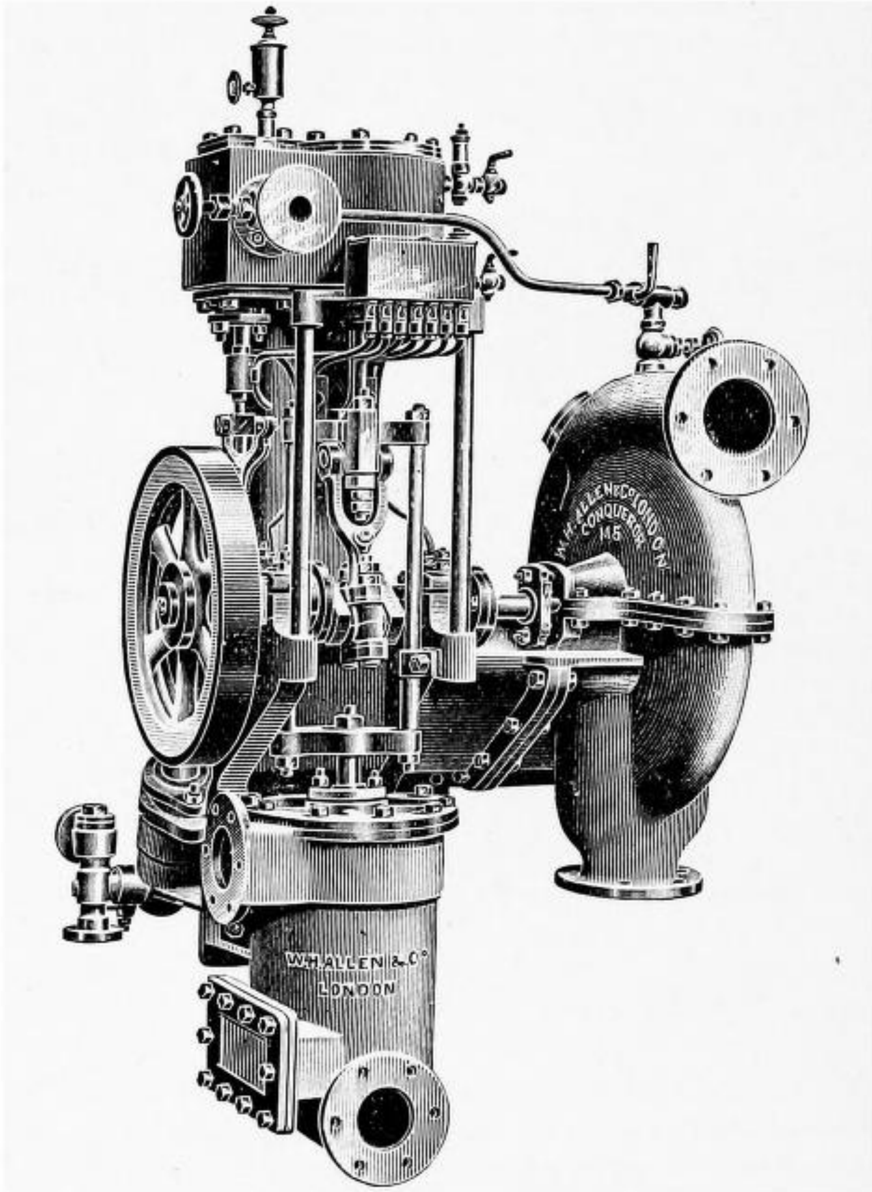



FIG. 84.

Fig. 84 is an illustration of a combined circulating and air pump, or pumping engine, also by Messrs. Allen, who describe it as follows :—

"The illustration shows our combined circulating and air pump, which is the form we recommend for medium sizes when the condenser is already fixed. As will be seen, the air pump is worked from the engine crosshead by steel connecting rods working in guides. The arrangement is particularly suitable where space is limited."

