NATIONAL
ENGINEERING
AND
TRADE LECTURES

BRITISH PROGRESS
IN
PUMPS AND
PUMPING ENGINES

BJÖRLING

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VOL. II.

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VOLUME II

British Progress in Pumps and Pumping Engines

BY

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WITH NUMEROUS ILLUSTRATIONS AND A DIRECTORY AND CLASSIFIED LIST OF PUMPS AND PUMPING ENGINES IN GREAT BRITAIN

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Introduction

THE design and construction of pumping and hydraulic machinery is one of the most important branches of mechanical engineering. It would be difficult to mention a mechanical industry which is independent of pumps and hydraulic apparatus. Without this class of machinery the mining, whether of coal or other minerals, would be at a standstill. It were needless to expatiate on the large part which pumps play in waterworks, sewage farms and in the irrigation of land. Pumping appliances are indispensable in the plant of bleaching works, dye works and paper mills. No user of steam could dispense with feed pumps.

The motive power of pumps must necessarily vary with the local conditions under which they are installed; in some cases, it must be confessed, the crude ideas of the engineer in charge of the works, rather than well defined principles, govern the details of installations.

Many factors enter into the choice of a pump and pumping engine, and in all cases the advice of an expert in hydraulic machinery should be sought. In the Colonies and in localities where workshops are not, and skilled labourers scarce: in a word, wherever breakdowns are to be dreaded, the utmost simplicity of construction is essential. On the other hand, where there are ample facilities for repair, and where trained engine minders are available, fuel may be dear. In such a case an economical consumption of fuel is a prime necessity, and it is to be regretted that hitherto engineers have been unable to attain absolute simplicity of construction with pumping engines of this type.

In dealing with small quantities of water, the hand pump is no doubt the simplest, handiest and cheapest appliance available. Such a pump can be operated by lever or levers, by cranks and hand wheels, or by crank handles.

Where there is a plentiful supply of water, a natural and cheap source of power is available; in some cases the user of water power has to pay nothing at all. Under a low fall, or in the case of a rapid stream, a water wheel should be installed; under a moderately high fall a turbine will usually give the best result. In the case of a very high fall or where water can be used under high pressure, "percussion" wheels, sometimes known as "Pelton" wheels, or hydraulic or water-pressure engines, are the most suitable forms of motor. It is an objection to fast-running motors that the speed must be reduced by gears or by belting; the former are liable to breakdowns, while the latter are apt to slip. In both cases there is a loss of efficiency.

In the case of small pumping plants, where good storage tanks or reservoirs can be constructed at a reasonable cost, "wind-engines" may be used to advantage; the working charges would be reduced to lubrication once a week, with a periodical overhauling of the pumps and pipes to test the soundness of all joints and the conditions of the packings.

Where little power is required, hot air engines are quite in place ; for powers up to about 1 horse-power, they are very economical and require but moderate attention. Such motors would often prove the best in country mansions, in farms and under similar conditions.

Compressed air is a valuable source of motor power. It can be carried in pipes for considerable distances without appreciable loss of pressure, always provided that the air compressor is of the right design and construction; otherwise the loss of power and the cost of compression are apt to be very heavy.

Electric motors are coming more and more to the front for pumping purposes, but an essential condition for the use of such power is this, that current is available at a reasonable cost. The advantages under suitable conditions of electricity are obvious. It is always ready ; no time is lost in starting ; there is no condensation of steam. No doubt users of electric power have their own troubles. If the diameter of the cable be too small, or if there are too few strands, there will be a very sensible loss of power, while with too large a cable the first cost will be excessive. But if a cable of suitable diameter be selected, the waste of power will be trifling. Where an electric motor is used three-throw single-acting pumps are the best, as these give a more even distribution of power, which is essential in electric driving.

Where fuel is readily available and considerable power is required, steam is and remains the best source of power. Engines for large pumping plants should be of the most approved design, constructed with a view to the utmost efficiency and economy. In the boiler too, economy must be carefully studied. The use of a wasteful boiler or boilers has often been the cause of serious loss in the working of a pumping plant. The selection of a boiler must be governed to a great extent by the route it has to traverse. If the boiler be taken by rail right up or near to its destination, or even if it can be carried over good roads, its type is a matter of minor importance, but where transport is difficult the sectional water-tube boiler is to be preferred.

The exact type of pumping engine cannot be decided on abstract principles. The engineer must be guided by the conditions of each case. The depth of the well or the source of water; the height at which the pumps have to be installed above the water level; the volume of water and the height to which it has to be raised; the economy desired in the plant; the distance through which the water has to be forced; these are one and all essential factors in the problem.

By the above conditions the engineer must also be governed in the choice of the pumps, with two additional considerations which are of great importance; namely, the nature and condition of the water. For sandy, gritty or muddy water, plunger pumps are by far preferable, because neither by grit, sand nor mud is the plunger affected. The piston or bucket packings will, however, wear more or less rapidly, relatively to the amount of impurities contained in the liquid. Plunger pumps are also suitable for an acidulated or saline water, because the lubrication will prolong the plunger's life.

Centrifugal pumps are well adapted for low-lifts and large volumes of water. As they are not easily choked they are suitable for dredging gold sand or for raising slime.

Strength is an all important factor in the construction of a pump, and an ample supply and proper distribution of metal is an essential condition of good design. This is a strong point with British pump makers. Many foreign engineers are either too sparing of metal or fail to put it in the right place. Buyers of pumps should beware of judging by appearances. Efficiency has too often been sacrificed to symmetry, in the quest for which many an otherwise good pump has been spoiled. By all means let the engineer turn out a finished article, but first and foremost let him ensure the utmost attainable simplicity of construction and working efficiency. After all, a polished exterior is of much less consequence than sound and well finished working parts. Polish is not so essential as the strength of the original surface of the metal, and especially of the castings, for the surface is the strongest part of the metal. Far more important than mere exterior polish and burnish are fine smooth and even surfaces to the cylinders, steam and water valves. The roughness of the surface is of small moment compared with true and smooth working parts.

I propose to illustrate and describe a number of different kinds of pumps and pumping engines made by some of the most eminent firms in Great Britain, pointing out by the way, such features as should be kept carefully in view by buyers and users of this kind of machinery.

Pumps may be divided into the following classes—

1. Pumps worked by hand.
2. Pumps driven by water power.
3. Wind power pumps.
4. Gas and oil engine pumps.
5. Hot air pumps.
6. Compressed air pumps.
7. Electrically driven pumps.
8. Steam pressure pumps.

1. Pumps Worked by Hand

THE common hand pumps are worked by a lever arrangement in different ways, to suit circumstances, such as the quantity of water required and the depth of the well.

For deep wells three-throw pumps are the best, but for bore holes the single-acting bucket pump, the bucket-and-plunger, and the "Ashley" pump must be recommended.

The "Dando" diaphragm pump, manufactured by Messrs. Duke and Ockenden, of Littlehampton, England, is shown in sectional elevation, Fig. 1, and perspective view of the "Odourless Dando" type in Fig. 2. This pump is worthy of special notice, and its work will readily be understood by reference to Fig. 1. *A* is the suction valve, *B* the pump chamber, *C* the diaphragm, made of indiarubber, in the centre of which is arranged the delivery valve *D*. The diaphragm is deflected by means of the two bolts, *E* and *E*, secured to the cross-head F, and pump lever *G*. *H* is the delivery spout, the diaphragm being held between that and the pump chamber *B*. Round the delivery hole in the diaphragm are placed circular flanged plates for stiffening it, and the top plate serves the purpose of the delivery-valve seat, the beat for which is formed by the inward flange of the diaphragm. When the disc is deflected downwards, as shown in Fig. 1, the capacity of the chamber is diminished, and, as the suction valve prevents the liquid returning into the suction pipe, it is forced to pass through the delivery valve in the disc. On the return stroke, that is, when the diaphragm is moved to the position shown by the dotted lines, the pump chamber is enlarged, the delivery valve closed, and the suction valve opened, the water enters the chamber, and so on. Fig. 2 illustrates the "Odourless" type, or Forcing "Dando" pump, worked by two handles. It is similar to Fig. 1, but is covered with an air vessel, and the suction branch is placed on one side of the body instead of underneath. Fig. 3 shows an "Odourless Dando" pump worked by a pulley and eccentric, or hand-wheel.

2. Pumps Driven by Water Power

Pumps are driven by water wheels, turbines and percussion wheels by means of gearing. The most suitable pumps for this class of motor are the three-throw bucket or plunger types, because they give the most regular distribution of work for the motor. Sometimes the pumps are driven by belting and pulleys. This latter method, however, is not so good, as there is frequently a certain amount of slip in the belt on the pulley which naturally reduces the efficiency of the pump, and consequently causes a loss of power.

Water applied to engines similar to a steam engine or a direct-acting steam pump is sometimes employed, but the valve gear must be of particular construction. There must be no lap on the slide valve or piston valves, and as

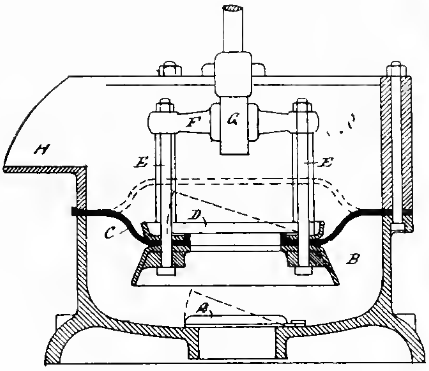


FIG. 1. SECTIONAL ELEVATION OF THE "DANDO" DIAPHRAGM PUMP.

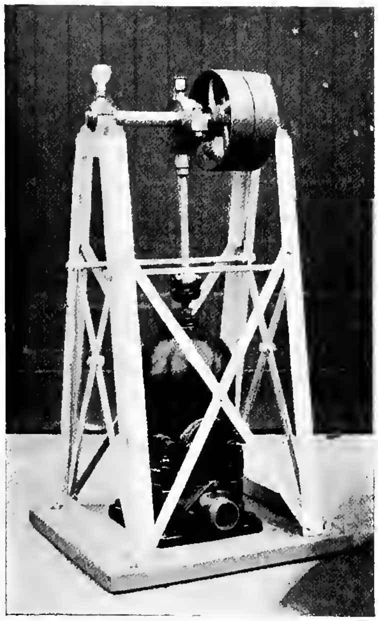


FIG. 3. "DANDO" PUMP FOR WORKING BY PULLEY OR HAND-WHEEL.

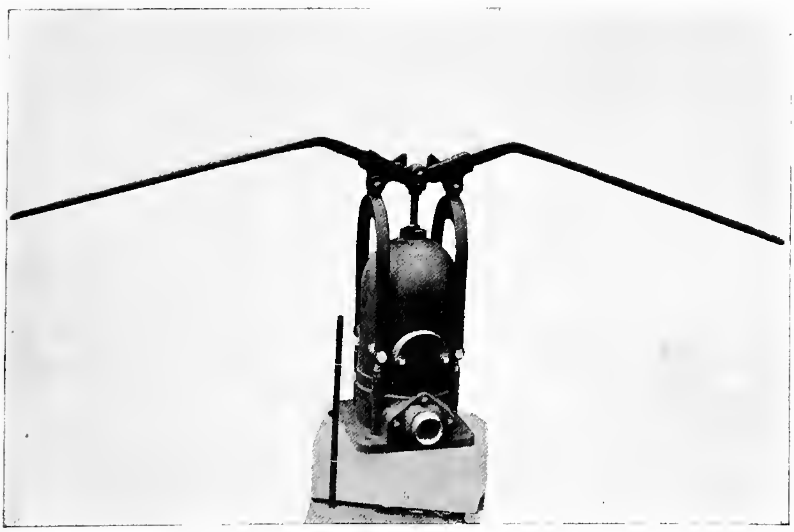


FIG. 2. THE FORCING "DANDO" PUMP.

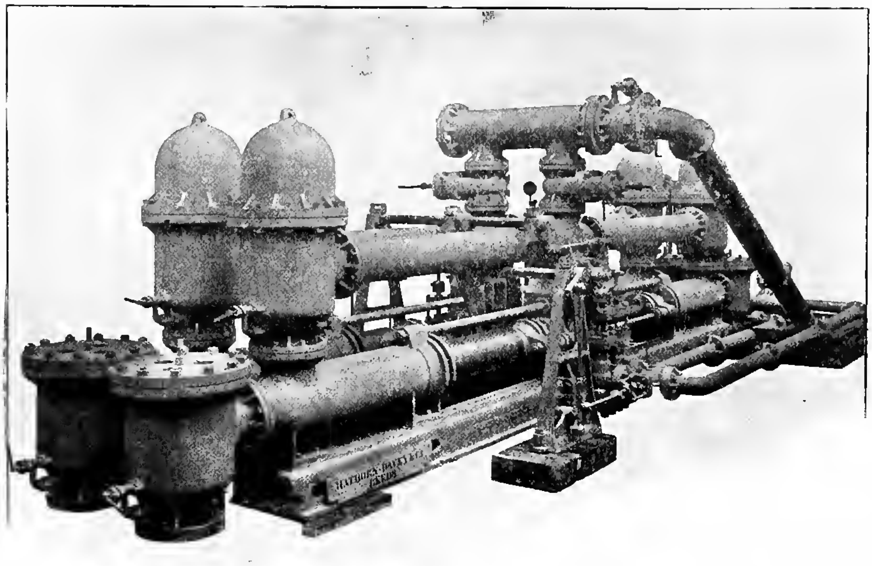


FIG. 4. DUPLEX HYDRAULIC UNDERGROUND PUMPING ENGINE.

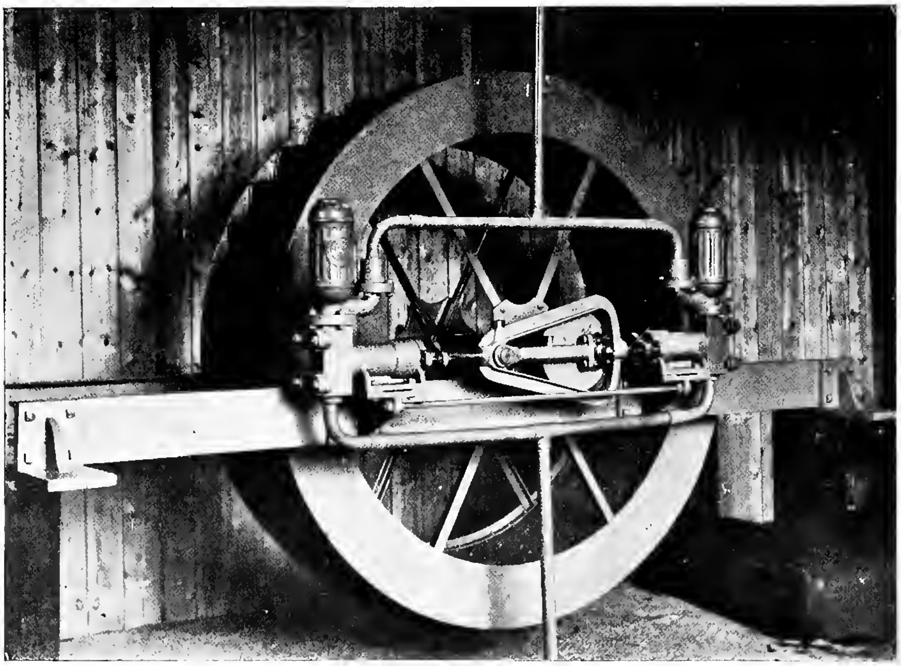


FIG. 5. UNDERSHOT WATER WHEEL ACTUATING A PAIR OF SINGLE-ACTING PLUNGER PUMPS.

there is no expansion in water an auxiliary valve must be connected with the engine.

Another method is shown in the duplex hydraulic underground pumping engine, designed by Mr. Henry Davey, of London, and built by Messrs. Hathorn, Davey & Co., Ltd., of Leeds, England, for the Miike Mines, Japan, which is shown in the general view, Fig. 4. The rams are 14 in. in diameter, with a stroke of 4 ft., and capable of running at fourteen double strokes, or 112 ft. per minute. The system upon which these are working was originated by Mr. Davey, and applied by him in a hydraulic power plant erected at a colliery at Marseilles many years ago. The power water is taken from an overhead tank in the engine room, and forced by means of the power engines into 7-in. pipes leading down the shaft to the hydraulic pumps, and returned by the hydraulic pumps to the tank, so that the power water is used over and over again. There are two sets of pipes, one for supply and the other for return.

The power engines pump the water under a pressure of 1,000 lb. per square inch, and that pressure is retained constant by means of a steam accumulator or regulator. The accumulator consists of a steam cylinder, 40 in. in diameter, and a hydraulic ram, 12½ in. in diameter, working in a hydraulic cylinder. The hydraulic cylinder of the accumulator is in free communication with the power pipe, whilst the steam piston is acted on by steam at a constant pressure, this pressure being adjusted by means of a reducing valve so as to maintain a pressure of 1,000 lb. per square inch on the hydraulic ram. The steam accumulator forms a governor to the power engine. If the power engine runs too fast, then the ram is pushed out, and made to actuate a throttle valve. By this system the evils arising from inertia which accompany the use of a weighted accumulator are obviated. The power engine is of the triple expansion type, having a 20-in. high-pressure cylinder, 29-in. intermediate, and 41-in. low-pressure cylinders, with a common stroke of 2 ft. 4 in. The pumps are of the ram type, worked direct from the pistons. Each ram is $5\frac{1}{4}$ in. in diameter. There are two sets of suction and two delivery valves to each pump. The power water is supplied with a little oil for the purpose of keeping the working parts in good order.

The hydraulic pumps raise 1,400 gallons per minute, against a head of 350 ft.

An undershot water wheel actuating a pair of single-acting plunger pumps, manufactured by Messrs. E. and H. Roberts, Ltd., of Stony Stratford, England, is illustrated in Fig. 5. In the design shown the water-wheel is 5 ft. in diameter by 2 ft. wide, the pumps having rams $2\frac{1}{2}$ in. in diameter, the stroke being variable by changing the position of the crank-pin in a slot in the pump crank disc, the slot being continued so that the pin can be put right into the centre, and the pump by that means remaining idle, while the wheel may be utilized for other purposes, such as are required on farms, etc. The two pumps being opposite one another and the plungers made in one with the yoke, one pump acts as a guide for the other. The wheel and pumps are mounted on a steel girder frame.

A double set of pumps of this pattern, worked by an undershot water wheel, was erected at Glevering Hall, Wickham Market, England. In this case the water wheel is 10 ft. in diameter by 5 ft. face, and is actuated by a 4 ft. 8 in. fall. It drives two pairs of 12 in. by 5 in. horizontal plunger pumps, variable from 1 to 12 in. stroke, so that the wheel, developing 4 brake horse-power, may be used for other purposes whilst the pumps are at rest. One set of pumps is placed on each side of the wheel. Each pump is fitted with an independent air vessel, and a large air vessel and safety valve are fitted on the main delivery pipe to prevent bursting. The pumps are worked at the lowest possible pressure for the water's elevation for storage to the extent of 7,000 gallons, but in case of fire, by closing one valve in the main, the whole power of the wheel can be secured, so that the force from the hydrants may in a few minutes be increased to the maximum pressure available and be rendered most effective. The water is lifted 80 ft. to the storage tank, and about 26 tons is the quantity usually available, but in the event of too much being pumped at any time the overflow is conducted to the sewers to flush them, and in this way most of the spent water in the yard is again used beneficially.

3. Wind Power Pumps

WIND is another natural motive power, which will be much more widely adopted for pumping than at present. There is no expense attached to this method of pumping excepting a very small cost for lubricating oil, and the usual attention to the pump parts. It is necessary that these should be examined periodically to see that all joints and packings are in good condition.

The water appliances employed, when wind engines are chosen as the motive power, are single-acting bucket pumps, single-acting plunger pumps, double-acting piston pumps, bucket-and-plunger pumps, chain pumps, scoop wheels and dash wheels.

When only small quantities have to be raised, the single-acting bucket or plunger pumps, or the bucket-and-plunger pumps, are usually employed, worked direct from a crank on which the wind wheel is secured. When larger quantities have to be dealt with and the lift is moderately high, three-throw bucket or plunger pumps are to be recommended; the pump crank-shaft being placed horizontally over the well or other source, and worked by gearing from the vertical shaft driven by the wind wheel.

The chain pump worked by a wind engine is sometimes used for raising water from quarries and brick yards, and to empty the workings.

Large quadruple semi-rotary pumps worked by wind engines are very useful for irrigating land and reclamation purposes.

For very large quantities and extra low lifts, as for pumping salt water into evaporating pans, reclaiming land, or irrigating purposes, scoop wheels, and dash wheels should be used.

The objection to wind engines is the uncertainty of the wind pressure, but this is provided against by having tanks or reservoirs, capable of holding three or four days' supply of water, as a calm seldom exceeds that length of time.

There are essentially two classes of wind engines, viz., the solid-wheel and the sectional-wheel engines. The solid wheel is very useful for small engines, say up to 14 to 16 ft. diameter, but above that, the sectional-wheel engine should be adopted.

The regulation of the speed of the engine should be automatic, as in the event of storms it makes the engine more powerful and durable.

The solid non-regulating wheel engine is, of course, the cheapest in first cost, and is therefore frequently adopted where a small amount of power is required. But a part of the cost is spent in making it strong enough to resist a storm, whereas, if it were made self-regulating the size could be so calculated that the full power required would be obtained when the wind has an approximate speed of 10 to 14 miles per hour, or 1,232 ft. per minute.

In the case of the solid-wheel wind engine the governor or regulator is the wind pressure. When, therefore, a storm occurs it causes the engine to jerk in and out of the wind, and brings undue strain and wear on the working parts; and, again, when the wind is unsteady, it causes the engine to run very unevenly. This is detrimental to the pump or pumps actuated by it. In strong wind the solid-wheel engine will throw so far out of the wind as to stop entirely, or run very slow, thus doing little or no work. The sectional wheel will not jerk or throw out and stop, but will keep a regular motion, and after attaining its maximum speed will hold it, no matter how strong the wind may be, because it is only governed by the wind pressure enough to keep it from all danger, and by centrifugal force sufficient to give a uniform speed.

It is a well-known principle that the speed of the wind wheel must be proportionate to the angle of the sails and the speed of the wind; thus to sharpen the angle at which the sails are set is to retard the motion of the wheel, and to flatten the angle is to accelerate the motion.

A solid-wheel wind engine, manufactured by Messrs. E. and H. Roberts, Ltd., of Stony Stratford, England, is shown in Fig. 6. The firm's usual method of connexion is by fixing the wind engine directly over the well and having a straight reciprocating pump rod right down to the pump, which is, of course, fixed within 25 ft. of the bottom, or according to the depth of the water in the well, the pump rod being guided.

The 12-ft. diameter "Hercules" wind engine, made by the above firm, has twenty-four blades, grouped in six sections, having a sail area of 82·5 square feet; with 27·5 square feet effective clearance area between the blades and 17·104 square feet clearance at centre of the wheel. The sails are secured by means of steel brackets to three angle steel rings. The wheel is strengthened by stay rods from the prolongation in front of the shaft upon which the wheel is fixed.

The wind engine illustrated in Fig. 6 was fitted with an 8-in. pump used for draining peat mosses for moss litter. The engine is fitted directly over the well and has a straight reciprocating pump rod made of wood, and guided in rollers and brackets, spaced every ten feet or so, and by using a single-acting pump the wood rod can be employed without fear of springing or whipping.

When the wind engine has to be placed some distance from the well, L-bobs are used, as shown in elevation, Fig. 7. *A* is a tube rod connected to a crank on the wind-wheel shaft, which oscillates the L-bob or quadrant *B*, which latter is coupled to the L-bob *C*, by means of a tube rob *D*, guided in roller guides E, at intervals. *F* is the pump rod coupled to the pump in the well *G*. It will be seen from this that on the up-stroke of the crank on the wind-wheel shaft, the pump is also making its up-stroke, so that the long rods are always in tension.

The pump which Messrs. Roberts recommend for wind engines is of the syphon type, illustrated in sectional elevation, Fig. 8. It will be seen that the suction pipe leads in at the upper part of the pump casting, the working barrel consisting of an internal liner with an annular space between it and the casing, through which the suction water passes by the syphon action, thus ensuring the casing always being full of water ready for starting, which is a great advantage for wind engines.

FIG. 6. SOLID-WHEEL WIND PUMPING ENGINE.

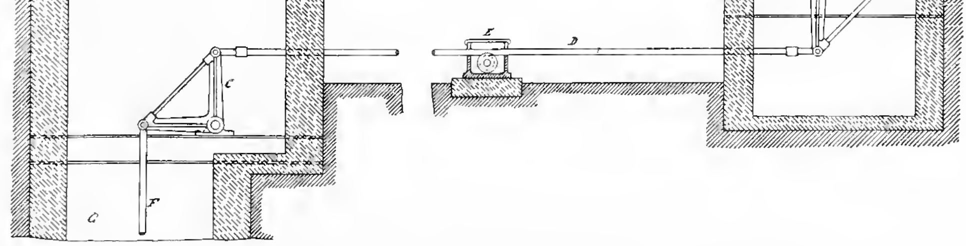


FIG. 7. L-BOBS AS USED TO CONNECT WIND MOTORS TO WELLS WHEN LATTER ARE NOT DIRECTLY UNDERNEATH.