In connection with their belt-driven centrifugal pumps, Messrs. Allen give the following particulars concerning one of large dimensions, as made for the irrigation of a large cotton plantation in Egypt:—

"The discharge pipe is 36 in. diameter, and the pump is capable of throwing 90 tons of water per minute. The engine for driving it is a 130 horse power, passed through a treble leather belt, 21 in. wide and $\frac{5}{8}$ in. thick. The pump is made in two pieces, and every facility is provided for getting at the interior without difficulty. The pulley is made extra large, so that there may be no slip on the belt; the shaft is supported by two bearings bolted on to a massive bed plate. To charge the pump, a patent ejector is fitted on the top of casing, and the pump is also provided with a gauge glass to enable the position of the water to be ascertained when starting the pump."

For marine salvage purposes Messrs. Allen construct centrifugal pumping engines having the whole of the working parts of solid manganese bronze forgings. The following description of such engines is from the pages of *Engineering*:—

"In these pumping engines the parts usually made of steel—that is, the piston rod, connecting rod, crosshead, crank shaft, pump spindle, eccentric rod, eccentric strap, and valves, as well as the bolts and nuts,—are of manganese bronze. The engines have been designed to prevent the loss of time which frequently occurs in raising ships which are only partially submerged at low tide. In such cases the machinery has sometimes to remain under water for several days together, until advantage can be taken of a low tide to pump out the ship. With steel working parts, great difficulty arises from the journals of the shaft becoming oxidised to such an extent as to cause a quantity of minute particles of steel rust to remain in the bearings.

Immediately the engines are started, seizing takes place, and then a complete overhaul has to be made, during which time the opportunity is slipping away, and when matters are put right the rise of the tide stops the work. Great difficulty was experienced in obtaining a suitable metal to form the bearings for forged bronze to work in, and many alloys were tried before one was found which fully answered the requirements. The alloy now used is a hard mixture which runs at high speeds without heating, and wears in a short time to a smooth and glassy surface. The strength of the forged bronze is about that of mild steel (29 to 30 tons per square inch), so that nothing is lost by the adoption of the new metal."

Concerning the method of charging centrifugal pumps by exhausting the air Messrs. Allen give the following description:—

"Where the pumping engine is placed above the water it is first necessary to charge it before working. For this purpose we employ a patent ejector, which will exhaust the air and draw the water up from a depth of 25 ft. The arrangement is very simple, and yet perfect, the ejector being the smallest and most convenient contrivance that can possibly be devised for this work. It is screwed into the highest part of the pump, and also connected by a separate steam pipe to the upper part of the steam stop valve on the engine or boiler. In a few minutes after turning on steam the pump will be charged, the engine remaining stationary meanwhile. To prevent the air returning through the discharge pipe a flap valve is fitted on to end of the delivery pipe. For marine engine purposes the ordinary Kingston valve answers the purpose. For charging the large pumps we strongly recommend this method of flap valve and ejector as in every way most convenient and suitable, being much less costly and more efficient than any other means. It does away with the necessity of a foot valve, and is a much neater arrangement than an air pump or mechanical exhauster, as it is always ready, and cannot get out of order. There are a number of instances, however, where the foot valve is indispensable, and where it is as useful and convenient as the ejector."

Some centrifugal pump makers insert in their published lists particulars as to the alleged horse power required to raise a given quantity of water per foot of height. It would be of very great advantage if the actual horse power necessary to drive the pump were stated, but if the figures simply represent work performed in raising the given weight of water through the height named, with no allowance whatever for frictional losses, they are worse than useless. A buyer who relied upon such figures in arranging for the power to drive the pump would be grossly deceived. Thus in one catalogue we find it stated that with a given centrifugal pump one horse power is required to raise 3,350 gallons of water in one minute through a height of one foot. Now, as 33,500 units of work must be performed in the raising of 3,350 gallons of water through a height of one foot, and as the rate of work represented by one horse power is only 33,000 units per minute, it will be seen that the statement is utterly misleading. If we allow that the efficiency of the particular pump referred to is 75 per cent (and we doubt whether the makers would give a guarantee to that effect), the actual horse power required to drive it on the service named will be—

$$\frac{33500}{33000} + \frac{1}{3}\left(\frac{33500}{33000}\right) = 1{\cdot}35 \text{ H.P.}$$

If the purchaser provides $1\frac{1}{2}$ horse power, he will probably find he has none to spare.