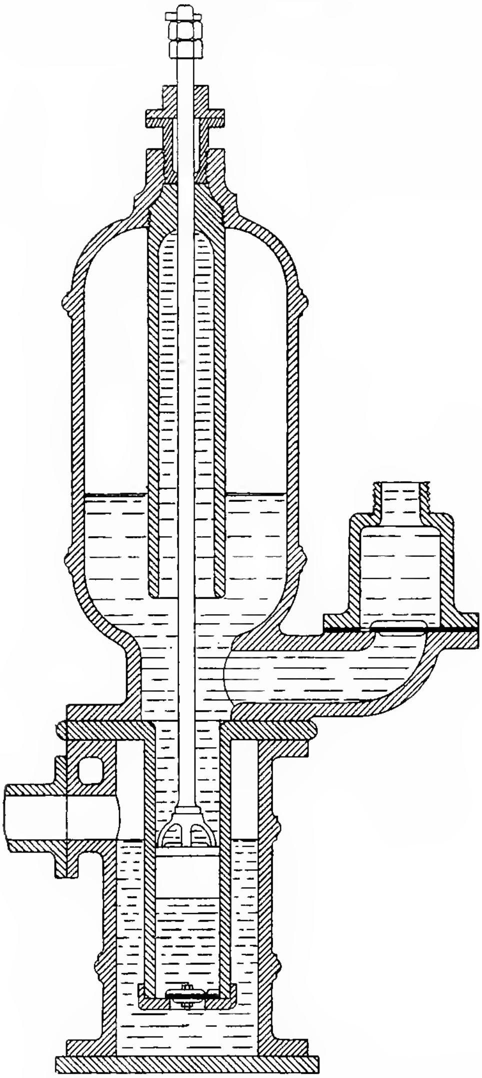


FIG. 8. SECTIONAL ELEVATION OF SYPHON PUMP AS RECOMMENDED FOR USE WITH WIND ENGINES.

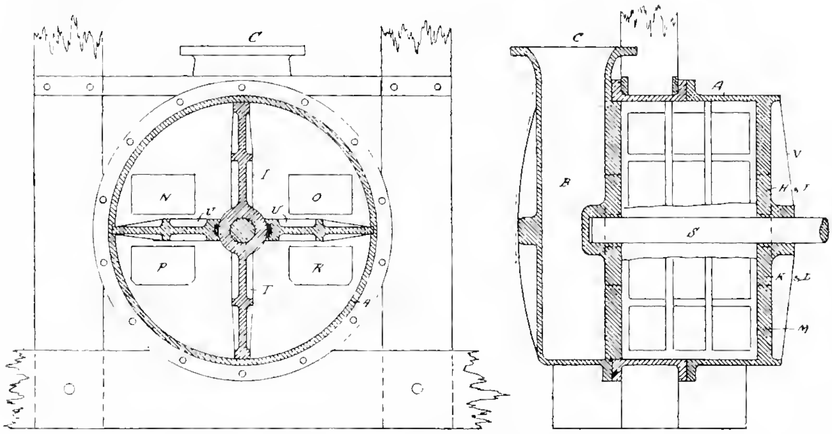


FIG. 9. TRANSVERSE SECTION. FIG. 10. LONGITUDINAL SECTION.

QUADRUPLE SEMI-ROTARY PUMP FOR IRRIGATING AND LAND-RECLAIMING PURPOSES.

The wheel is controlled by means of a tail vane which normally stands at right angles to the wheel when the latter is facing the wind. The wheel is fixed a little out of the centre of the tower, so that when the wind increases the wheel tends to move out of the wind, but the tail vane is driven into it against the torsion of a spiral spring, which, when the wind is reduced, draws the wheel into the wind.

A quadruple semi-rotary pump, suitable for working in connexion with wind engines for irrigating and land reclaiming purposes, is shown in transverse section, Fig. 9, and longitudinal section, Fig. 10.

To one end of the cylinder, *A*, is secured a collecting chamber *B*, from which the delivery-branch *C* ascends. The pump is fitted with eight valves, four for suction and four for delivery. The valves *H*, *J*, *K* and *L*, in the end *M* of the cylinder, are provided with strengthening flanges, and are placed on the inner side of the cylinder end, so that they may open inwards to the pump, and thus become the suction valves. The valves *N*, *P*, *O* and *R* are opposite the suction valves and open towards the delivery chamber *B*, and constitute the delivery valves. On the shaft *S*, which passes through the pump cylinder, the wings *T* are fixed; the interior of the cylinder is divided into two parts by the fixed partition wall *U*, which fits into a groove in the ends and sides of the cylinder, and extends close up to the centre boss of the wings. By imparting an oscillating action to the wings, by means of a lever fitted on to the end of the shaft *S*, the pump has a quadruple action. A metallic wire gauze *V* is fastened on a projecting flange on the cylinder, and on the centre of the boss surrounding the shaft, preventing any solid matter from getting into the pump. Messrs. Duke & Ockenden are the makers in England.

A sectional-wheel wind engine, designed by Mr. John Wallis Titt, of Warminster, England, is shown in elevation, Fig. 11, actuating a set of three-throw pumps, fixed in a well. The pumps are worked by means of a pair of angular wheels at the wind wheel, a pair of bevel-wheels at the base of the tower, a horizontal shaft fitted at the outer end with a spur-pinion, gearing into a spur-wheel keyed on the three-throw crank shaft. The pump crank is on the opposite end to the spur wheel fitted with a fast and loose pulley, so that the pumps can be worked by a belt from an auxiliary engine in case of draught. The pinion on the outer end of the counter-shaft is either fitted with a clutch or made to slide out of gear, when the wind engine is not employed.

The working barrels of the pumps and the suction valves are placed at the bottom of the well, and the suction pipe is placed in a bore hole at the bottom of the same. As the water rises high up in the well, when the pumps are standing, the delivery-box is placed high up near the surface of the ground, the box and the working barrels being connected by stand-pipes, made slightly larger in diameter than the working barrels, so as to allow the buckets and suction valves to be lowered down freely without injury to the leathering or other kind of packing used.

The suction valves are provided with eyes, so that they can be "fished" out from the top at the delivery box. On the side of the delivery box a branch is provided on to which is secured a retaining valve, and above the delivery bend in the rising main an amply large air vessel is provided. The pump-rods are reciprocated by the usual class of deep-well pump connecting rods, technically termed "pump slings."

The pump employed by Mr. Titt, when it is worked direct, that is, when the wind engine is placed on the top of the well, is shown in sectional elevation, Fig. 12. It is of the differential or bucket-and-plunger type, being single-acting in the suction and having a double-acting delivery, so that it delivers an equal quantity on the up and down stroke; the plunger being one-half the area of the bucket. When this class of pump is employed the wind wheel is mounted on a horizontal crank shaft, by means of a short connecting rod, which actuates a lever, to the outer end of which the pump-rod is connected. In this way a short crank can be used and the stroke of the pump is increased.

The head of this engine is built of steel angles and plate, so that there is no danger of breakage. The wheel is controlled by a tail vane and weighted lever. The lever is raised by a starting wire, over small pulleys, which passes down to near the ground level of the tower for starting without going up the tower.

Fig. 13 illustrates a Pumping Plant made and erected by Mr. John Wallis Titt for the Italian Government at Margherita di Savoia, Italy, for raising sea water for distribution in vaporizing beds for the production of salt.

It consists of a 37-ft. 6 in. diameter wind wheel, mounted on a 50-ft. hexagonal type steel tower and driving a dash wheel, 14 ft. in diameter, 2 ft. wide, with 16 vanes, made wholly of wrought iron. The duty varies from a minimum of 2 ft. to a maximum of 5 ft. 9 in., according to the tide, the average being 4 ft. 6 in. Provision is made by sluices suitably placed to regulate the depth of immersion at intake of wheel. The main tees of the tower are of steel 4 in. by 3 in. by $\frac{5}{8}$th of an inch. The engine is capable of developing 15 horse-power in a wind of 25 miles per hour. With a wind velocity of from $7\frac{1}{2}$ to 10 miles per hour 106,920 gallons of water can be raised by the dash wheel; a wind velocity of from $15\frac{1}{2}$ to $18\frac{1}{2}$ miles per hour enabling it to furnish a supply of no less than 283,536 gallons hourly. The wind wheel was furnished with 100 sails, but now Mr. Titt employs 50 sails, each 12 ft. long and controlled by two 14-ft. diameter tail wheels, instead of the single wheel illustrated. The wind wheel shaft is $5\frac{1}{2}$ in. in diameter, the vertical shaft $3\frac{1}{4}$ in. in diameter, and the dash wheel shaft 6 in. in diameter. The tower foundation is 13 ft. in diameter by 9 ft. 7 in. deep; the foundation bolts are 10 ft. 2 in. long by $1\frac{1}{4}$ in. in diameter. The driving wheel is 10 ft. in diameter and the pinion 37 in. in diameter. The weight of engine resting on the foundation is about 20 tons.

This class of pumping plant is also very suitable and economical for drainage and irrigation purposes, where large quantities of water have to be dealt with, and may be modified as to size to suit requirements.

Mr. Titt has made a number of wind engines of this description, amongst others one 35 ft. in diameter, "Simplex Geared," on 50 ft. steel tower, driving an 18 ft. diameter scoop wheel, capable of lifting 2,000 to 3,000 gallons of water per minute 8 ft. high. This wind engine was erected at Limavady Junction, Co. Derry, Ireland, for drainage of slob land.

4. Gas and Oil Engine Pumps

A Gas Engine coupled to a set of vertical two-throw plunger pumps is illustrated in front elevation, Fig. 14. It has been constructed by Messrs. Crossley Bros., Ltd., Manchester, England. The gas engine is of the ordinary "Crossley" type, actuating the pumps by means of a spur pinion on the crank shaft, gearing into a spur wheel keyed on to the pump crank shaft. The pinion can be released by a clutch operated by a hand wheel. To economise height the pump plungers are open at the top and the

FIG. 13. LARGE PUMPING PLANT FOR RAISING SEA-WATER FOR DISTRIBUTION IN VAPORIZING BEDS FOR THE PRODUCTION OF SALT. DIAMETER OF WIND WHEEL, 37 FT. 6 IN.

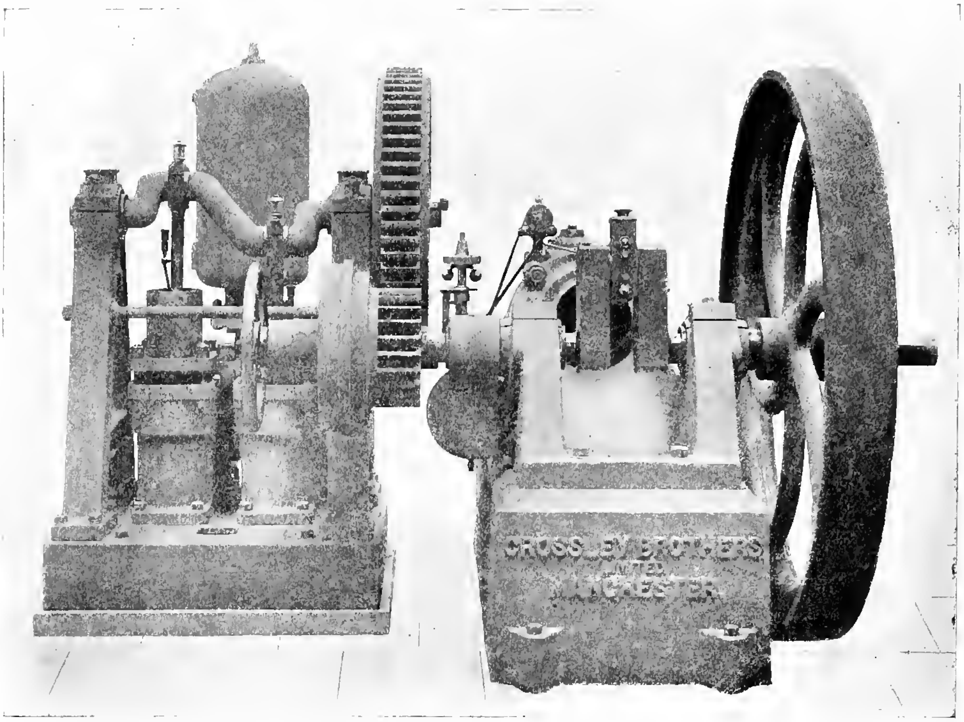


FIG. 14. TWO-THROW PLUNGER PUMPS DRIVEN BY A "CROSSLEY" GAS ENGINE.

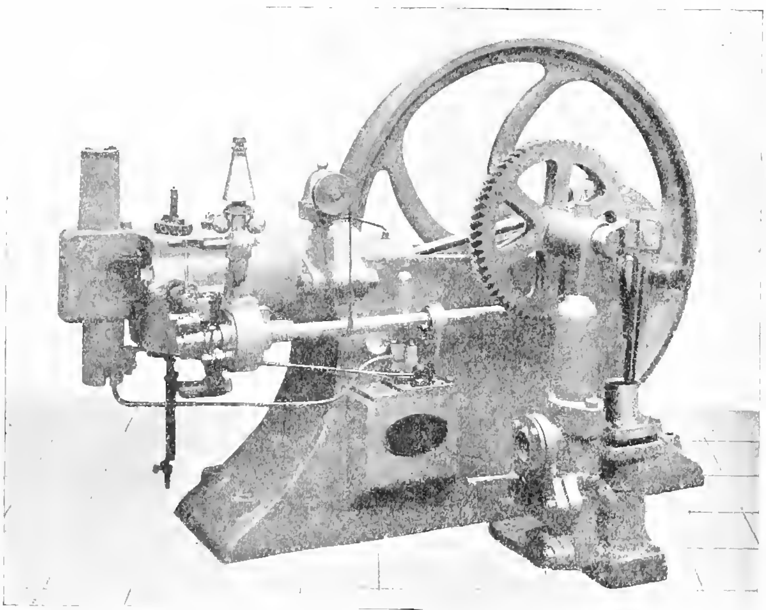


FIG. 15. GAS-ENGINE DRIVEN PUMP DESIGNED FOR DOMESTIC WATER SUPPLY.

connecting-rod pins are secured at the bottom of the plungers. The pump crank-shaft is carried on two A-frames. The delivery branch is provided with a large air vessel. The suction inlet branch is cast in the pump bed plate.

These engines and pumps are suitable for town's water supply, sewage works, etc.

An engine and pumps, made by the same makers, for small quantities, such as domestic water supply, is illustrated in Fig. 15. The engine is horizontal, driving a vertical single-acting plunger pump, fitted with an air-vessel, by means of a wheel and pinion, and over-neck pump crank.

Another arrangement of "Crossley" engine and pump is designed for domestic water supply, but it can also be used for any other purpose, as the pump can be disengaged by means of a friction clutch and hand wheel. This is illustrated in Fig. 16. The engine in this case is vertical, driving a vertical single-acting plunger pump, the counter-shaft, carrying the spur wheel and pump crank pin, is carried by brackets on the engine standard.

A gas engine and centrifugal pump for emptying docks, etc., manufactured by Messrs. Crossley is shown in Fig. 17. The centrifugal pump is worked direct from the crank-shaft, and a heavy fly-wheel is provided at each end of the shaft, to ensure steady working. The engine and pump can be started in a few minutes. At a recent trial of a plant fitted by this firm, 521,416 cubic feet of water was raised from a dock, in 2 hours and 21 minutes, the consumption of gas being only 8,678 cubic feet.

When not required for pumping, the engine can be used, if desired, for electric lighting, or driving machinery, or any of the numerous purposes for which power is employed in ship-building yards.

An oil engine and pump combined, manufactured by Messrs. James B. Petter and Sons, Ltd., of Yeovil, and London, England, is illustrated in Fig. 18. These are suitable for use where the water is within 20 ft. of the surface. The pump, of the single-acting plunger type, is bolted to the side of the engine bed plate, and driven by means of a spur wheel and pinion from the engine crank shaft. The pinion can be fitted with a clutch, so that the pump can be thrown out of gear, and the engine driving any other machinery, either direct from the flywheel, or from a pulley keyed on the engine shaft outside the flywheel.

A 3 horse-power "Petter" oil engine will deliver about 2,500 gallons of water per hour, at a point 100 ft. above the surface of the water in the well or other source. The gearing is machine-cut, and the valves, valve seats and plunger are made of brass.

A $1\frac{1}{4}$ horse-power "Petter" delivers about 1,000 gallons, at a point 100 ft. above the surface of the water.

The engine is fitted with patent automatic ignition, which renders the use of any lamp or outside flame unnecessary except at starting.

A $2\frac{1}{2}$ brake-horse-power oil engine coupled direct to a pump, bolted to the side of the engine bed-plate, manufactured by Richard Hornsby and Sons, Ltd., Grantham, England, is illustrated in Fig. 19. This engine has been specially designed for crude oil. The pump is of the

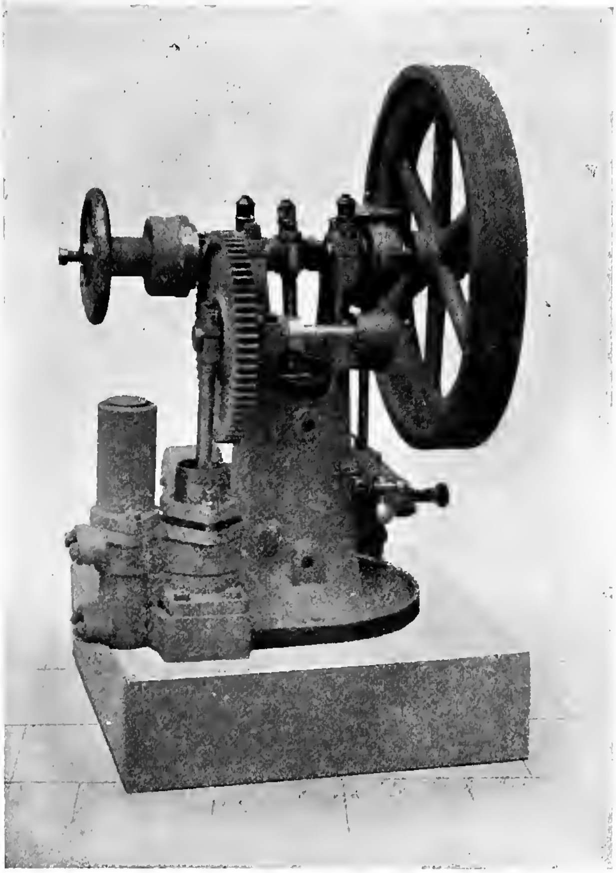


FIG. 16. SINGLE-ACTING PLUNGER PUMP ACTUATED BY VERTICAL GAS ENGINE.

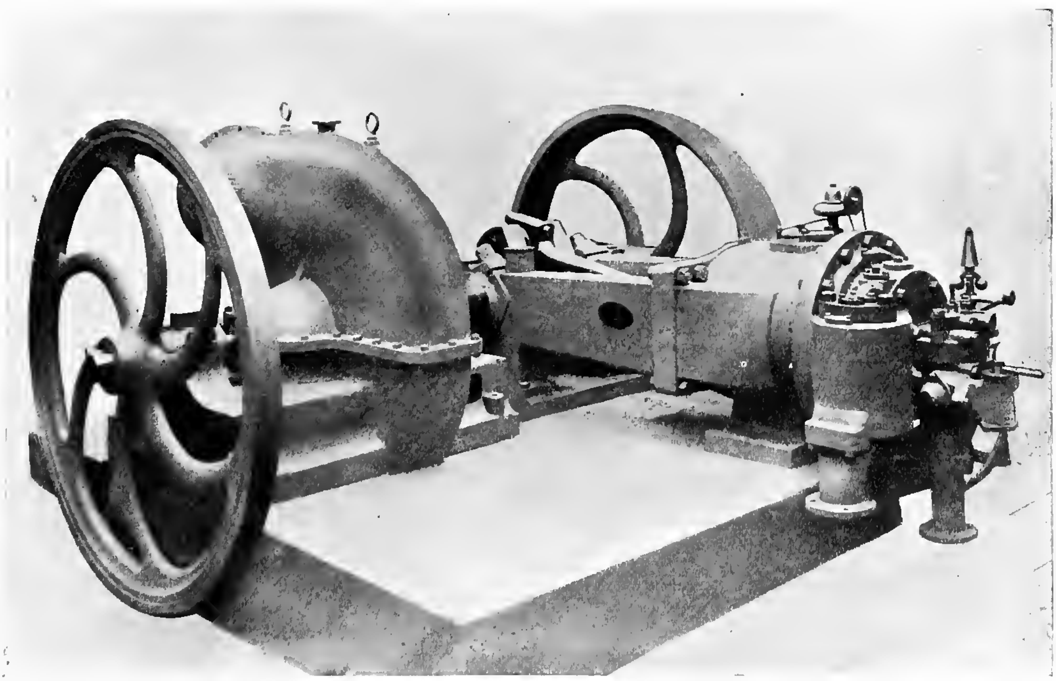


FIG. 17. GAS ENGINE DRIVING CENTRIFUGAL PUMP DIRECTLY CONNECTED TO CRANK SHAFT.

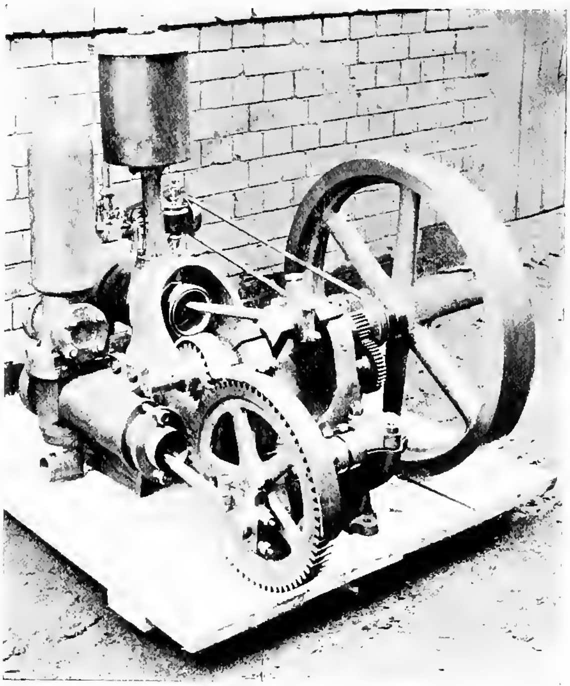


FIG. 18. SINGLE-ACTING PLUNGER PUMP DRIVEN BY A "PETTER" OIL ENGINE.

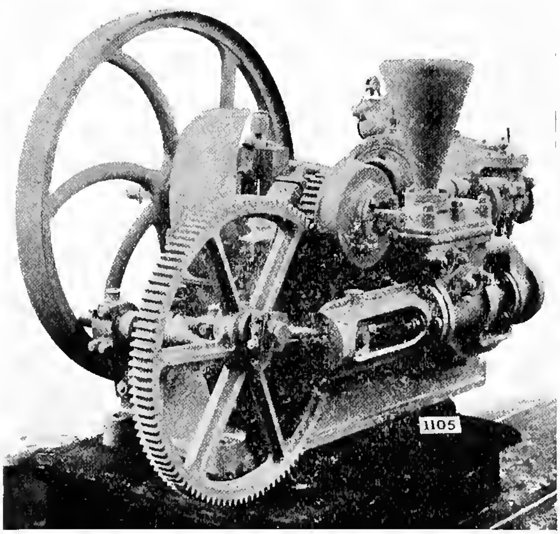


FIG. 19. PLUNGER PUMP DRIVEN BY A "HORNSBY" OIL ENGINE.

externally packed plunger type, driven by an overhanging spur wheel, in which is fitted the pump crank pin. The wheel is rotated by means of a spur pinion on the engine crank shaft. The pinion is driven by a friction clutch, so that any class of machinery can be driven by belt from the engine fly-wheel or a pulley on the outer end of the crank shelf, when the pump is not required.

The Grantham Water Works pumping engine, made by the above firm, is shown in Fig. 20. The engine is 42½ brake-horse-power, of the horizontal type, having a cylinder 19½ in. in diameter, by 22 in. length of stroke, having a nominal speed of 175 revolutions per minute.

The pumps are of the three-throw plunger type, having plungers 11 in. in diameter, by 15 in. length of stroke, running at a speed of 34¾ revolutions per minute, delivering 536·5 gallons of water per minute against a head of 160 feet.

At the official test of this pumping plant the engine indicated 48·80 horse-power, giving out 41 brake-horse-power. The pump-horse-power was 26·33, so that the mechanical efficiency of the engine was 84 per cent.

The following is a copy of the test :—

Trial of 42½ B.H.P. Hornsby-Akroyed cheap fuel oil engine and a set of geared treble ram pumps at Grantham Water Works.

Consumption of Texas crude oil per hour, 35·125 lb.

Consumption of Texas crude oil per B.H.P., 0·856 lb., or 0.744 pint.

Consumption of Texas crude oil per pump H. P. per hour, 1·33 lb. or 1·15 pint.

Consumption of Texas crude oil per million foot-lbs. of water pumped, 0·585 of a pint.

With oil at 2½*d.* per gallon per million foot-lbs. of water pumped, 0·18*d.* for fuel.

The oil used was Texas liquid fuel oil, having a specific gravity of 0·92, and a flash point of 170 degrees Fahr., open test.

An arrangement of an oil engine driving a set of vertical three-throw plunger pumps is shown in illustration, Fig. 21. The engine is of the "Ruston" horizontal type, manufactured by Messrs. Ruston, Proctor and Co., Ltd., of Lincoln, and the pumps were made by Messrs. Hayward-Tyler and Co., London.

One of these engines of 25 effective horse-power during a trial of three hours' duration, at a speed of 200 revolutions per minute, gave an effective horse-power of 26·5. It made 90·6 explosions. Russian oil of the "Russolene" brand was used, having a specific gravity of 0·825 and a flashing point of 85 degrees Fahr. Weight of oil used per effective horse-power per hour was :—

Exclusive of Lamp at start,			0·593	lb.
,,	,,	,,	0·575	British pint
,,	,,	,,	0·327	litre.

Time required to start this engine was 15 minutes and it used during that time 1 lb. of oil.

In this type of oil engine the pressure due to the explosion gradually rises, commencing shortly before the crank reaches its inner "dead centre," but does not attain its maximum pressure until the crank is well past the "dead centre," and in such a position as to make the fullest use of the pressure on the piston. The ignition tube is made of a special mixture of cast iron, and is kept hot by the explosions, it works automatically after starting, and dispenses with the attention to lamps. The vaporizer is bolted to the cylinder end, and after starting is quite automatic in action, the oil being vaporized before entering the cylinder, prevents waste from clogging and deposit in the cylinder. The speed of the engine is regulated by a centrifugal governor, controlling a hit-and-miss device. A speeder is fitted by which the revolutions of the engine can be varied within wide limits, while running.

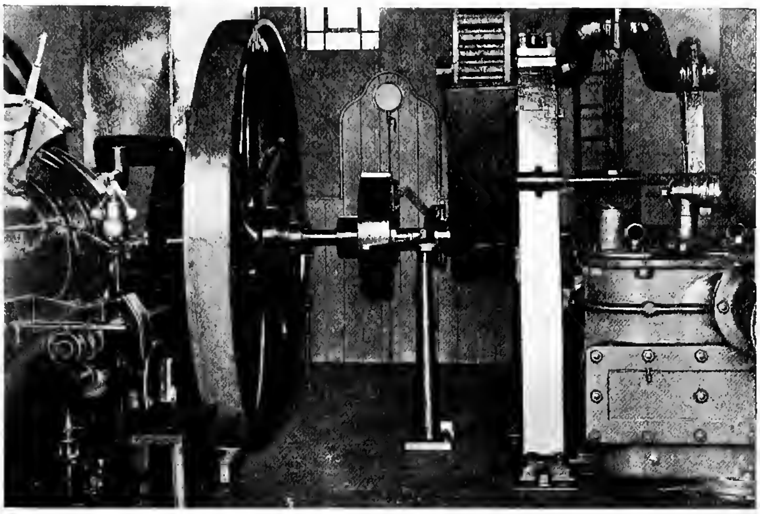


FIG. 20. 42½ B.H.P. "HORNSBY" OIL ENGINE DRIVING THREE-THROW PUMPS AT THE GRANTHAM WATER WORKS.

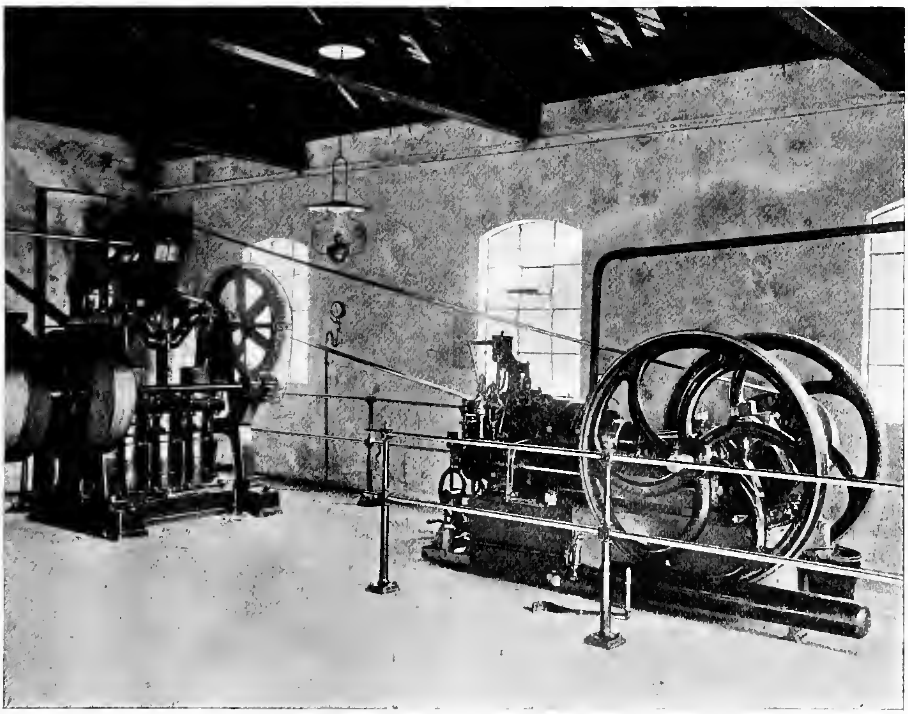


FIG. 21. "RUSTON" OIL ENGINE DRIVING A SET OF VERTICAL THREE-THROW TRUNK PLUNGER PUMPS.

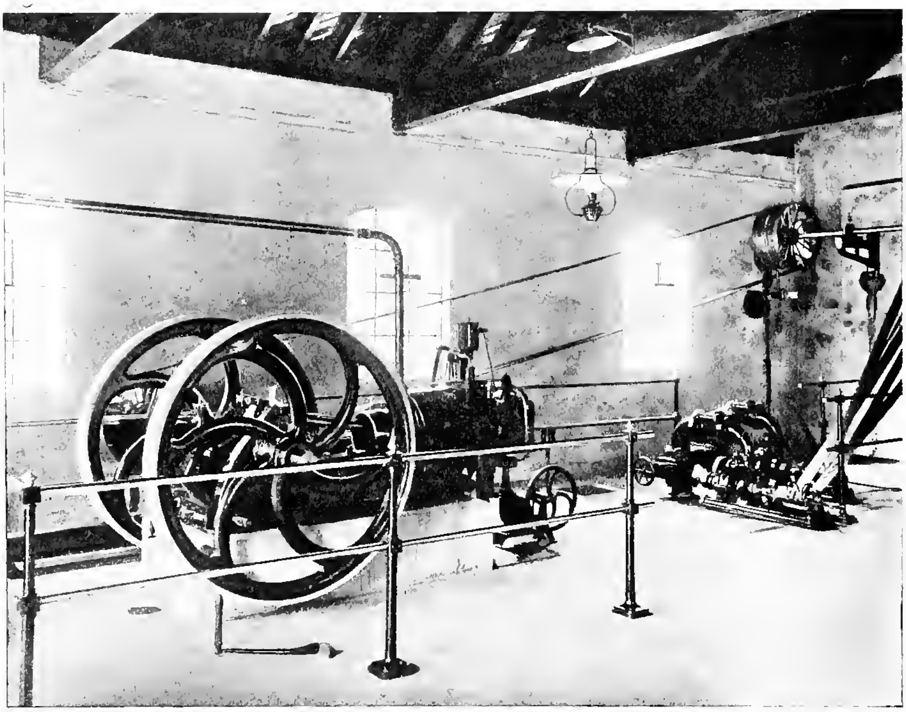


FIG. 22. "RUSTON" OIL ENGINE DRIVING TWO LOW-LIFT CENTRIFUGAL PUMPS.

Messrs. Ruston, Proctor and Co., have applied a number of their engines for pumping. A very fine set consisted of a 16 B. H. P. oil engine driving a set of vertical three-throw trunk plunger pumps, having plungers $9\frac{1}{2}$ in. in diameter with a stroke of 12 inches, forcing 300 gallons of water per minute to a vertical height of 80 ft.

Fig. 22 illustrates an oil engine, made by the same firm. The engine is 16 brake-horse-power, driving two 4-in. low-lift centrifugal pumps, each delivering 250 gallons of sewage per minute to a total height of 17 ft.

5. Hot Air Pumps

THE Rider's hot air engine and pump is illustrated in Fig. 23. It is fitted with patent removable furnace. This engine has a pump $1\frac{5}{8}$ in. in diameter, fitted on one side, capable of pumping 360 gallons of water per hour to a height of 108 feet. The cost of running this engine is about one penny per 1,000 gallons of water pumped to a height of 80 ft. There is no explosion, and therefore no danger.

The principle upon which the engine works is as follows :—

The compression piston, shown on the left side of the illustration, first compresses the cold air in the lower part of the cylinder into about one-third its normal volume, when, by the advancing or upward motion of the power piston, shown on the right-hand side, and the completion of the down stroke of the compression piston, the air is transferred from the compression cylinder, through the regenerator, which is shown connecting the top of the two cylinders, and into the heater without appreciable change of volume. The result is a great increase of pressure corresponding to the increase of temperature, and this impels the power piston up to the end of its stroke. The pressure still remaining in the power cylinder and re-acting on the compression piston, forces the latter up-wards till it reaches nearly the top of its stroke, when, by the cooling of the charge of air, the pressure falls to its minimum, the power piston, and the compression again begins. In the meantime the heated air passing through the regenerator, has left the greater portion of its heat in the regenerator to be picked up and utilized on the return of the air towards the heater. This process recurs at each revolution. The lower portion of the compression cylinder is kept cold by a current of water which circulates through the cooler, which surrounds the lower portion of the cylinder. In pumping engines, the water which is pumped answers this purpose. The heater is kept at a dull red by a steady fire—generally coke—which is under-neath it. The furnace is of the simplest form, similar to an ordinary greenhouse stove. The same air is used continuously, as there is neither influx nor escape, the air being merely shifted from one cylinder to another.

6. Compressed Air Pumps

Compressed air is applied for raising water in many ways, but none of the methods have yet been brought to perfection, except by the direct-acting pump similar to the ordinary pump driven by steam. The only difference in the two is that, if no heater is employed for heating the air before it enters the power cylinder, the exhaust must be made quite free or it will soon become blocked up with ice.

The advantage of compressed air over steam, is that there is no appreciable difference in the pressure and no condensation in the pipes, when a long distance is placed between the compressor and the pump.

Another method employed for raising water by compressed air is on the direct contact principle, similar to the steam in a pulsating steam pump, (which latter is illustrated in Fig. 85, and described on page 66.)

Yet another method is by the air-lift pump, which consists of a rising pipe in the form of a tube, driven down in the ground and air admitted from a compressor by means of a small pipe to the bottom of the rising main. The air and water become mixed, by which means the water is reduced in weight, rises up the main, and is delivered at the top. This method has not yet come into general use, and its action is not well known.

Some engineers are of the opinion that the air is admitted at the bottom of the rising main in volumes, forming as it were alternate layers of air and water, the air acting as pistons, which gradually expand as they rise. Other engineers think that the air comes in with the water in the form of small bubbles, at the bottom. Another opinion is that the air enters at the bottom forming air pistons, but as the air expands on its passage up the rising pipe, it gradually mixes with the water. There is no doubt of the matter if the air-lift is not properly proportionate, for the water is delivered at the top of the well, in some cases in a jerky fashion, plainly proving that layers of air and water have been present in the pipe.

The air-lift pump is undoubtedly to be recommended under certain circumstances, if carefully designed, but if misapplied and not of a first-class design it is one of the most expensive and wasteful plans that can be adopted. Air-lift pumps vary in almost every case, as regards air pressure, depth of submerged part of the pipes, and quantity of air required. For the above reasons no definite rules of a general description can be laid down, besides it also greatly depends upon the kind of air nozzle employed for spraying the compressed air into the bottom of the rising main.

In some cases the pipes have been made taper, some installations tapering larger downwards and others upwards, but neither gives such good results as a well-designed parallel pipe.

The air-pipe is sometimes taken down the centre of the rising pipe, which is an advantage, as the rising pipe can then be made of almost the same external diameter as the bore hole. At other times the air pipe is run down the outside of the rising pipe, in which cases the latter must be made smaller in diameter to leave space for the air pipe to pass down.

7. Electrically-driven Pumps

Electricity is now rapidly making headway as a motive power for pumps of every description, especially for underground working in collieries and mines, and in places where a number of pumps have to be worked which are situated a great distance from the motive power station.

Pumps are driven by the electric motor in different ways :—

In the case of a high-speed pump, such as one of the centrifugal kind, it is driven direct from the motor spindle.

If the amount of space is limited and the pump is of the quick-speed type, it is driven by a wheel and pinion ; if the pump is of the slow-speed class, two sets of gearing and a countershaft are employed.

If there is plenty of space, some engineers prefer to drive the pump or pumps by a belt from the motor.

When gearing is employed, it is frequently of the "Helical" type, because this class of gearing is stronger and works more quietly. If ordinary gearing is used the pinions are generally made of raw hide.

When belting is used and the installation is large, the leather-link belt is to be preferred, being stronger and gripping the pulleys better. A good belt of the latter class wears remarkably well.

Centrifugal Pumps Driven Direct.

In Fig. 24 is shown an "Invincible" centrifugal compound pressure pump driven by an electric motor, manufactured by Messrs. Gwynnes, Ltd., London, England, well adapted for mining purposes, waterworks, etc. It is claimed to be one of the most efficient water raisers in the world. It is simple, durable, occupies very little space, and only requires an inexpensive foundation, and may be driven direct by electric motor, as shown above, or by steam, gas or oil engines, either direct or by belt.

A high-lift turbine pump and electric motor, manufactured by Messrs. Mather and Platt, Ltd., Manchester, England, is shown in Fig. 25. It was made for the Menangle Water Works, Sydney. The engine for driving this set is of the double-acting open vertical marine type, compound and condensing, capable of indicating 500 horse-power when running at 150 revolutions per minute, with 160 lbs. of steam pressure. The dynamo has eight poles, and is compound wound, and gives an output of 550 ampères at 550 volts. The motor is similar to the dynamo, but has only four poles, and is shunt wound. It works at 500 volts at its terminals, and gives out 354 brake-horse-power, when running at 720 revolutions per minute.

The pump is of the high-lift turbine type, coupled direct to the motor spindle. It is designed to deliver 2,800 gallons of water per minute to a height of 265 feet. The water enters the revolving vane wheel axially and symmetrically on each side, so that axial thrust is eliminated; the water then traverses the curved internal passages between the vanes, and is discharged tangentially at the periphery of the vane wheel into a stationary guide ring, concentric with the revolving vane wheel, and having its guide blades so arranged as to form channels gradually

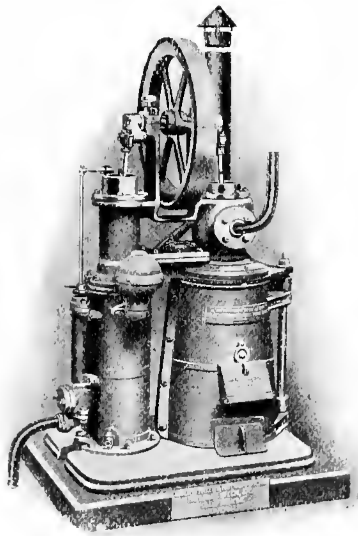


FIG. 23. "RIDER'S" HOT AIR ENGINE AND PUMP.

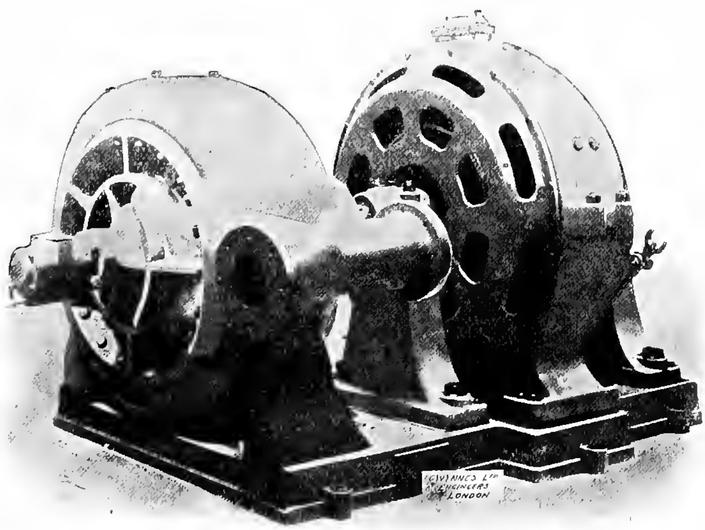


FIG. 24. GWYNNE'S "INVINCIBLE" CENTRIFUGAL COMPOUND PRESSURE PUMP DIRECTLY DRIVEN BY ELECTRIC MOTOR.

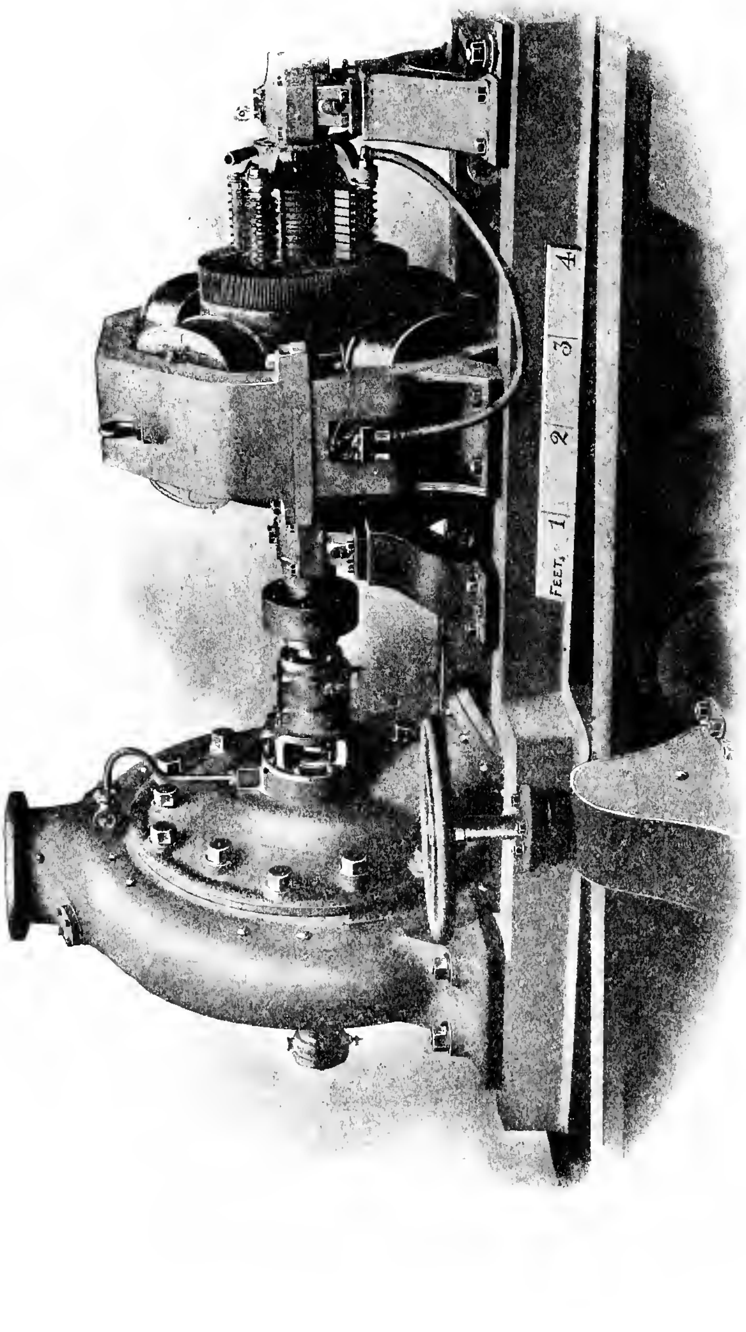


FIG. 25. MATHER AND PLATT'S HIGH-LIFT CENTRIFUGAL PUMP DIRECTLY DRIVEN BY ELECTRIC MOTOR.

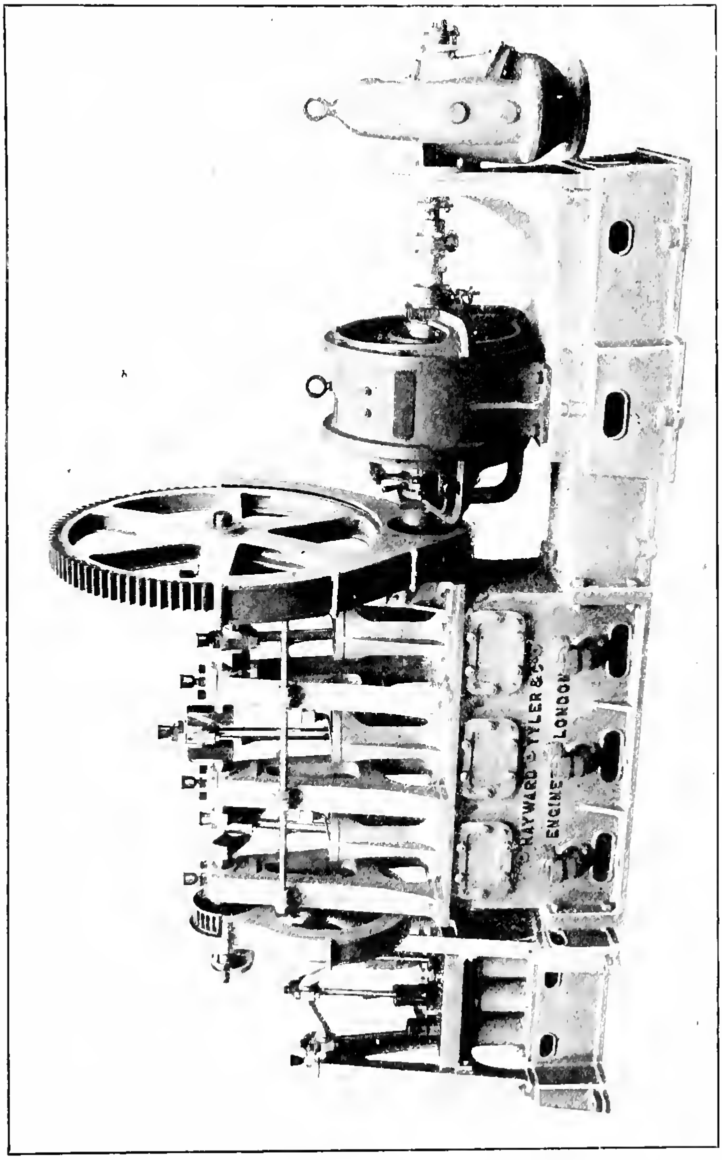


FIG. 26. THREE-THROW EDWARDS' AIR PUMP ELECTRICALLY DRIVEN BY SINGLE GEARING.

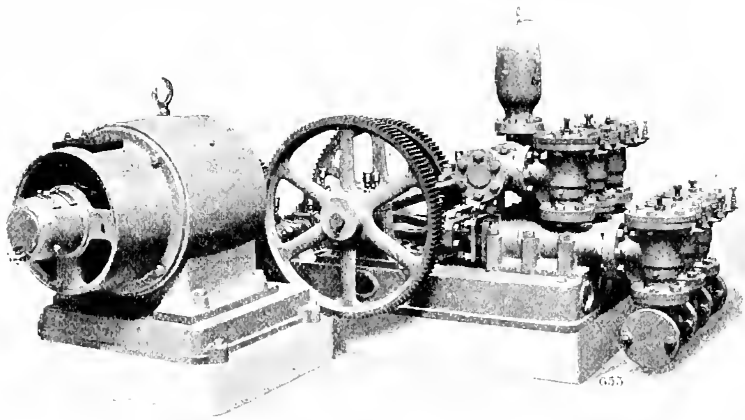


FIG. 27. MOTOR-DRIVEN THREE-THROW LOW-LIFT PUMP WITH SINGLE GEAR DRIVE.

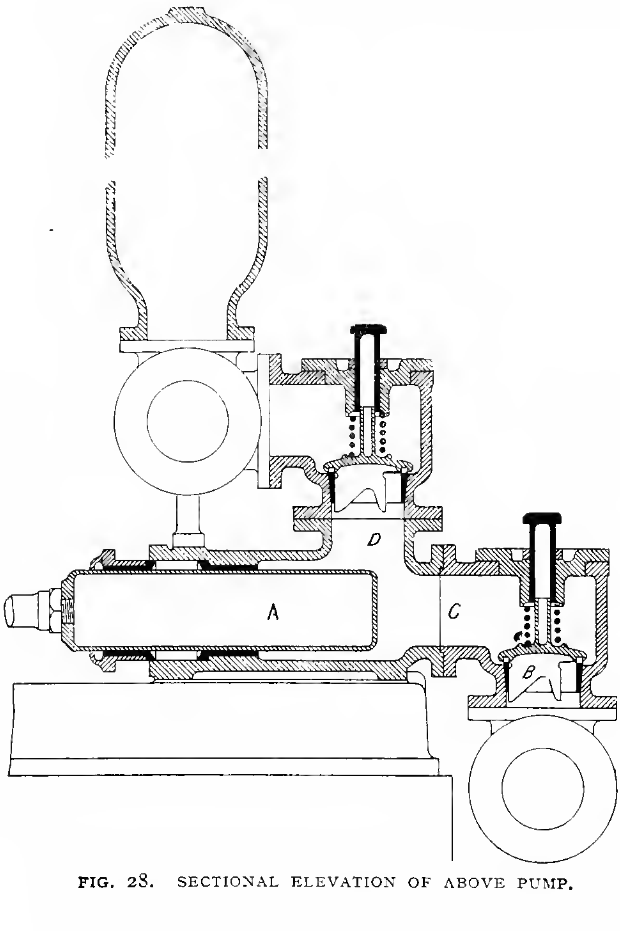


FIG. 28. SECTIONAL ELEVATION OF ABOVE PUMP.

widening from within outwards, so that the water is nowhere restricted or opposed in its course through the pump.

Pumps Driven by Single Gearing.

One of two sets of pumps constructed by Messrs. Hayward-Tyler and Co., of London and Luton, to the order of the War Office for use in the generating station at Aldershot, is shown in Fig. 26. Each set consists of vertical three-throw air pumps of "Edward's" type, 8 in. in diameter by 8 in. stroke, geared direct to an electric motor by single reduction gear. A 6-in. centrifugal pump is coupled direct to the motor spindle, and a set of $3\frac{1}{2}$ in. by 6 in. stroke vertical three-throw trunk plunger pumps are driven by gearing from the air pump crank-shaft, for pumping water into a tank. The latter can be stopped by means of a friction clutch.

The whole of the above pumps are driven by means of a 17 brake-horse-power multipolar motor, running at a speed of 86 revolutions per minute.

Pumps Driven by Double Gearing.

Fig. 27 shows a set of low-lift pumps designed for lifts below 200 ft. driven by an electric motor, manufactured by Messrs. Ernest Scott and Mountain, Ltd., Newcastle-on-Tyne, England. The pumps are of the three-throw horizontal plunger type.

One of the pumps is shown in sectional elevation, Fig. 28. The ram is made of gun-metal, and the stuffing-box and gland are lined with the same material. In this pump is a free current for the air to flow through the working barrel, and therefore no air lodges. The valve-seat *B* is kept below the under side of the waterway *C*. This is a good feature, as it allows the water to rise straight up a short distance without having any tendency to draw the valve towards the waterway. The valve boxes are all separate, bolted to the pump body, and interchangeable, like all the other parts, which is a great advantage in case of a break-down, especially when far removed from a foundry and mechanical workshop. Suction and delivery branches are arranged on either side, so that, if it is more convenient, the pipes can be taken from either side. The plungers are not provided with slipper guides in the low-lift pumps, except when specially ordered.

The motor is placed at the side of the pumps, and drives them by means of a pinion gearing into a wheel on a countershaft. The pump crank is driven by pinion and spur wheel in the usual manner from the countershaft.

A set of portable three-throw vertical pumps and protected type motor, made by Messrs. Scott and Mountain, is illustrated in Fig. 29. It consists of a set of three-throw externally packed plunger pumps driven by spur gearing from a countershaft, which latter is worked by an electric motor bolted to the same bed-plate, the latter being mounted on four wheels, so that the whole pump and motor can be run down the workings in mines and collieries, as the work proceeds. The motor is covered in, to protect it from falling débris, and this prevents any sparking from the brushes from igniting any explosive gases that may be contained in the air.

Electrically-driven a set of boiler feed pumps, as

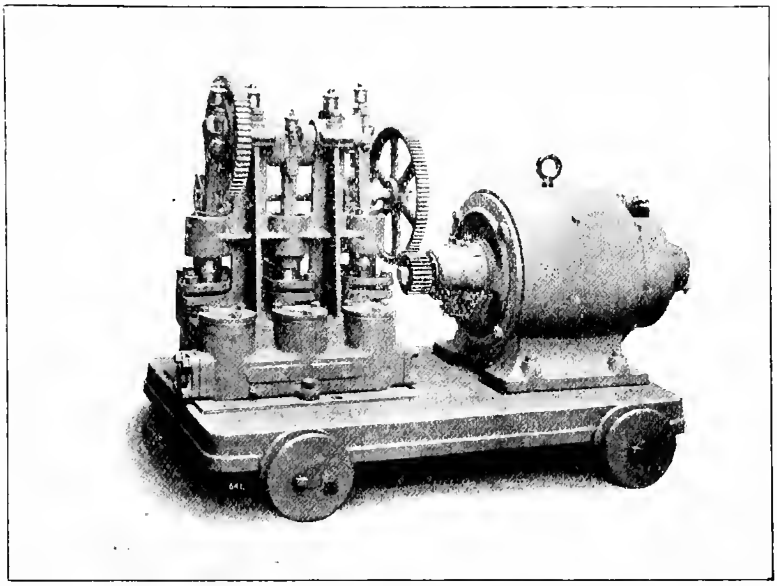


FIG. 29. PORTABLE THREE-THROW VERTICAL PUMP AND PROTECTED TYPE MOTOR.

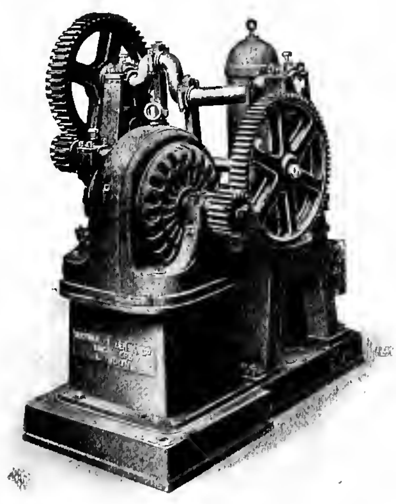


FIG. 30. ELECTRICALLY-DRIVEN BOILER FEED PUMPS.

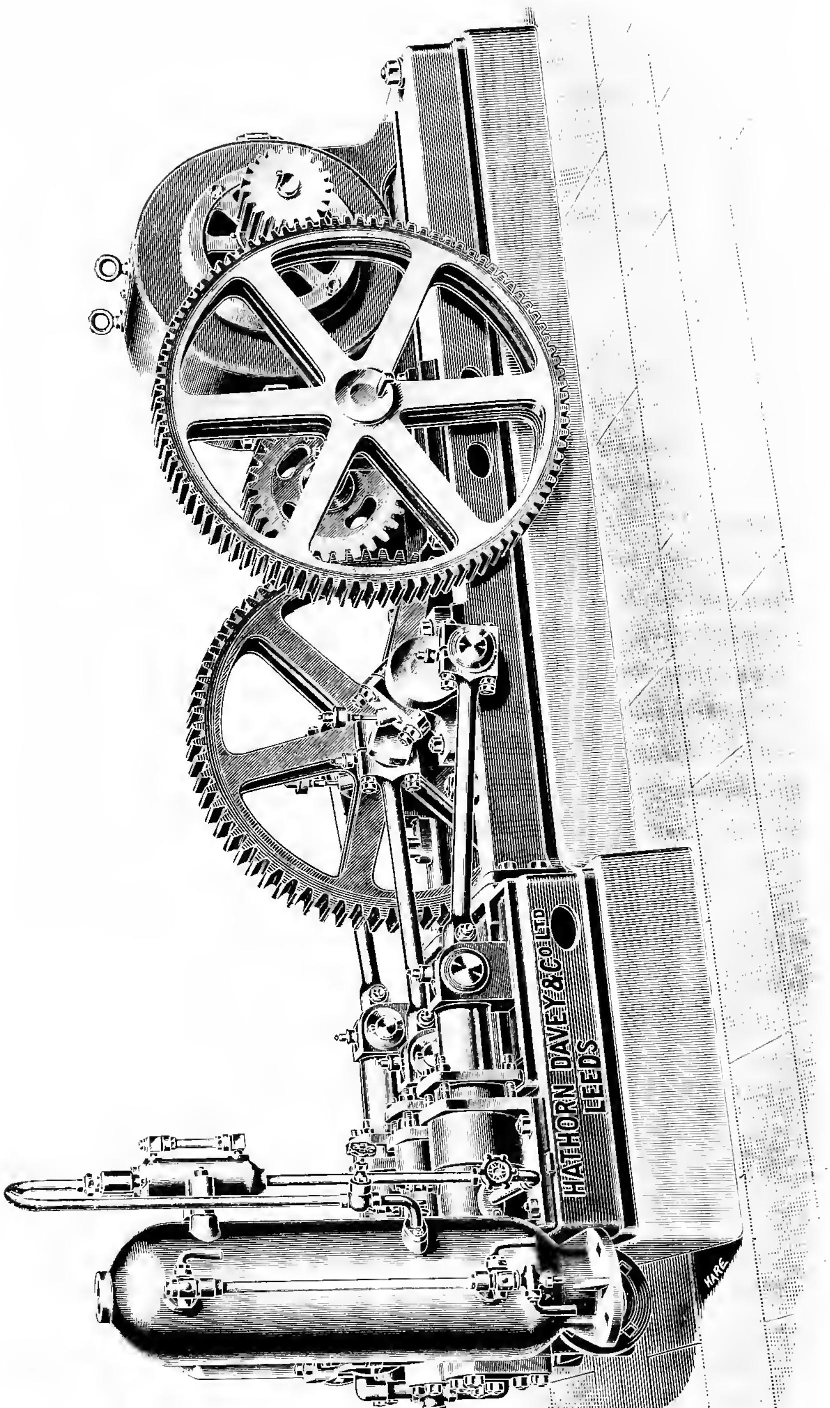


FIG. 31. HORIZONTAL THREE-THROW PLUNGER PUMPS ELECTRICALLY DRIVEN BY TREBLE GEARING.

ordered for the South Wales Distributing Company, at Pontypridd, manufactured by Messrs. Hayward-Tyler and Co., is shown in Fig. 30. The pumps, plungers, valves and valve seats are of gun-metal. The crank shaft is of the bent type, made of steel. These pumps are capable of delivering 10,000 gallons of water per hour against a boiler pressure of 125 lb. per square inch. The pumps are driven through double reduction gearing.

Pumps Driven by Treble Gearing.

A set of three-throw horizontal plunger pumps driven by an electric motor, manufactured by Messrs. Hathorn, Davey and Co., Ltd., of Leeds, is illustrated in Fig. 31. The plungers are $5\frac{1}{2}$ in. in diameter by 9 in. length of stroke. It is capable of delivering 100 gallons of water per minute, at 44 revolutions per minute, against a head of 540 ft. The plungers are provided with slipper cross-heads working in guides provided on the top of the bed-plates. The electric motor is of 25 brake-horse-power.

Pumps Driven by Belt.

A combined electric motor and three-throw plunger pump for raising 60 gallons of water per minute under a head of 300 ft. is shown in Fig. 32. It is manufactured by the Sandycroft Foundry and Engine Works Company, Chester, England. In this arrangement the motor foundation plate is secured to the pump bed. The motor drives a countershaft by means of a belt and two pulleys, and the pump crank shaft is driven by a pinion on the countershaft and a helical wheel on the pump shaft. The pumps are of the usual externally-packed single-acting plunger type. A delivery air vessel is provided on the delivery branch pipe. A motor switch is arranged on the motor bed-plate.

"Riedler" Pump Driven by Single Reduction Gear.

A "Riedler" pump connected by single reduction gearing to an electric motor, is illustrated in elevation, Fig. 33, and end view, Fig. 34. This shows clearly how the control of the valves is effected, the principle being the same whatever the size of the pump or nature of the driving gear. It consists of a wrist plate which is oscillated by means of an eccentric and rod, from the pump crank shaft, and the suction and delivery valves are actuated from the said wrist plate by means of levers and connecting rods or links.

A section of the "Riedler" differential plunger or plunger-and-plunger pump is shown in Fig. 35.

The pump consists of a body casting, fitted with two plungers, *J* and *H*, the former being twice the area of the latter; the two being connected by means of the rods *G*, one on each side of the pump body. The action of this pump is as follows:—When the plungers are moved towards the right, the water enters the suction pipe *A*, through the pipe *B*, and the suction valve E, into the large working barrel. On the return stroke, that is, when the plungers move towards the left, the suction-valve *E* closes and the water is forced through the delivery valve *F*; but as the plunger *H* is only half the area of the plunger *J*, half the water will pass into the left-hand working barrel, the remaining half is forced through the passage *C* into the delivery-pipe or rising main *D*. On the return stroke towards the right the small plunger *H* discharges the other half of the water through the passage *C* into the delivery pipe *D*. From this it will be seen that the suction is single-acting and the delivery double-acting with only two valves. The displacement must be calculated as a single-acting pump with an area equal to the larger plunger *J*, or as double-acting if the area of the small plunger is taken.

An electrically-driven sinking pump, manufactured

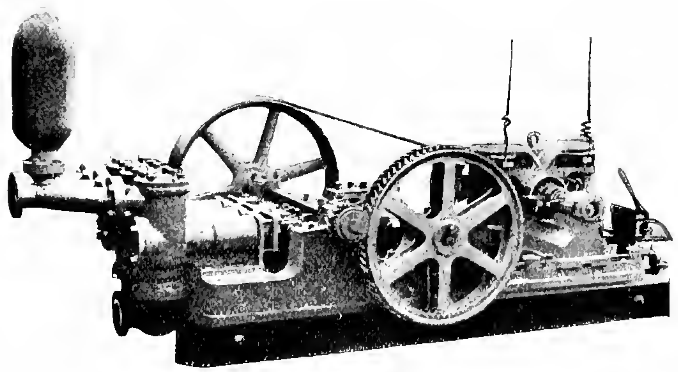


FIG. 32. THREE-THROW PLUNGER PUMPS ELECTRICALLY DRIVEN BY BELT DRIVE.

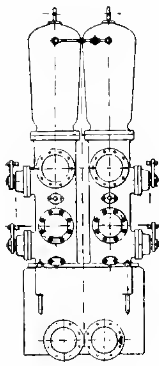


FIG. 34.

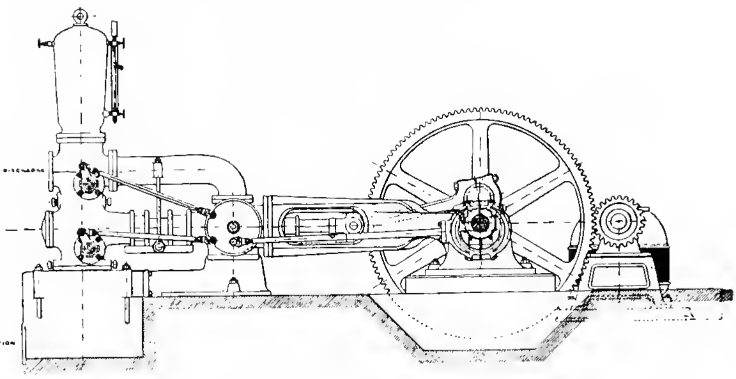


FIG. 33.

SMALL-SIZED "RIEDLER" PUMP CONNECTED BY GEARING TO ELECTRIC MOTOR.

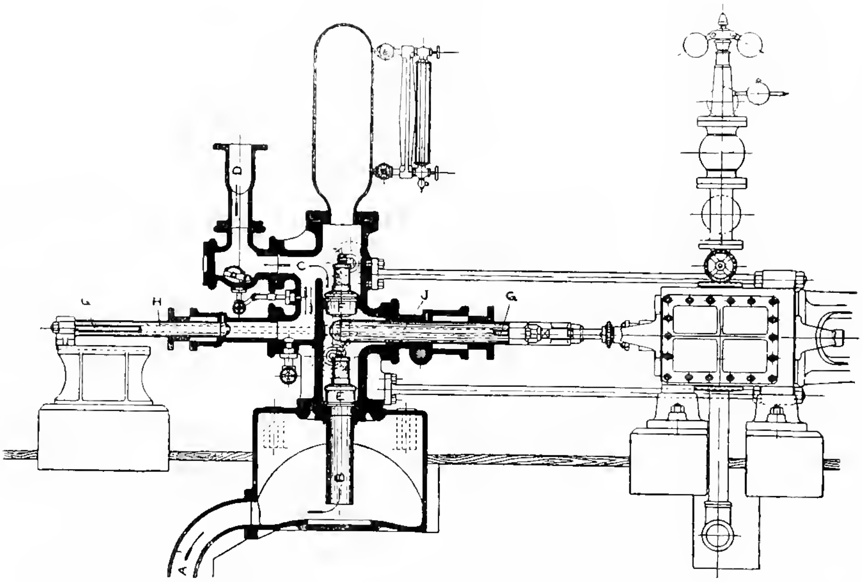


FIG. 35. SECTIONAL VIEW OF A "RIEDLER" PUMP BUILT ON THE "DIFFERENTIAL" PRINCIPLE.

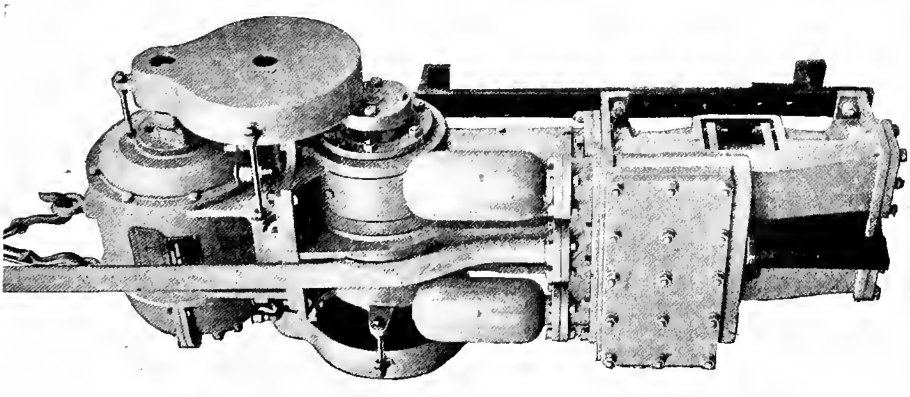


FIG. 36. AN ELECTRICALLY-DRIVEN SINKING-PUMP.

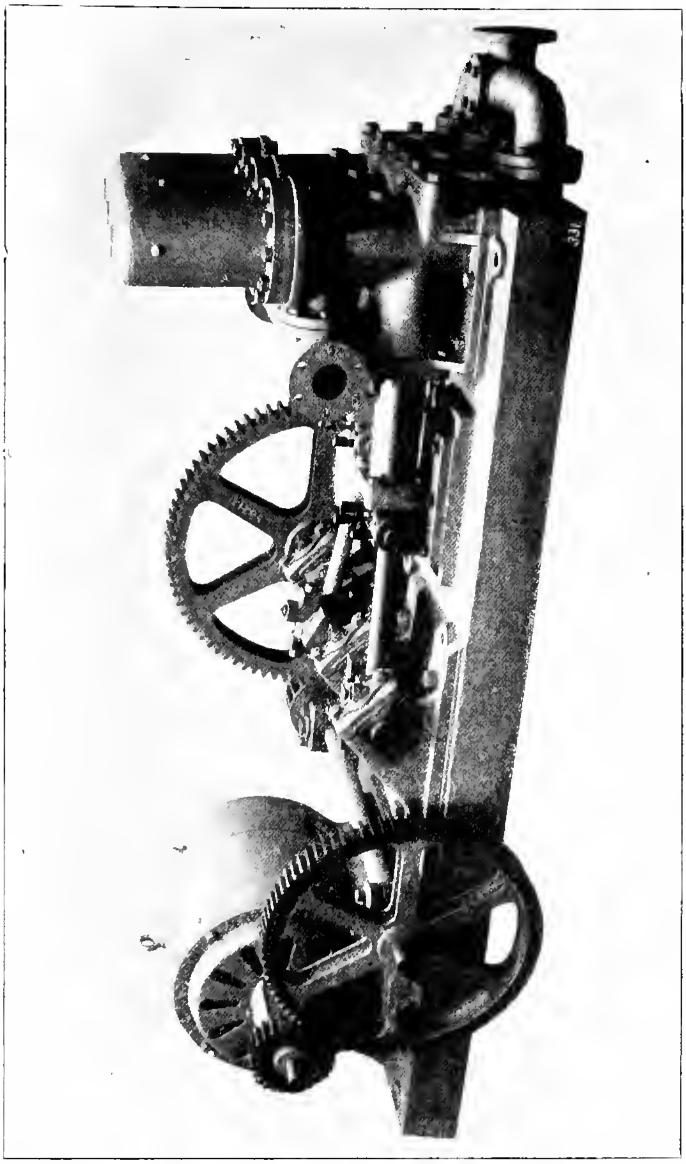


FIG. 37. THREE-THROW PUMPS ELECTRICALLY DRIVEN BY DOUBLE REDUCTION GEARING.

FIG. 39.

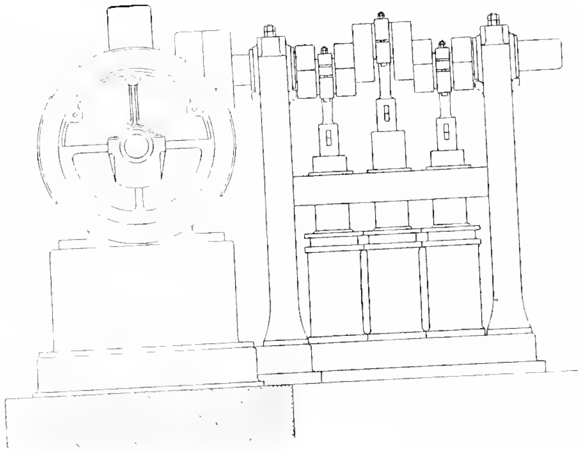
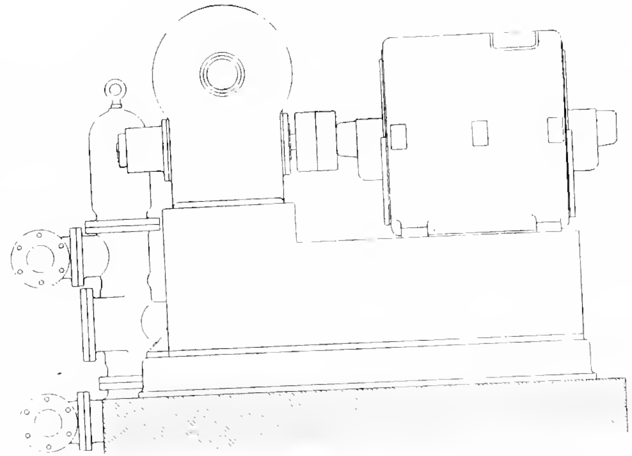


FIG. 38.



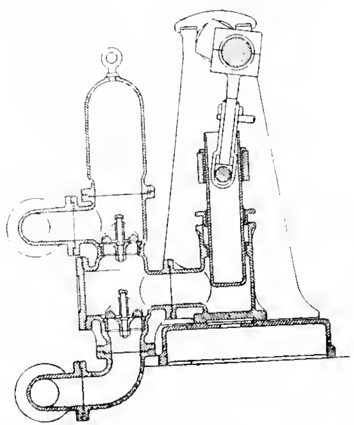


FIG. 40.

SET OF VERTICAL THREE-THROW PLUNGER PUMPS ELECTRICALLY DRIVEN BY WORM GEARING.

by the Sandycroft Foundry and Engine Works Co., Ltd., Chester, England, is illustrated in Fig. 36.

The pump is of the duplex single-acting plunger type. The pumps and valve boxes are in one casting, a single cover giving access to all the valves. The plunger glands are easily packed, being outside. Above the pump body is an intermediate piece carrying the cranks, reduction gearing, connecting rods, and guides. Two eye-bolts are provided on the top of the motor for slinging the whole apparatus in a shaft or winze. A provision is also made for securing the pump to cross timbers, if desired.

The reducing gearing comprises a raw-hide pinion on the motor shaft, gearing into a cast-iron wheel on the second motion shaft. A cast-iron pinion on the second motion shaft gears into a cast-iron wheel on the pump crank shaft.

The motor is of the damp-proof type. It is provided with laminated poles and a slot wound armature, the winding consisting of former wound coils. The bearings are self-oiling.

A set of three-throw electrically-driven pumps, manufactured by Messrs. P. R. Jackson and Co., Ltd., Manchester, England, is shown in Fig. 37. The pumps are driven by double reduction gearing, consisting of ordinary spur wheels and pinions. The plungers are provided with cross-heads, working in slipper-guides furnished on the top of the bed-plate. The pump crank-shaft bearings are diagonal, so that the thrust of the plungers does not come on the cap bolts, but on the solid part of the casting.

A vertical set of three-throw plunger pumps driven by an electric motor, is shown in elevation, Fig. 38, and end view Fig. 39. It has been designed by Messrs. Andrew Barclay, Sons, and Co., Ltd., Kilmarnock, Scotland. The reducing gear in this case consists of a worm and worm-wheel. The plungers are 7 in. in diameter by 9 in. stroke, and they run at a speed of 40 revolutions per minute. These pumps are capable of forcing 8,000 gallons of water per hour into a boiler having a working pressure of 225 lb. per square inch. Fig. 40 shows a sectional elevation of one of the pumps and valve boxes.

> The crank-pin ends of the connecting-rods are of the marine type and cross-head pin ends are made adjustable by means of a gib and cotter. The cross-head pin is secured inside the plungers. The plungers, besides being guided inside the pump stuffing-boxes and glands, are also working in gun-metal bushed guides, secured between the two A-frames, which carry the pump crank-shaft. The suction and delivery valve boxes are cast in one and secured by branches to the working barrels, and an air vessel forms a cover for the delivery valve-boxes, a side cover being furnished for access to the suction valves. A relief valve is provided on the main delivery pipe.
>
> When these pumps are worked by spur gearing, the ratio is usually made six to one.

Fig. 41 is a reproduction of a photograph of a set of horizontal three-throw pumps made by the same firm, worked by an electric motor. The plungers, in this case, are 10 in. in diameter by 12 in. stroke, and are designed for running at a speed of 50 revolutions per minute and to deliver 500 gallons of water per minute against a head of 165 ft. All the spur wheels used in these pumps are machine cut.

8. Steam Pressure Pumps

THE steam engines employed for actuating pumps may be divided into two classes :—

1. Direct-acting; and
2. Rotative Engines.

STEAM PRESSURE

1. Direct-Acting Steam Pumping Engines.

A direct-acting pumping engine is a machine for raising water or any other liquid, fluid or semi-fluid, so constructed that the pump is worked by a motor cylinder without the intervention of connecting-rods, cranks, or fly-wheel.

These engines may be subdivided into :—

A. Single cylinder, or Simplex ; and

B. Duplex pumping engines.

A. Single-cylinder, or Simplex.

Although the "Cornish" and the "Bull" engines come under this class we will leave them out, as they are so seldom employed, having been superseded by the more modern types.

This class of pumping engine or, perhaps, more correctly speaking, steam pumps, originally did great service in its simplest form, as feed-pumps, when comparatively low steam pressures were used, the plant small, and the price of coal moderate. Now, when fuel is dear, and the steam pressure high, more economical types are employed, having their cylinders compounded.

The direct-acting pumps are made both horizontal and vertical, and used for an endless variety of purposes. A steam fire engine for large factories, manufactured by Messrs. Hayward-Tyler and Co., London and Luton, England, is illustrated in Fig. 42. It is of the "Universal" long-stroke type, with outside slide valve. The steam valves are actuated by steam on the positive principle, that is, they are moved by the direct pressure on steam from the piston through shooting ports provided in the steam cylinder. Directly the main piston has passed a small port in the cylinder, the steam passes on to the back of an auxiliary valve, working inside the main valve, and admits steam behind it, and opens the main steam ports ready for the return stroke. The same operation goes on at the other end of the steam cylinder.

The water cylinder is of the double-acting piston type, fitted with indiarubber ball-valves, for rapid running.

In this example the steam cylinder is 12 in. in diameter, and the water cylinder $7\frac{1}{2}$ in. in diameter, both having a stroke of 15 in.

Illustration Fig. 43 shows a steam pump for colliery work of the "Niagara" type made by the same firm, with outside steam valves, and provided with a long stroke. The valve gear is similar to that of the fire engine, Fig. 42, but the water part is of the externally packed double-acting plunger type. It consists in reality of two single-acting ram pumps placed face to face and one plunger working into both working-barrels, and connected to the pump rod, which latter works through a stuffing-box and gland.

This example has a steam cylinder 21 in. in diameter, plunger 9 in. in diameter, and a stroke of 48 in., suitable for a lift of 320 ft., with a steam pressure of 50 lb. per square inch.

A sinking pump fitted with Bailey and Lindemann water part, called the "Denaby" sinking pump, manufactured by Messrs. W. H. Bailey and Co., Ltd., Salford, England, is illustrated in sectional elevation, Fig. 44, and perspective view, Fig. 45. In this pump there are three

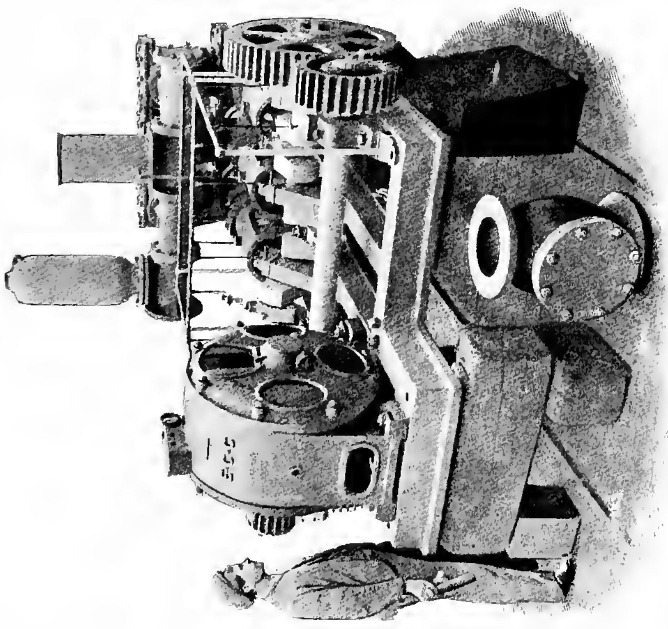


FIG. 41. A SET OF ELECTRICALLY DRIVEN THREE-THROW PUMPS.

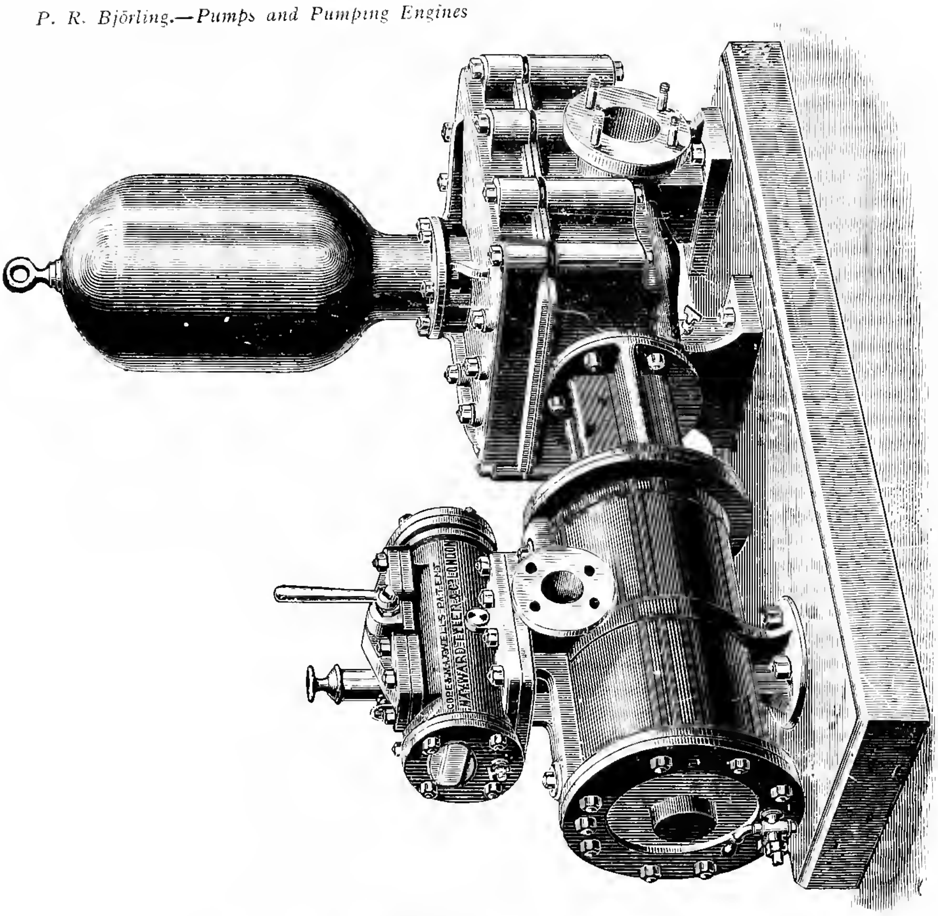


FIG. 42. STEAM FIRE ENGINE FOR LARGE FACTORIES.

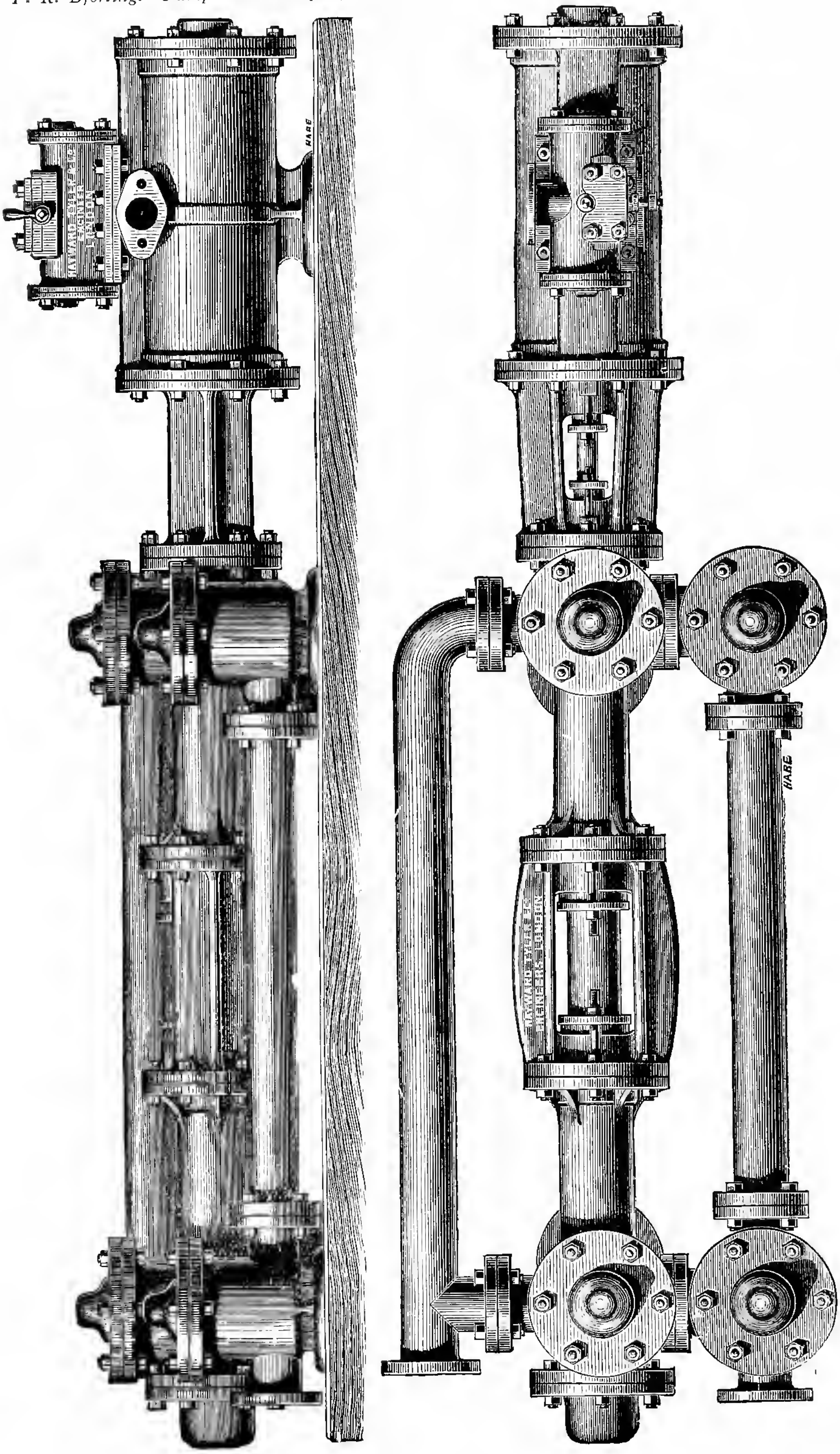


FIG. 43. ELEVATION AND PLAN OF "NIAGARA" TYPE STEAM PUMP FOR COLLIERY WORK.

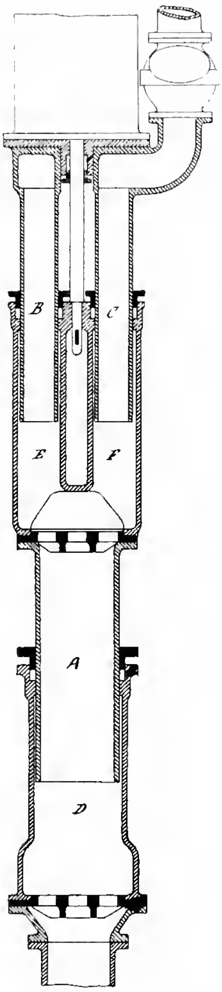


FIG. 44. SECTIONAL VIEW.

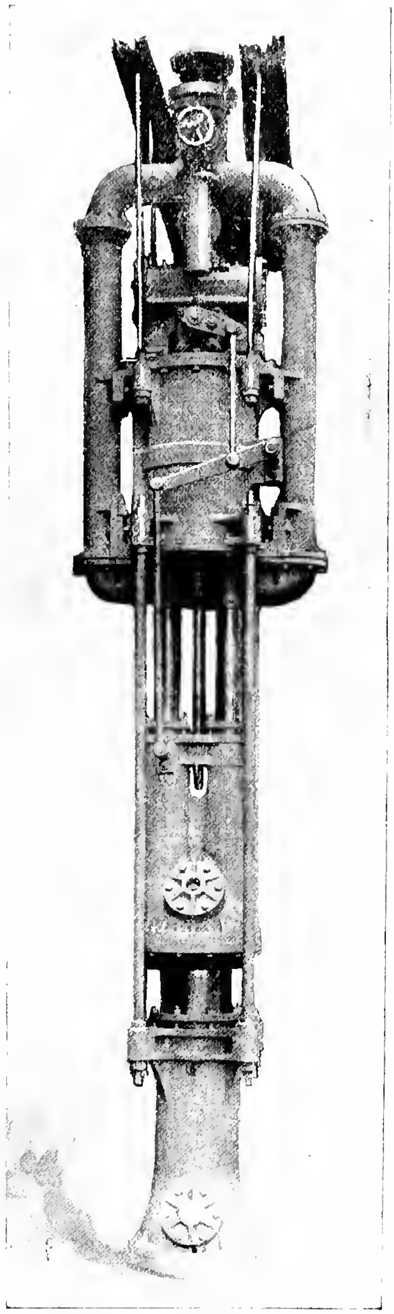


FIG. 45. OUTSIDE VIEW.

THE "DENABY" SINKING PUMP.

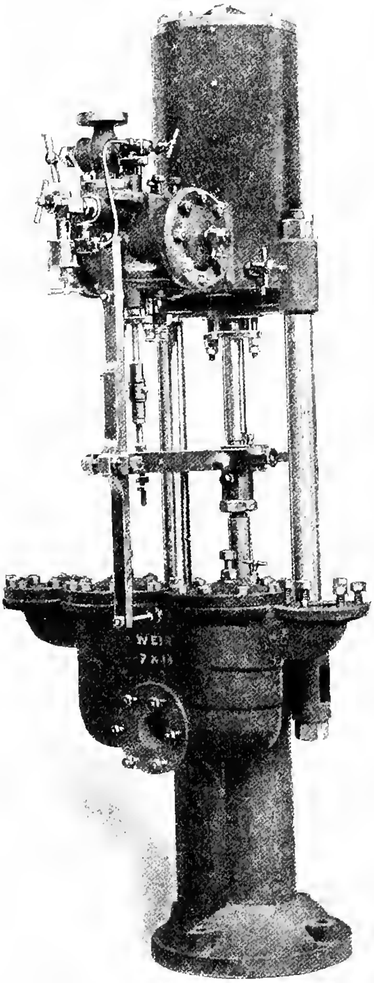


FIG. 46. WEIR'S DIRECT ACTING BOILER FEED PUMP.

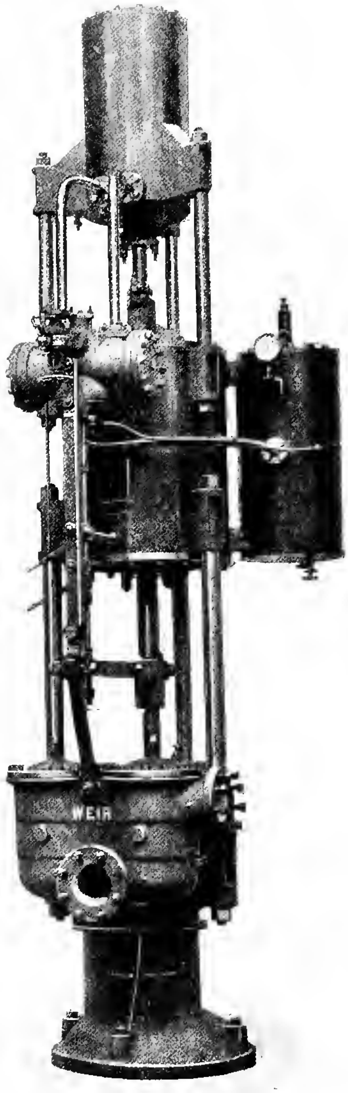


FIG. 47. WEIR TANDEM COMPOUND FEED PUMP.

plungers, *A*, *B*, and *C*; the small plungers *B* and *C* are one-fourth of the area of the large plunger; *E*, *F* are the cases for the two small plungers; and the delivery valve or valves, as the case may be, is placed in a clack-piece formed on the top of the plunger-case for the large plunger. In the example before us the pump is worked direct from a steam cylinder, and the case for the plunger is coupled to the piston-rod by a cotter. In Fig. 44 the plunger *B* acts as an air vessel, and the water is delivered through the small plunger *C*, into the back-pressure or retaining valve. In Fig. 45 the water is delivered through both the small plungers *B* and *C*, carried through two pipes which are joined above the cylinder into one central rising-main, so that everything is perfectly balanced.

The steam cylinder is fitted with Davidson's direct-acting valve gear.

The "Weir" patent direct-acting feed pump, illustrated in Fig. 46, is manufactured by Messrs. G. and J. Weir, Ltd., Cathcart, Glasgow. The peculiar feature in this pump is the patent steam valve gear.

It consists of a main and an auxiliary valve. The main valve is for distributing steam to the cylinder; the auxiliary for distributing steam to work the main valve. The main valve is moved horizontally from side to side, being driven by steam admitted and exhausted from each end alternately. The auxiliary valve is actuated by lever gear from the pump rod, and moves on a face on the back of the main valve, and in a direction at right angles to the main valve. By this arrangement there is no dead centre, the action being absolutely positive, because the only possible position in which the main valve can rest is at full travel—either for an up or down stroke of the piston.

Both the main and auxiliary valves are simply slide valves, but the former is half round, the round side working on the cylinder port face, which is bored out on one side to fit the valve. On the back of this main valve a flat is formed for the auxiliary valve to work upon. Both ends of the main valve are lengthened so as to project beyond the port face, and are turned cylindrical with flat ends. Caps are fitted on each of these ends forming cylinders, which are closed at the mouth by the flat ends of the main valve, which act as pistons.

The functions of the auxiliary valve are to admit steam through the ports on the back of the main valve to move the main valve from side to side. The ports for admitting steam to the top and bottom of the cylinder are arranged to cut off before the end of the stroke, and so slow down the pump, thus permitting the water valves to settle quietly and relieve the connections from any shock. On the last quarter of the stroke the steam is thus used expansively, so effecting a considerable economy in steam consumption. Provision is made, however, round the caps covering the end of the main valve by admitting live steam during the entire stroke, as, when the pumps are standing and the metal is cold, the steam condenses and it is necessary to clear out the chamber of water. These caps are turned by means of a gun-metal spindle with indicating pointers at each side of the steam valve chest. The stroke of the pump can be adjusted while the pump is working by nuts on the valve spindle.

The pump is of the double-acting piston type, the valves at each end are of the multiple gun-metal type, placed at the upper part of the working barrel, at the proper place, so as to prevent the too usual air-lodge at the top end of vertical piston pumps. The steam and water cylinders are connected by two columns, and the valve lever is fulcrumed on a rod connecting the steam chest with the pump valve-box.

Fig. 47 represents the "Weir" vertical tandem compound feed-pump, suitable where the boiler plant is of comparatively small dimensions, and a single pump is available. The high-pressure cylinder is fixed above the low-pressure and a single steam valve is employed for the steam distribution. A steam receiver is bolted to the low-pressure cylinder, connected with the exhaust from the high-pressure cylinder, and the steam admission on the low-pressure cylinder.

The water cylinder is similar to the single cylinder type, illustrated in Fig. 46.

Messrs. Weir's water pistons are of a novel description. There are three rings forming a T; the packing rings are of specially manufactured ebonite, and are cut at an angle to permit of their expanding and filling the working barrel.

The independent direct-acting high-pressure feed pump, illustrated in sectional elevation, Fig. 48, is manufactured by Messrs. Clarke, Chapman, and Co., Ltd., of Gateshead-on-Tyne. The pump shown is of the single cylinder type, fitted with Woodeson's patent steam valve gear. The hydraulic part is of the double-acting piston type, and fitted with multiple suction and delivery valves for the top and bottom of the working-barrel. The steam cylinder is secured to the hydraulic cylinder by means of three steel columns.

The valve chest is fitted with a liner manufactured of the best close-grained cast iron, of a suitable thickness to withstand any tendency to distort through the temperature of high-pressure steam. This liner is divided into two chambers, a top chamber or main steam chest, and a bottom chamber or auxiliary steam chest. In the top chamber the main valve is fitted, which gives steam and exhaust to the steam cylinder, and is controlled by an auxiliary valve, which is fitted in the bottom chamber of the liner and is actuated by a lever and spindle which are moved backwards and forwards by the cross-head on the piston rod. Both the main and auxiliary valves are of the piston type and are perfectly balanced. The main valve is free to be moved up and down by the steam admitted to it by the auxiliary valve through ports and passages cut in the outside of the liner for that purpose; it also cushions itself and is prevented from sticking each time it is moved up or down by closing the exhaust port at either end of the top chamber. The auxiliary valve is fitted on the spindle between a collar and a nut, and it is impossible to replace either main or auxiliary valves in a wrong position after overhauling the pump. To the top of the main valve is attached a small spindle with handle fitted to it; by this means it is possible to see exactly what the main valve is doing, and it is also useful to move the valve up and down by hand to free it from any impediment which may have accumulated, should the pump have been standing for any length of time.

The pump rods are cold-rolled manganese bronze, working in gun-metal glands and neck-bushes.

Fig. 49 is a reproduction of Messrs. Clarke, Chapman and Co.'s compound feed-pump. The low-pressure valve gear is exactly like the one just described, but the high-pressure valve is a plain piston valve actuated by the spindle of the low-pressure valve.

The hydraulic part is similar to that of Fig. 48.

Clarke-Chapman horizontal direct-acting feed-pump outside packed ram type, fitted with Woodeson's valve gear, is illustrated in elevation, Fig. 50, and plan, Fig. 51. The pump part is of the two-ram type, the rams being provided with cross-heads and connected by side rods. The suction and delivery valve boxes are bolted to the barrels. This is a good arrangement in case of a breakdown, but it increases the clearance space in the pump, hence prevents the pump from raising the water from any great depth, which is seldom the case with boiler feed-pumps, especially if the feed-water is hot, when the water must be run into the pump, or the lift reduced to the smallest amount possible.

The following is a copy of an official test taken with Clarke-Chapman Tandem Compound Direct-acting Feed-pump, "Woodeson's Patent," supplied to the Charing Cross and City Electric Co., Ltd., London :—

Date	Sept. 12, 1901.
Steam-pressure, per square inch . .	182 lb.

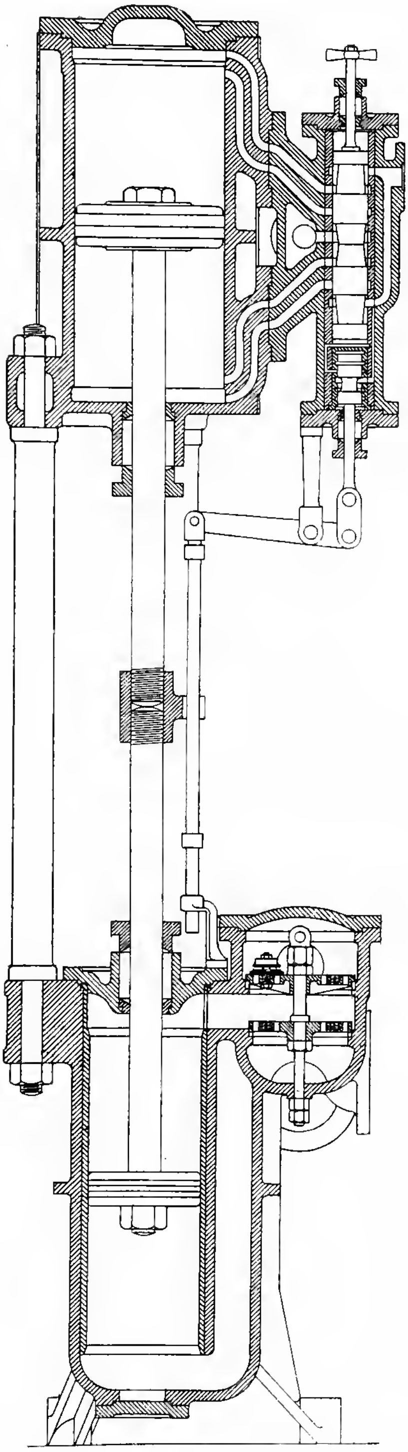


FIG. 48. INDEPENDENT DIRECT-ACTING HIGH-PRESSURE FEED PUMP.

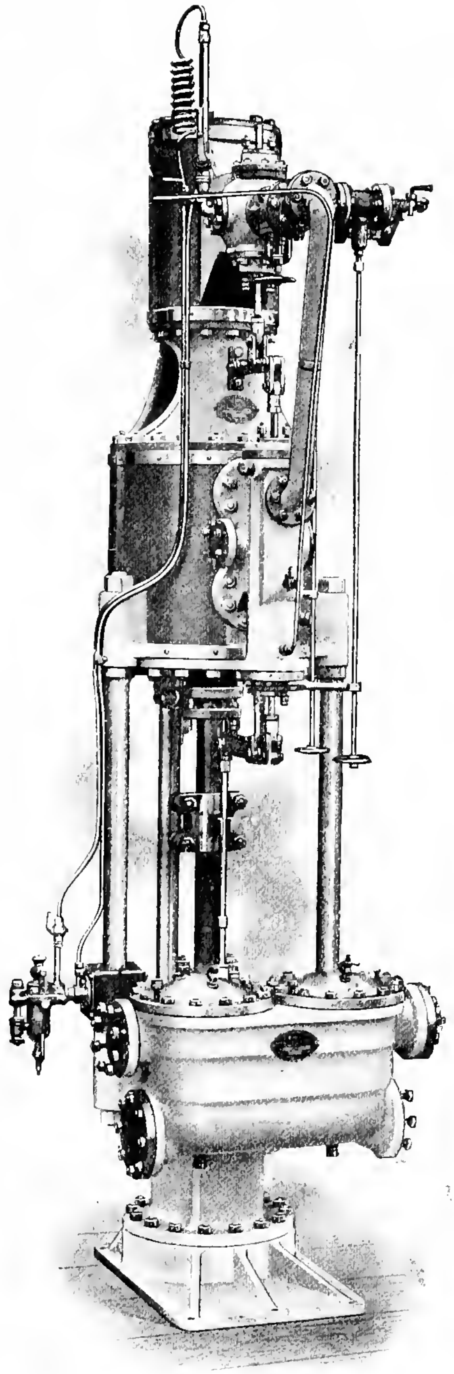


FIG. 49. TANDEM COMPOUND SLOW SPEED DIRECT-ACTING FEED PUMP.

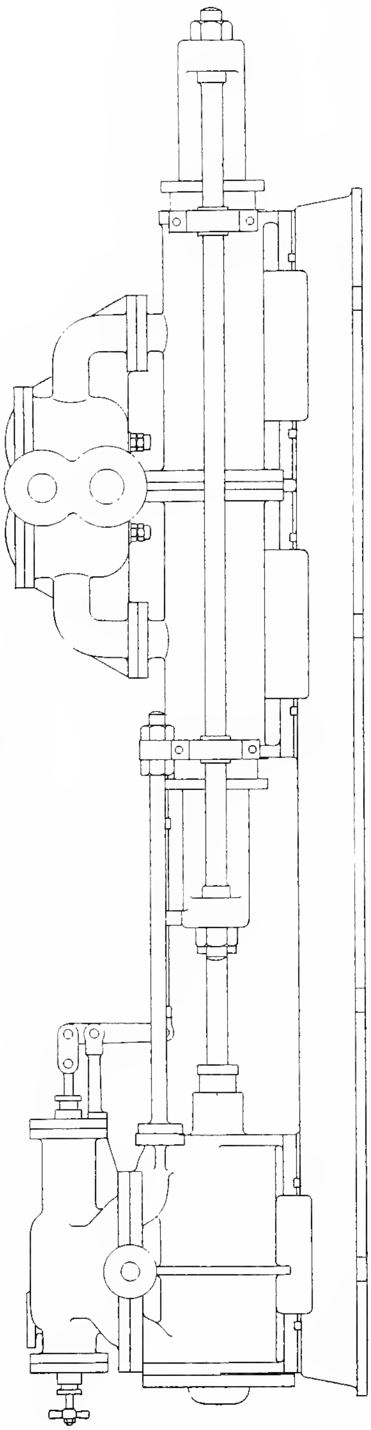


FIG. 50.

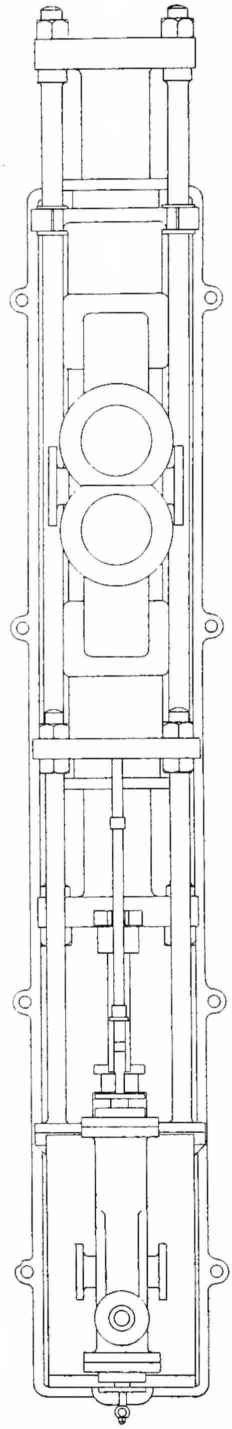


FIG. 51.

CLARKE-CHAPMAN HORIZONTAL DIRECT-ACTING FEED PUMP.

Pressure in delivery pipes, per square inch	183 lb.
Water horse-power developed	20·96 ,,
Weight of steam used per hour	849 ,,
Pounds of steam used per water horse-power per hour	40·5 ,,
Pounds of water discharged against	185 ,,
lb. pressure per 8 lb. of steam used	114·6 ,,
Number of strokes per minute	17 ,,
Efficiency of pump	97·1 ,,
High-pressure cylinder	$9\frac{1}{2}$ in.
Low-pressure cylinder	18 ,,
Water cylinder	$9\frac{11}{16}$,,
Length of stroke	19 ,,

Tests of a Clarke-Chapman Simple Slow Speed Feed Pump, "Woodeson's Patent," taken by W. Foggin, Esq., of Messrs. Foggin and Reed, Consulting Engineers, Newcastle-on-Tyne, England.

Diameter of steam cylinder	8 in.
Diameter of water cylinder	6 ,,
Length of stroke	18 ,,
Average double strokes per minute	16·8 ,,
Average steam pressure in lb. per square inch	150 ,,
Average pressure of discharge of pump	168·5 ,,
Gallons of water per double stroke	3·8 ,,
Pounds of water discharged against a pressure of 166·5 lb. per square inch per lb. of steam used at a pressure of 150 lb. per square inch	78·04 ,,

The pump efficiency during the whole of the above tests was 99·4.

Fig. 52 is a sectional and front elevation, and Fig. 53 an outside view of a very economical pump of this class. It is of the vertical direct-acting compound type, and manufactured by Messrs. J. P. Hall and Sons, Ltd., Peterborough, England. The water cylinder is of the double-acting piston type, fitted with flat seat gun-metal valves, provided on their back with springs for rapid and certain closing. The steam cylinders are worked tandem fashion, the low-pressure cylinder being placed below the high-pressure one.

The valve arrangement is of a peculiar construction, consisting of two piston valves controlled by an auxiliary valve on the front of the steam-chest. The auxiliary valve is also of the piston type, and is operated by means of levers from the engine piston-rod. The upper valve is that of the high-pressure cylinder, which is operated by steam, thus giving motion to the low-pressure valve by means of a rocking lever shown in the end view, Fig. 52. The rocking lever is provided with a handle, in order to start the pump, which is done by placing the high-pressure valve in the opposite position to that it would occupy if the pump were working. This fills the high-pressure cylinder with steam, so that when the positions of the valves are reversed such high-pressure steam is exhausted into the low-pressure cylinder and the pump then continues in motion as long as steam is on.

B. Duplex Pumps.

A vertical duplex single-cylinder boiler feed-pump is illustrated in Fig. 54. The steam cylinders are of the ordinary duplex type, in which one cylinder actuates the slide valve of its neighbour; the valves being moved by levers from the piston-rods. The brasses in the wiper brackets are made adjustable.

The water cylinders are of the double-acting piston type. The water valves have their lift controlled by a spiral spring, the valves being threaded upon the central spindle, which also serves to retain the valve studs in place. This arrangement makes a very quiet working valve.

This and two following pumps are manufactured by Messrs. J. H. Carruthers and Co., Ltd., Glasgow, Scotland.

In Fig. 55 is shown a vertical compound boiler feed-pump. The high-pressure steam valves are of the piston

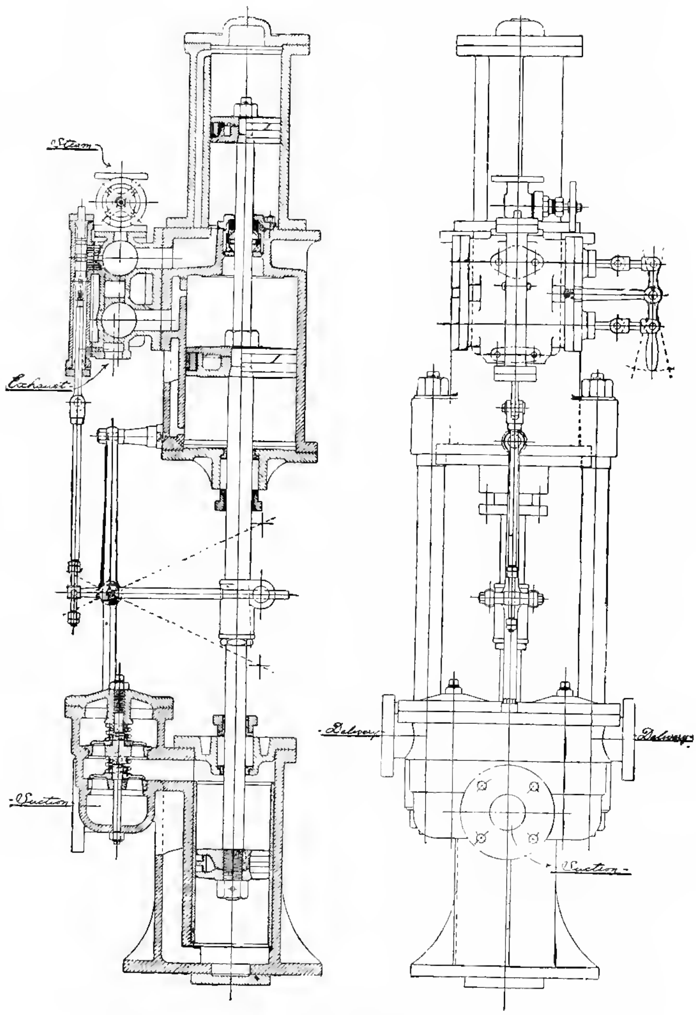


FIG. 52. HALL & SONS' COMPOUND DIRECT-ACTING BOILER FEED PUMP.

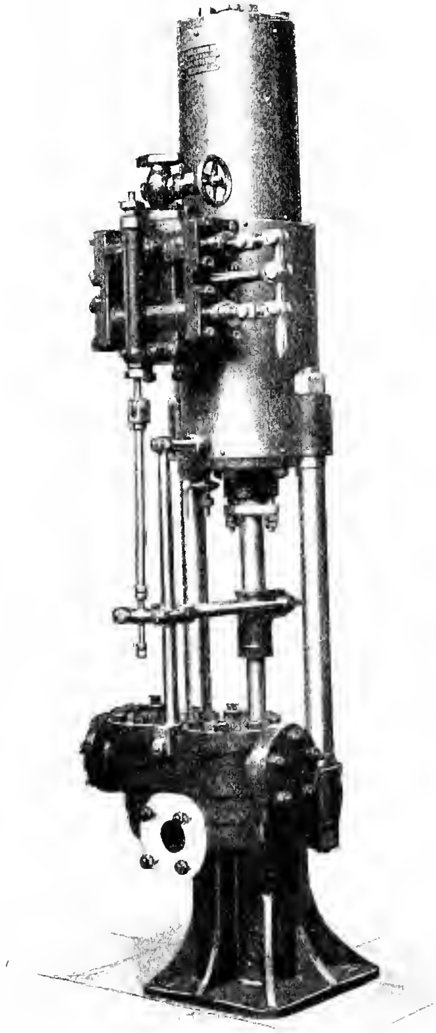


FIG. 53. PERSPECTIVE VIEW OF HALL & SONS' FEED PUMP.

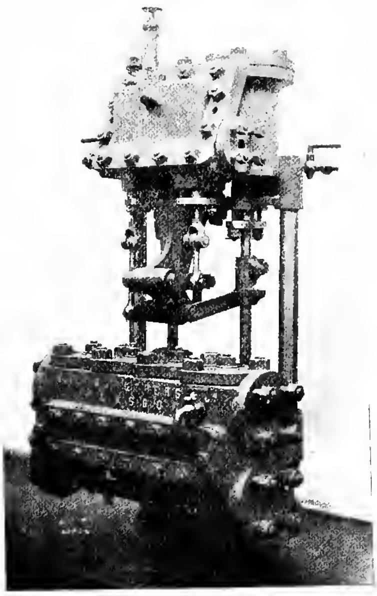


FIG. 54. VERTICAL DUPLEX SINGLE CYLINDER BOILER FEED PUMP.

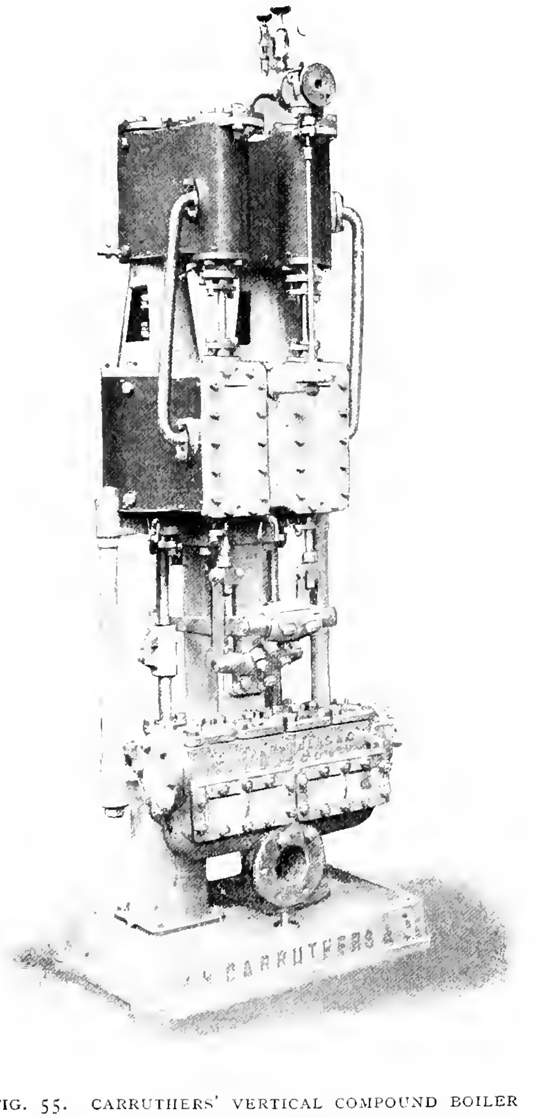


FIG. 55. CARRUTHERS' VERTICAL COMPOUND BOILER FEED PUMP.

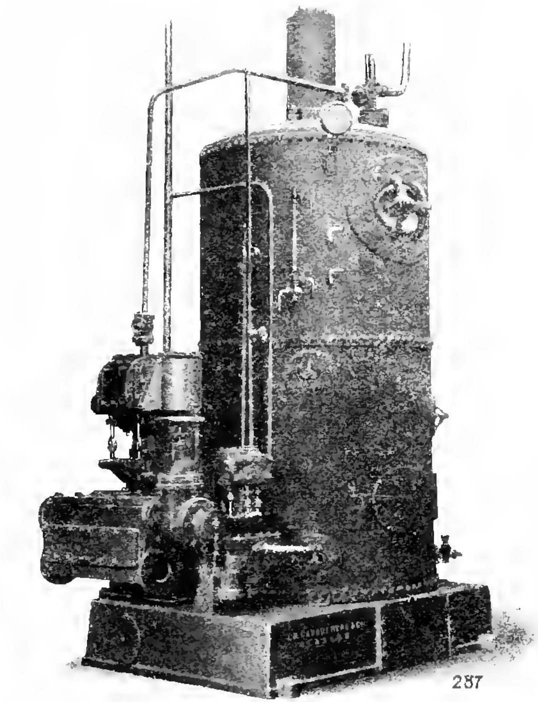


FIG. 56. COMBINATION OF VERTICAL LOW-SERVICE DUPLEX PUMP, STEAM BOILER AND DUPLEX BOILER FEED PUMP.

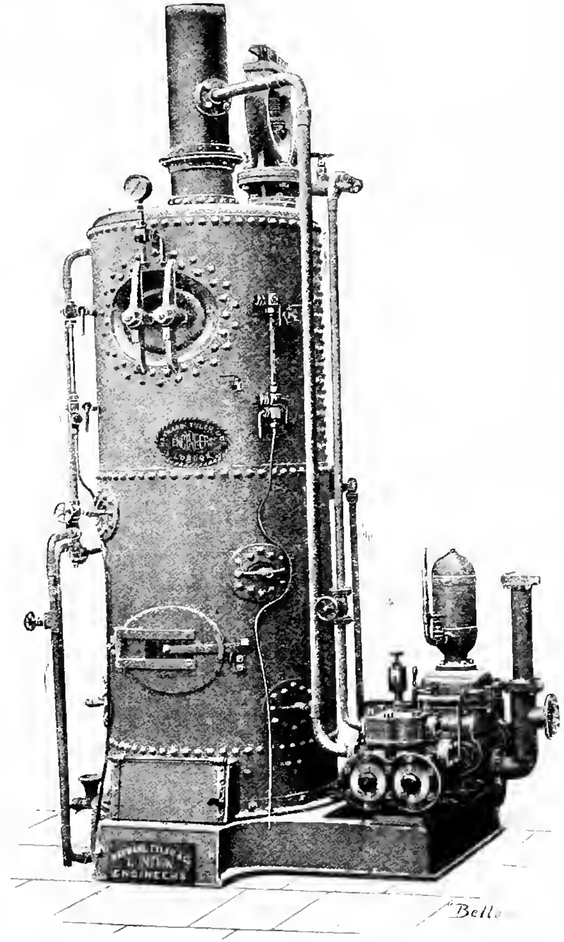


FIG. 57. COMBINATION OF STEAM BOILER AND DUPLEX STEAM PUMP.

type and the low-pressure valves are of the ordinary slide type. There are double stuffing-boxes, which separate the high-pressure and the low-pressure cylinders; this arrangement prevents any leakage of steam from the one cylinder to the other, and is always open to inspection.

A combination of vertical low-service duplex steam pump, vertical steam boiler and vertical duplex boiler feed-pump is illustrated in Fig. 56. The boiler is 4 ft. in diameter by 8 ft. high, having a working pressure of 100 lb. per square inch. The duplex low-pressure pump has 6-in. steam cylinders, 8-in. water cylinders and 6-in. length of stroke. The duplex boiler feed-pump has 3-in. steam cylinders, $1\frac{3}{4}$ in. double-acting piston pumps, all having a stroke 3 in. in length. The plant illustrated was fitted in a barge for supplying fresh water to steamers in an open harbour.

Another combination of vertical boiler and duplex steam pump, mounted on one bed-plate, is illustrated in Fig. 57.

The pumps are of the low-service "Gordon" duplex type, as manufactured by Messrs. Hayward-Tyler and Co., and supplied to the India Office. These pumps have steam cylinders 6 in. in diameter by 6-in. stroke, the water cylinders being $5\frac{1}{4}$ in. in diameter. One water cylinder of each pump is fitted with end-feed attachment for boiler feeding, against a pressure of 70 lb. per square inch.

The pumps are capable of delivering 6,000 gallons of water per hour, 100 feet above the source of supply, from a depth of 20 ft. below centre of pump.

The boiler is of the vertical cross-tube, 3 ft. 6 in. in diameter of shell by 9 ft. 2 in. in height of shell.

Reading water-works engine is shown in sectional elevation, Fig. 58. This plant consists of a triple expansion, high-duty surface condensing Worthington pumping plant, manufactured by Messrs. James Simpson and Co., Ltd., of London. It is capable of raising 3,000,000 gallons of water in 24 hours, against a head of 120 feet, with a steam pressure of 150 lb. per square inch, and a piston speed of 125 ft. per minute.

The steam cylinders are arranged tandem fashion. The high-pressure cylinder is 11 in. in diameter, the intermediate 17 in. in diameter, and the low-pressure 30 in. in diameter. The main plungers are 16 in. in diameter, all having a stroke of 18 in.

The main steam and exhaust valves are of the semi-rotary or Corlis type, arranged so as to insure the perfect drainage of the valve chests and steam cylinders. The exhaust valves are operated by means of levers connected directly with a wrist plate, and so arranged that the motion of the piston rod on one side operates the exhaust valves of the opposite side. The main steam admission valves are attached to a floating fulcrum on the wrist plate mentioned above: the cut-off motion being given by a direct connection between the floating fulcrum and its own engine. By this means an absolute positive cut-off is obtained.

The high-duty attachment consists of two oscillating cylinders attached to each piston rod, and supported in the main frame. These cylinders are connected by pipes and are filled with oil, receiving from the main pump air-chamber the air-pressure increased in the desired proportion by means of an interposed differential accumulator. The plungers resist the advance of the piston-rod at the beginning of the stroke and assist it at the end. The action is substantially that of a fly-wheel.

The main pumps, two in number, are of the multiple valve type, having two internal plungers.

A surface condenser is placed on the delivery main, and all water pumped by the engine passes through it, the use of a circulating pump being thus avoided.

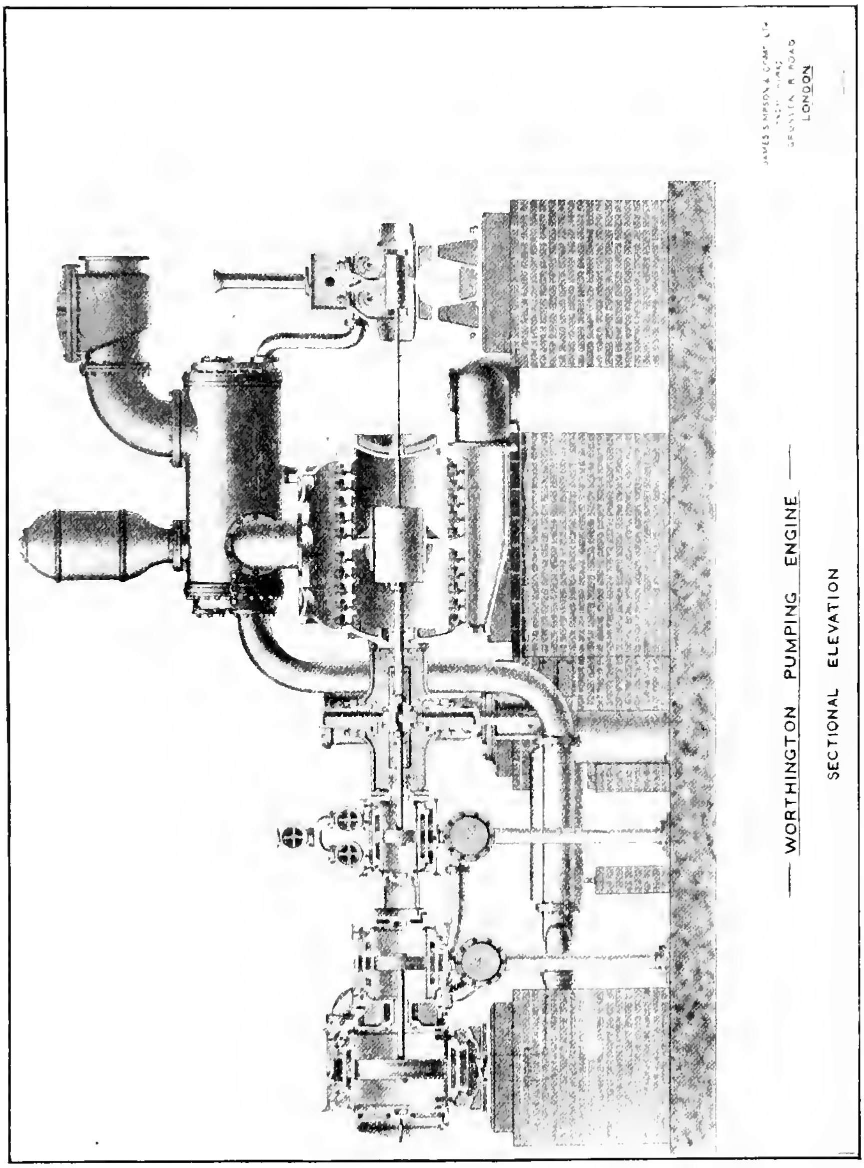


FIG. 58. WORTHINGTON ENGINE MADE BY MESSRS. JAS. SIMPSON & CO., LTD., LONDON.

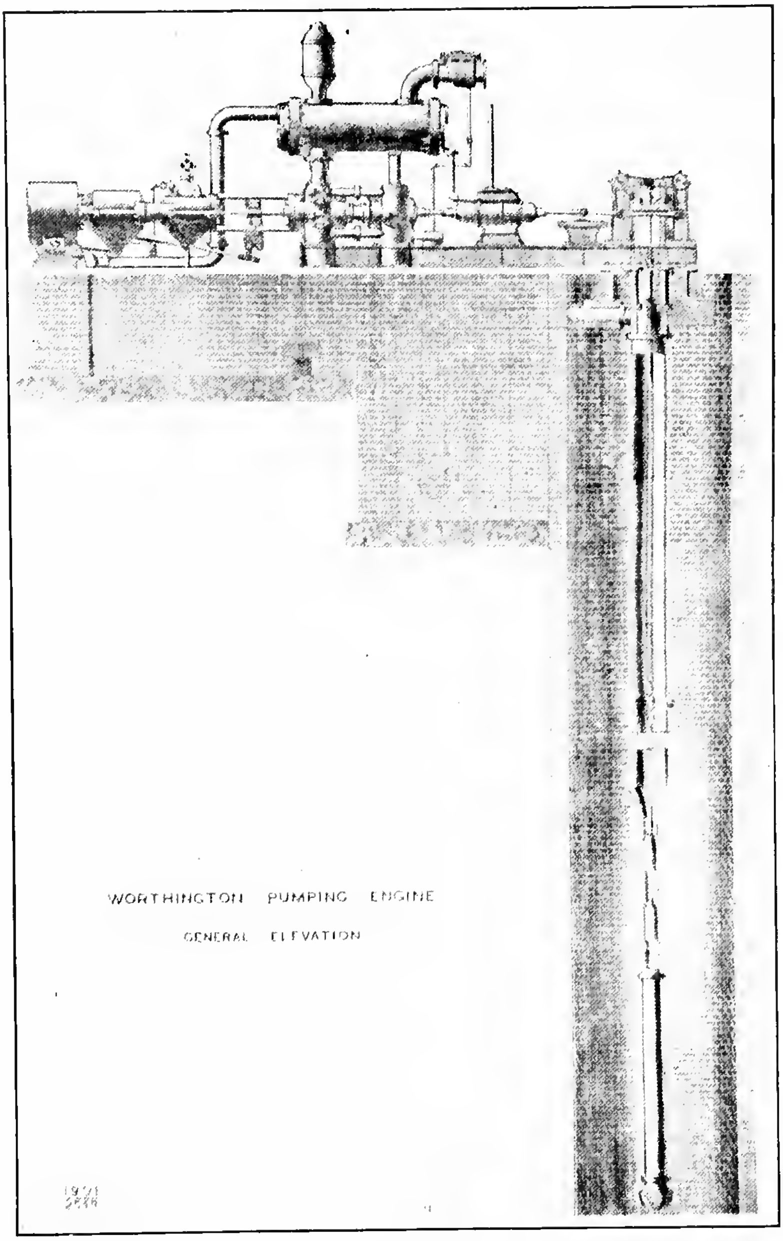


FIG. 59. WORTHINGTON PUMPING ENGINE MADE BY MESSRS. JAS. SIMPSON & CO., LTD., LONDON.

Frimley and Farnborough Waterworks, Itchell Well, is shown in Fig. 59. This plant, manufactured by the above firm, consists of two triple expansion horizontal surface condensing Worthington pumping engines, with two sets of pump work. Each engine is capable of raising 20,000 gallons of water per hour from a well 50 ft. deep, and forcing the same through three miles of 8-in. main to a static height of 400 ft. The boiler pressure employed is 120 lb. per square foot.

The steam cylinders are arranged tandem, with one high-pressure cylinder 8 in. in diameter, one intermediate 12 in. diameter, and one low-pressure 20 in. diameter on each side, the low-pressure cylinder being farthest from the high-lift pumps. The high-lift pumps are of the plunger type, 7¼ in. in diameter, which, like the cylinders, have 15 in. stroke. The low-lift pumps are of the bucket type, 8½ in. in diameter by 10 in. stroke.

All the cylinders are steam jacketed, covered with non-conducting composition and lagged with planished sheets.

The steam valve gear consists of two separate and distinct systems, viz., the main steam valve system and the expansion valve system. The former is operated by the cylinder on the opposite side of the engine and controls the steam inlet and exhaust, whilst the latter system is operated from the pistons of its own engine and controls the amount of expansion. The main steam valves are of the semi-rotary type and are arranged underneath the cylinders. The steam and exhaust valves are operated by directly connected levers, thus avoiding the uncertainties of eccentrics, gears, and cams. The amount of expansion in the high-pressure cylinder can be adjusted by hand while the engine is running.

A surface condenser is arranged on the delivery; the whole of the water passes through the body outside the tubes, whilst the exhaust steam passes inside the tubes on its way to the air pump.

The high-lift pumps are Worthington externally packed plunger pumps, double-acting on both suction and delivery, the pump valves being multiple spring-closed valves with gun-metal seats readily accessible and easily removed, replaced, and examined.

A small compact installation for pumping from a bore-hole erected at Kesteven Asylum, Lincolnshire, by Messrs. Hathorn, Davey and Co., of Leeds, is illustrated in Fig. 60. The engine is of the beam type, having a steam cylinder 10 in. in diameter by 2 ft. stroke. From the opposite end of the beam is worked a bucket-and-plunger pump, having a bucket 6½ in. in diameter and plunger 4½ in. in diameter by 3-ft. stroke, and a ram-pump 8 in. in diameter by 2-ft. stroke, the steam pressure being 80 lb. per square inch. This engine raises 5,000 gallons of water into a tank 20 ft. above the engine-house floor level. The delivery from the force-pump passes through the dome-topped casting which supports the beam. The upper part of the casting acts as an air-vessel, while the surface condenser is placed in the lower part. The pumps deliver on both up and down stroke, the ram at the top being half the area of the bucket. The steam-valve gear is of Mr. Henry Davey's well-known "differential" type. The whole of the engine is self-contained, on a cast-iron bedplate, which rests on a concrete bed at the top of the bore-hole.

2. Rotative Steam Pumping Engines.

A pumping engine constructed for the Leicester Corporation Waterworks for raising 10,000 gallons of water per hour, against a head of 60 ft., from a well 20 ft. deep, manufactured by Messrs. Hayward-Tyler and Co., is shown in Fig. 61.

This engine is of the vertical fly-wheel type, having two cylinders 9 in. in diameter by 9-in. stroke, placed over-

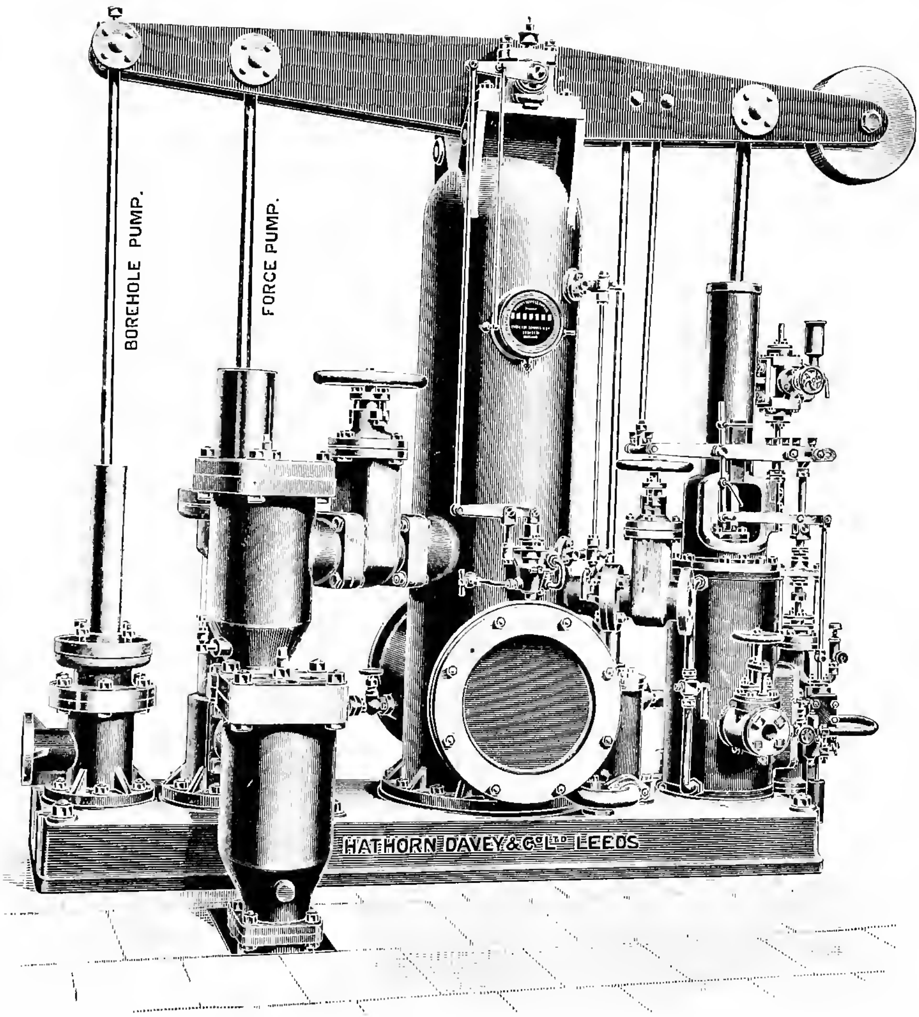


FIG. 60. BOREHOLE STEAM PUMP—BEAM TYPE.

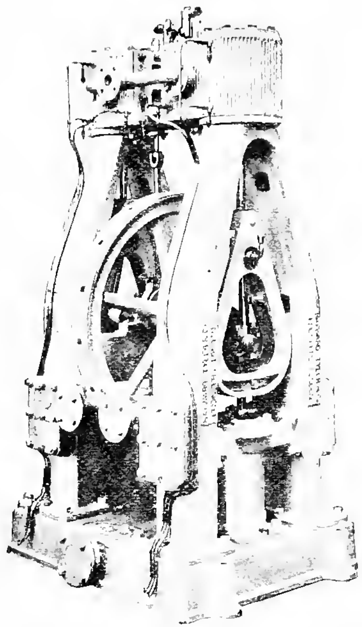


FIG. 61. VERTICAL FLYWHEEL STEAM PUMPING ENGINE.

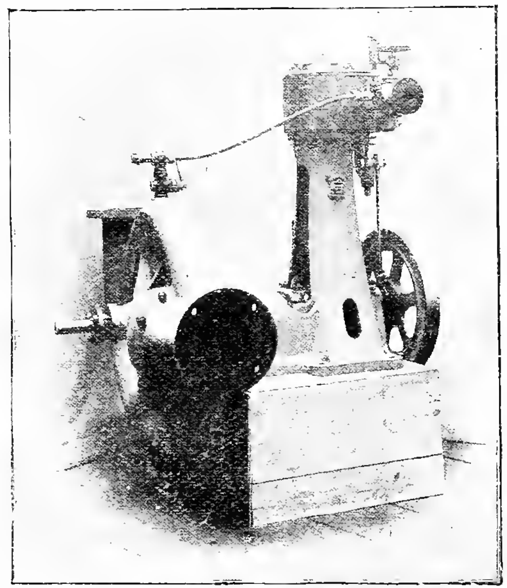


FIG. 62. GWYNNE'S STEAM-DRIVEN CENTRIFUGAL PUMP.

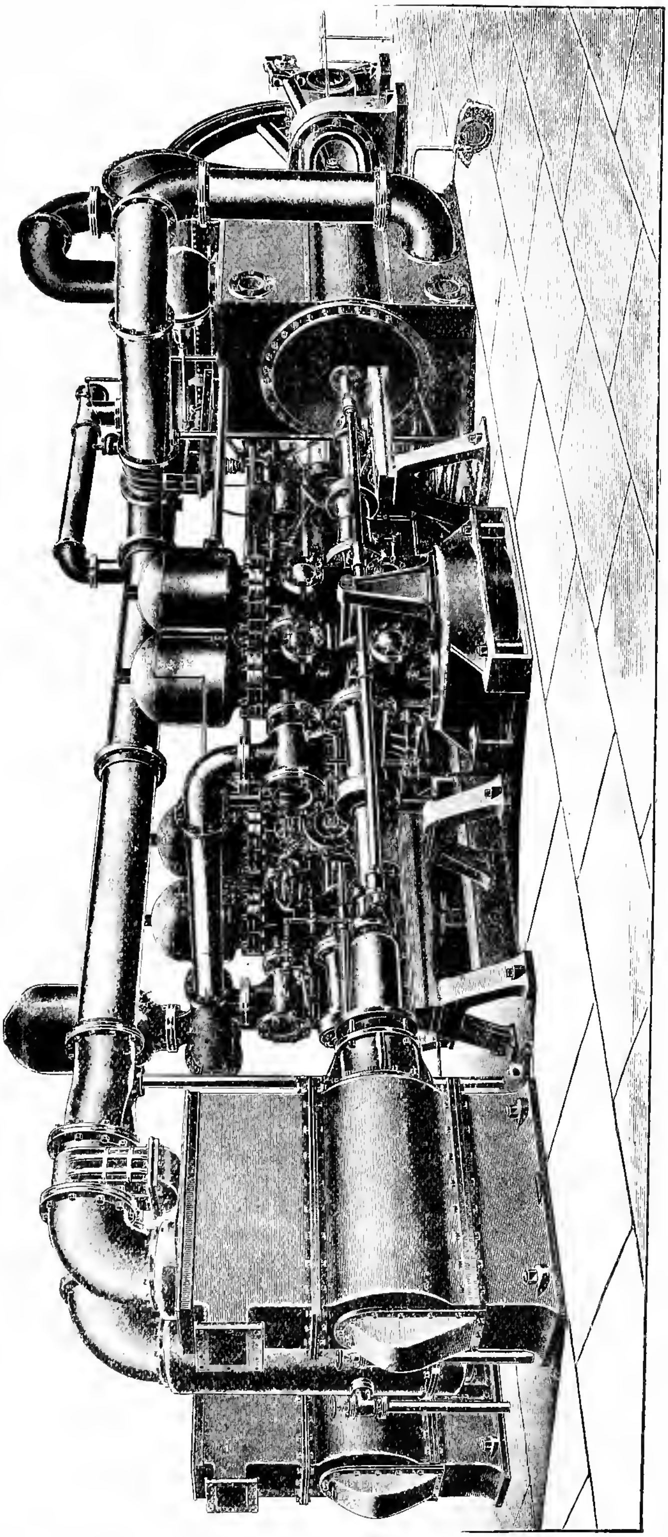


FIG. 63. FRASER & CHALMERS' CROSS COMPOUND PUMPING ENGINE FITTED WITH RIEDLER PUMPS.

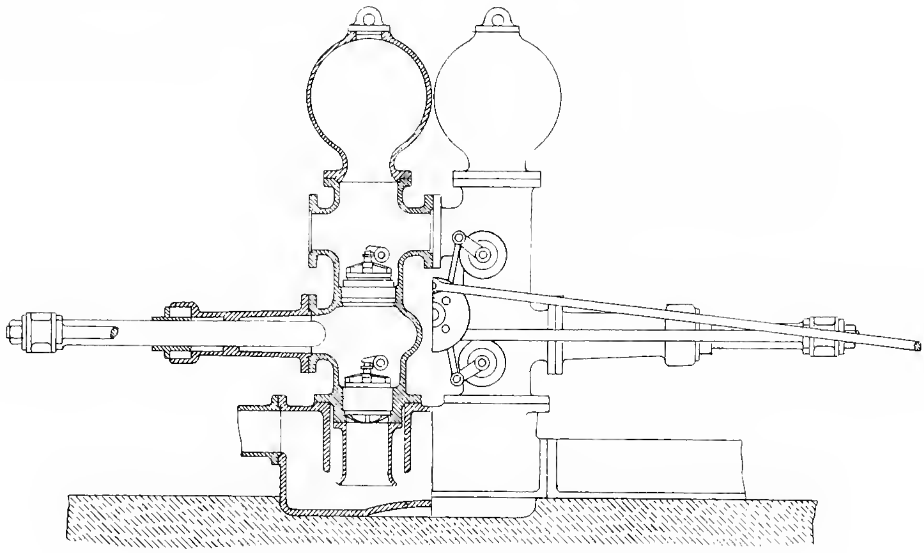


FIG. 64. PART SECTIONAL ELEVATION OF RIEDLER PUMPS.

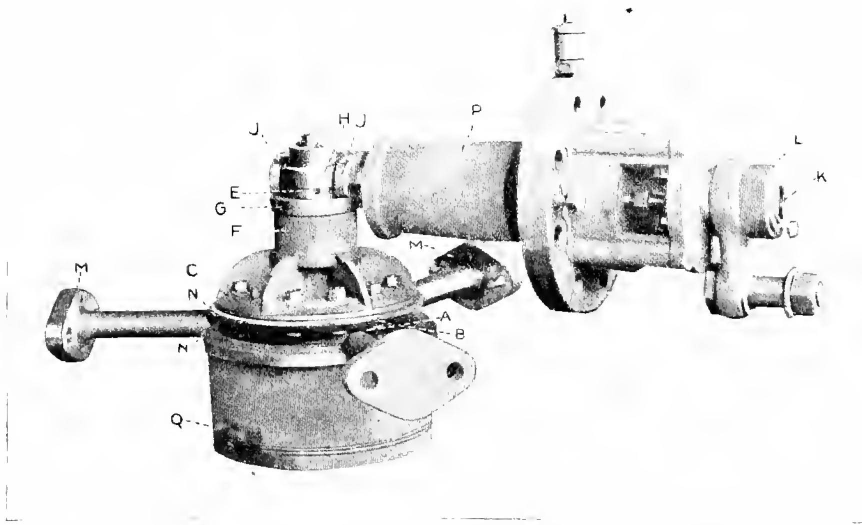


FIG. 65. VIEW SHOWING "RIEDLER" VALVE PARTS ASSEMBLED.

head, working two bucket-pumps, having buckets 7 in. in diameter by 9-in. stroke. The pump barrels are lined with gun-metal. The buckets are fitted with cup-leathers. The valves are of gun-metal, disc type, with gun-metal seats, and brass springs for rapid closing. The steam piston-rods and the pump-rods are connected by a kite, which is coupled to the crank pin by means of a short connecting-rod. The pump valves are arranged in the standards which carry the cylinders.

Fig. 62 illustrates an "Invincible" centrifugal steam-driven pump, as manufactured by Messrs. Gwynnes, Ltd. It is provided with the Gwynne-Sargeant patent balanced tubular disc, which permits of exceptionally large solids, compared with the area of suction and delivery pipes, passing through the pump. Every part is of great strength, and the arrangement of the inside is such that the cutting action of the slime is reduced to a minimum.

The pump is secured to the end of the vertical engine frame in such a manner that it can be swivelled and the suction and delivery can therefore be placed at any angle.

Messrs. Fraser and Chalmers, of London and Erith, England, supplied the engine shown in reproduction Fig. 63, and sectional elevation of the pumps, Fig. 64, to the Powell Duffryn Steam Co., in June, 1897. This engine is of the Cross compound type, fitted with Riedler pumps behind each cylinder. The high-pressure cylinder is 30 in. in diameter, and the low-pressure 57 in. in diameter, both having a stroke of 48 in. The plungers are $6\frac{7}{8}$ in. in diameter. The capacity of this pump is 1,000 gallons per minute, against a head of 1,600 feet, when running at 40 revolutions per minute, that is, a piston speed of 320 ft. per minute. When desired, either side is capable of being cut out, and the full duty can be done by the remaining side when running at 80 revolutions per minute, or a piston speed of 640 ft. per minute.

Both cylinders are jacketed with valve chambers cast in the body of the cylinders. The steam valves are single-ported in the high-pressure and double-ported in the low-pressure cylinder. The inlet valves are closed by spring dash-pots, the point of cut-off being controlled by a governor on the high-pressure side, by hand adjustment on the low-pressure side, or by governor when running that side only.

Both high- and low-pressure pistons are fitted with two rings and a lining of special babbit. A reheater receiver is mounted overhead and fitted with 3½-in. wrought-iron tubes, the steam passing through the tubes.

The feature of this pump is that all pipes are kept above the floor. On account of the bad nature of the ground a substantial framework was built of H beams and channels set on walls to carry this engine.

The governor is of the " Porter " or central-weight type, having adjustable weight, so that the engine can be controlled at any desired speed.

The pump barrels are of cast steel, suction and delivery valves and all the valve seats are of gun-metal, with an area of 58 square inches, through the valve seats. The valves are cone seated, fitted with leather seating rings. The delivery air-vessels are of steel.

One of the pumps is shown in sectional elevation, Fig. 64. There is only one suction and one delivery valve to each of the pumps, which are mechanically controlled, so that the valves work equally well under all pressures. The valve arrangement is shown in Fig. 65, on the left of which is the valve beat, the face for which is shown at *A*, the spindle of same terminating with a cap *H*. *B* is the valve proper. *F* is a rubber buffer fitted over the shank *G*, which in turn fits over the valve shank and is prevented from slipping off same by cap-nut *E*. That portion of the valve bonnet extending into the valve-chamber is shown at *P*. This bonnet contains the packing through which the spindle *K* passes, having on its end the forks *J*. Keyed to the spindle *K* is lever *L*, through which the spindle receives its motion from the pump wrist-plate. The bronze pins *M* have taper ends, which bear on the taper on edge of valve-seat, and hold the valve-seat down in position. *Q* is a groove used for hydraulic packing.

At the beginning of the suction stroke the valve opens automatically, controlled, however, by a mechanical device. Near the end of the stroke, the forks on the end of the shaft move downward, and before the plunger starts on its return stroke close the valve, thus preventing all slip and pounding of the valve so common in ordinary pumps.

It is well to note here that there is no metal-to-metal contact, as there is always a film of water over the faces of both valve and valve seat. It is these films that actually come in contact, thus practically forming at this point a water cushion; which not only aids in preventing pounding but greatly adds to the life of valves and seats.

In case of an obstruction between the valve and its seat, the rubber buffer will be compressed, thus preventing any injury to mechanism. The work required to close the valves amounts to very little, practically nothing more than the friction of the gear. This, as can be seen from the construction, is very small. The motion to the valve mechanism is obtained from an eccentric on main shaft through an intervening wrist-plate. The low-lift pumps at the back of the main pumps act also as air pumps, and deliver water pumped to a tank at the back of the engine-room, and from there the water is delivered to the main pumps. This avoids any chance of the main pumps drawing air, which might be dangerous under a high head. These air or low-lift pumps are single-acting, with 13 in. diameter of plungers, with gun-metal valve plates and special "Kinghorn" type of valves. The jet condensers are at the side of these air pumps, with the exhaust pipe leading into the top of them. The amount of water drawn through the condenser and air pumps is controlled by a float in the tank at the back.

The fly-wheel is 16 ft. in diameter, weighing about 16 tons, and a two-stage air-compressor is supplied to charge air-vessel, and in addition to these an independent one, steam driven, so that the air-vessel may be charged when the engines are standing.

Another Cross compound engine made by Messrs. Fraser and Chalmers, for Rockhampton Waterworks, Queensland, is illustrated in Fig. 66. The high-pressure cylinder is 14 in. in diameter, the low-pressure 24 in. in diameter, both having a stroke of 36 in. A double-acting plunger pump is fitted behind each cylinder, the pumps being of the Riedler type. The plungers are $7\frac{3}{4}$ in. in diameter, the capacity being 1,670 gallons per minute against a head of 205 ft., or maximum 252 ft., when running at 70 revolutions per minute, equal to a piston speed of 420 ft. per minute.

The duty guaranteed was 110,000,000 ft.-lb. per 1,000 lb. of dry steam, or 15 lb. per indicated horse power; steam pressure 101 lb. per square inch. The engine is fitted with a surface condenser and "Edwards" patent air pump.

The cylinders are steam jacketed, with valves in the body. The pump wrist-plate is driven from the same eccentric as the steam wrist plate. The cut-off gear is controlled by a Hartnell governor.

The fly-wheel is 12 ft. in diameter, weighing about 4½ tons. The piston-rods are fitted with "Tripp's" metallic packing. A reheater receiver is provided, fitted with 2½-in. wrought-iron tubes. There are two vertical single-acting "Edwards" air pumps, 10 in. in diameter by 18-in. stroke, fitted with "Kinghorn's" delivery valves. These pumps are connected direct to the tail rod of the high-pressure side.

An independent air charger is fitted to the delivery air vessel; it is of the Westinghouse type, which can also extract the air from the suction chamber when necessary.

In connection with the air pumps there are two boiler-feed pumps. The surface condenser is mounted overhead. The tubes are all of brass, having an area of 360 square feet. The water delivered from the Riedler pumps passes through the condenser and round the tubes, that is, between the tube plates.

The "Edwards" air pump is shown in sectional elevation, Fig. 67. The condensed steam, and in the case of jet pumps the injection water also, flows by gravity from the condenser into the base of the pump. It is there dealt with mechanically by the conical bucket, which, working in conjunction with a base of similar shape, projects the water silently and without shock, through the ports into the working-barrel. Free air inlets are maintained and the water, instead of obstructing the entrance

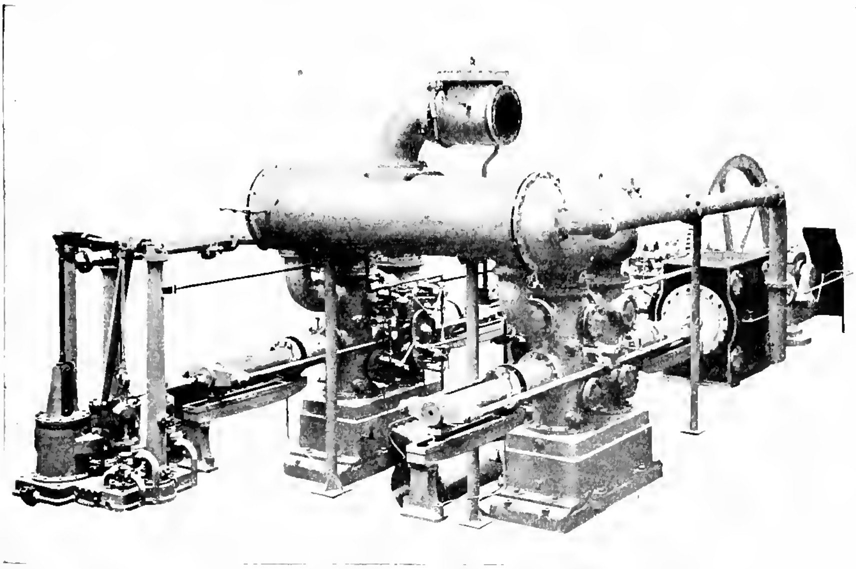


FIG. 66. FRASER & CHALMERS' CROSS COMPOUND ENGINE FITTED WITH DOUBLE-ACTING PLUNGER PUMP.

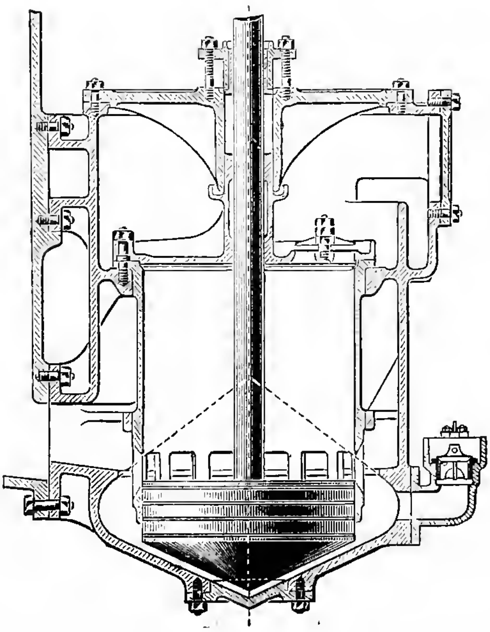


FIG. 67. SECTIONAL ELEVATION OF "EDWARDS" AIR PUMP.

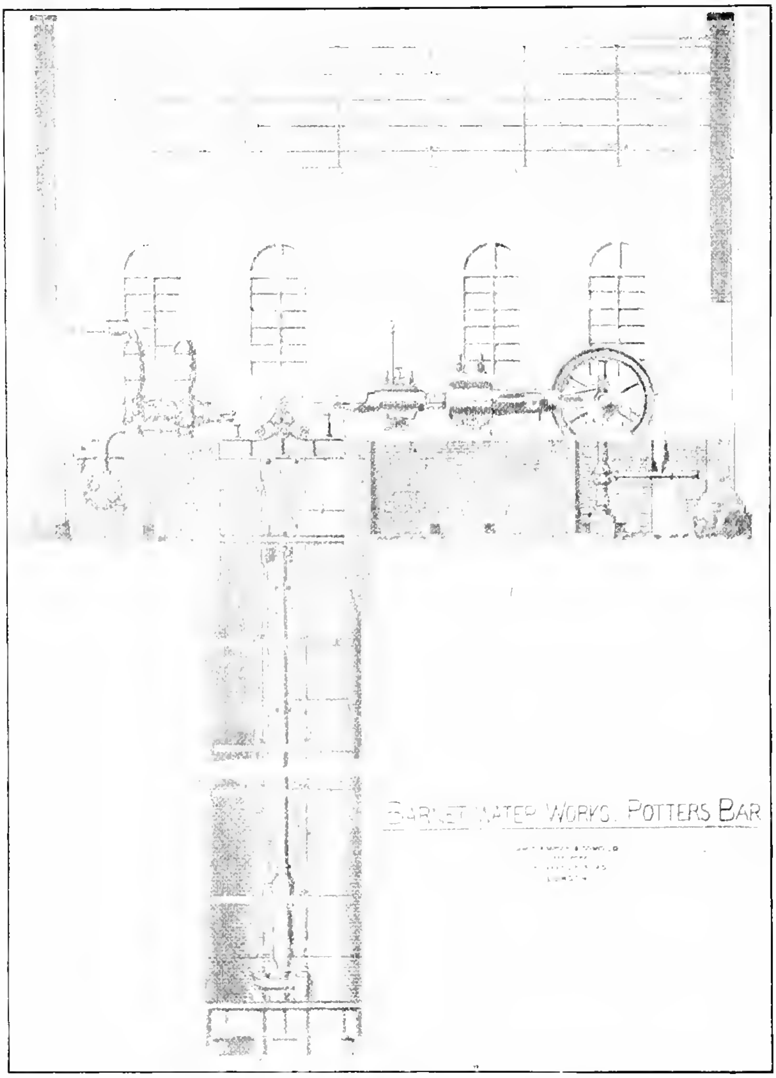


FIG. 68. HORIZONTAL TANDEM SURFACE CONDENSING ENGINE AND HIGH-LIFT PUMPS BY MESSRS. JAMES SIMPSON & CO., LONDON.

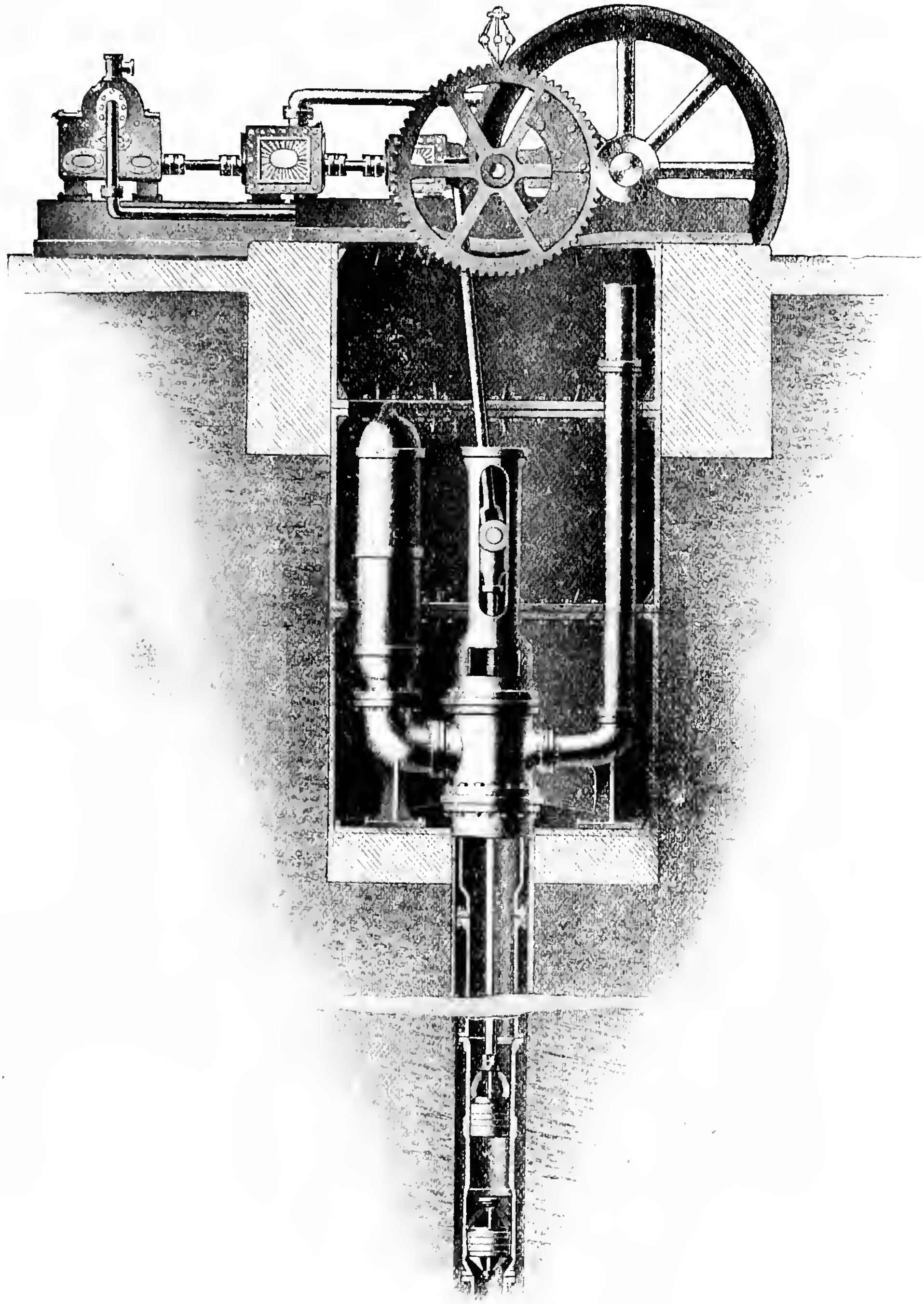


FIG 69 MATHER AND PLATT'S SINGLE-ACTING DEEP LIFT PUMP.

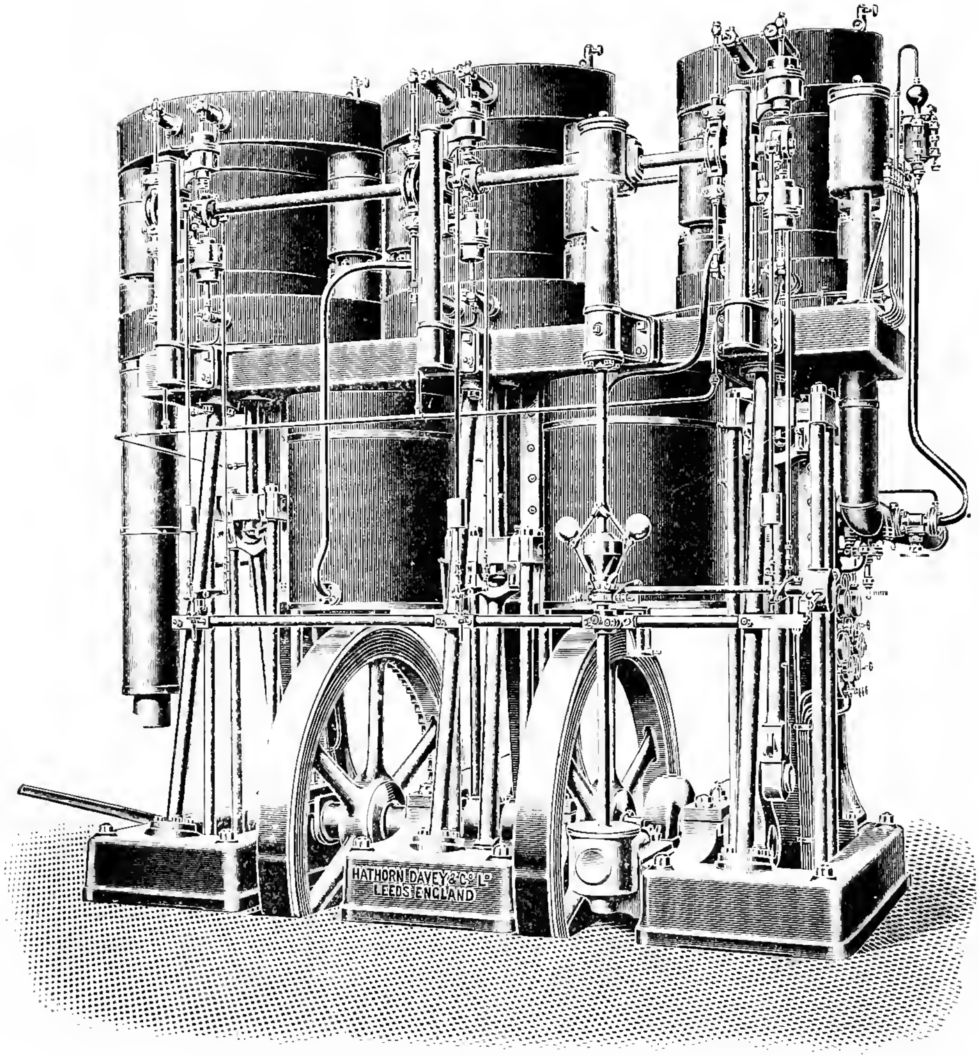


FIG. 70. TRIPLE-EXPANSION PUMPING ENGINE AT THE LEEDS CITY WATERWORKS.

of the air, as is the case in the ordinary type of pump, tends to compress the air already in the barrel, and to entrain or carry in more air with it. The clearance space above the piston at the top of the upward stroke is reduced to a minimum, thereby considerably increasing the efficiency of the pump. In the "Edwards" pump the speed of the water must correspond to the bucket, and is in no way dependent upon pressure in the condenser to drive it into the pump, consequently is not impaired as the speed is increased. It has a small and regular quantity of water to deal with at each revolution, and the violent shocks due to sudden flooding are avoided. There are no valves except the overflow valves at the top of the working barrel.

Barnet Waterworks machinery, represented in Fig. 68, was manufactured by Messrs. James Simpson and Co. The engine is of the horizontal tandem surface-condensing type, with two sets of pumps, capable of raising 500,000 gallons of water in 24 hours. The well-pumps raise the water from a depth of 325 ft. and deliver into a tank on the surface. The high-lift pump draws its water from this tank and delivers into the district supply main.

The high-pressure cylinder is $11\frac{1}{2}$ in. in diameter, and the low-pressure 24 in. in diameter, both having a stroke of 24 in. The deep well pumps are $10\frac{1}{4}$ in. in diameter by 18 in. stroke, and the high-lift pumps 11 in. in diameter, by $15\frac{1}{2}$-in. stroke.

The engine is of the Corlis frame type, the low-pressure cylinder being placed next the crank-shaft, with the high-pressure cylinder tandem to it. Both cylinders are bolted to a girder bed forming part of the foundation, and are connected by a central trunk casting.

Both high- and low-pressure cylinders are fitted with trip valve gear having circular double beat-drop valves. The valves are lifted and released by trip-levers actuated by eccentrics driven from a horizontal shaft rotating at the same speed as the crank-shaft, and running parallel to the engine-bed. The governor automatically controls the length of time the trip-levers are in contact, thus regulating the speed of the engine. The exhaust valves of both cylinders are of the double gridiron type, placed underneath the cylinders. In this way the draining is efficiently carried out.

The main frame is a heavy cast-iron frame, forming a bored guide for the piston-rod cross-head. The end projects into the cylinder, forming the front cover.

The engine is fitted with a surface condenser having solid drawn brass tubes fitted with stuffing-boxes having screwed gun-metal packing glands. Large doors in the condenser make the overhauling and repairing of the packings a very simple matter. The exhaust steam is led to the condenser by easy bends, passing inside the tubes on its way to the air pump ; whilst the whole of the water delivered by the well pumps passes through the condenser outside the tubes.

The high-lift pump is a horizontal externally packed plunger pump, double-acting on both suction and delivery and driven direct from a bell-crank, having a connecting-rod to the guided cross-head at the tail end of the piston-rod.

The well pumps are driven from the same bell-crank, the two top lengths of pump rods being attached to the cross-heads working in vertical guides. From these cross-head connecting-rods are carried the bell-cranks. The working-barrels are hung from the pump heads, and form part of the rising main. This enables them to be drawn up at any time for examination or repair with the greatest ease.

A trial was held on this engine, the duty obtained being 114,000,000 foot-lb.

In Fig. 69 is depicted a single-acting deep-lift pump, designed by Messrs. Mather and Platt, Ltd., for raising water from bore-holes. The engine is of the horizontal compound type, the pump crank-shaft being driven by means of a spur wheel and a pinion secured on the engine crank-shaft. The working-barrel, fitted with a foot valve, is placed well below the lowest level in the bore-hole. Both the bucket and the foot valves are of the quadruple beat class, permitting a very small lift of the valve, thus reducing the concussion and wear to a minimum.

A triple-expansion pumping engine, built by Messrs. Hathorn, Davey and Co., Ltd., for the Leeds City Waterworks, is illustrated in Fig. 70. The high-pressure cylinder has a diameter of 15 in., the intermediate 25 in., and the low-pressure cylinder 40 in. in diameter, all having a stroke of 36 in., the mean ratio of the cylinders being 1, 2·80, 7·33. The crank sequence is intermediate-, high-, low-pressure. The steam valves on the cylinders are "Corlis" valves in the cylinder heads, with a very simple trip gear. The trip gear of the high-pressure cylinder is controlled by a centre-weight governor. The trip gear of the other cylinders is ordinarily set to a fixed cut-off, but is variable by hand adjustment. The cylinders are steam jacketed—the high and intermediate with boiler steam, and the low-pressure with steam of 50-lb. pressure per square inch. There are jacketed receivers between the intermediate- and low-pressure cylinders, the former having a capacity of 16·3 cubic ft., the latter 20 cubic ft.

Each engine has three single-acting ram pumps, with numerous valves of small diameter fitted with rubber faces. The pump discharge is therefore very uniform.

The contract conditions specified that the engine under full head should pump one and one-third million gallons in 12 hours, with a steam consumption not exceeding 16 lb. per pump horse power per hour.

The engine is working against an actual head of 286·9 ft.

Professor W. Cawthorne Unwin, F.R.S., on November 11, 1899, tested this engine, the trial lasting 24 hours, which gave the actual duty of 125,350,000 foot-lb. per 112 lb. of coal.

In this trial the efficiency of the boiler was not good, and the duty, which depends on the performance of the boiler and engine, was not so good as it would have been if steam had been supplied by a more efficient boiler. With a good boiler, hand-fired with Welsh coal, the evaporation might well have been 9·5 lb. per pound of coal. Then the coal consumption would have been 240·8 lb. per hour. In that case the duty would have been 154,350,000 foot-lb. per 112 lb. of coal.

In America it is common to reckon the duty of pumping engines as the effective work per 1,000 lb. of steam supplied to the engine. Taking this measure, the duty of the engine is 151,670,000 foot-lb. This is almost as high a duty as has been recorded. It involves no assumption as to the performance of the boiler.

There are two boilers of the Lancashire type, 28 ft. in length by 7 ft. 6 in. in diameter, each having two flues 3 ft. in diameter, taper to 2 ft. 6 in. at the back end, with four cross-tubes in the flues. Each boiler is fitted with Bennis' sprinkling stoker. The grate area is 36 square feet and the heating surface is 850 square feet. A Green's economiser is arranged in connection with the boilers, consisting of 128 tubes, having a heating surface of 1,280 square ft.

We will now notice a new style of deep-well pump, invented by Mr. Herbert Ashley, engineer at the Waterworks, manufactured by Messrs. Glenfield and Kennedy, Ltd., Kilmarnock, Scotland, and illustrated in Fig. 71. It is suitable for wells, bore-holes and mines. The pump illustrated has a bucket 20½ in. in diameter, by a stroke of 3 ft. 6 in., and was made for the East London Waterworks, of London, to the order of William B. Bryan, Esq., M.Inst.C.E., chief engineer. Four of these pumps stand upon the bottom of a well 200 ft. deep, and lift their water to the surface of the ground only, while two stand in another well of similar depth, and are fitted with plungers to lift their water to a height of 80 ft. above the surface of the ground, a total lift of 280 ft.

A perfectly plain working-barrel stands on the bottom of the sump a few feet below the level of the floor of the collecting adit. In this particular example it is built up in three pieces, bored inside, in which the upper turned end of the bucket reciprocates; the middle piece, also turned internally, within which the lower turned end of bucket reciprocates; and the lower piece, which closes the end of the working-barrel and also forms the necessary base piece for the pump columns to stand on. The middle piece is furnished with the suction openings—perfectly free and open and uncontrolled by valves of any kind. These openings are so placed that the turned ends of the bucket never obscure them. These three pieces are flanged and bolted together, and so placed in the well that the top of the suction openings are sufficiently below the lowest level to which the water is ever pumped, so as to prevent air being sucked in. The construction of the working-barrel is very simple. There is no clack-box or snore-piece, and everything is so compact that it is found possible to place these pumps with centres only three feet apart.

The bucket may be described as a hollow cylinder, somewhat greater in total length than the stroke of the pump. The two ends of the bucket are accurately turned to fit the two bored portions of the working-barrel, the upper end reciprocating in its upper bored portion above the suction openings and the lower end in its lower bored portion below the suction openings. Between the two turned portions the bucket is reduced in diameter, forming waist, which is made hexagonal or square in section for convenience. The upper end of the bucket is precisely similar to an ordinary bucket, and carries the delivery valve of any desired pattern. The lower end is quite free and open. In the waist of the bucket are secured circular valve-seats containing the suction valves, opening inward, of which any desired number may be put in. Both the working-barrel and the bucket are in all cases placed in the same relative position to the other parts of the machinery as the working-barrel and bucket of an ordinary bucket pump.

The action of the pump is simple. On the up-stroke the delivery valve is closed and water is lifted. At the same time the suction valves open and the water pours into the interior of the bucket and lower part of the working-barrel. Upon the down-stroke the delivery valve opens and the suction valves close, and the bucket sinks to the bottom, ready to commence another up-stroke, and so on.

In Fig. 72 is illustrated a set of three-throw plunger pumps for raising 30 litres per second (396 gallons per minute) to a height of 60 metres (196·8 ft.) high, with 6 metres (19·68 ft.) of suction. The plungers are 10 in. in diameter, having a stroke of 18 in. The set is driven by means of spur-wheel and pinion from one of Messrs. Robey, Ltd., Lincoln, England, undertype jet-condensing engines and feed-water heater. The steam boiler is of the ordinary locomotive type. The air pump is driven by the tail rod of one of the steam cylinders.

The pumps were manufactured by Messrs. Hayward-Tyler and Co.

The same firm has also supplied similar sets having

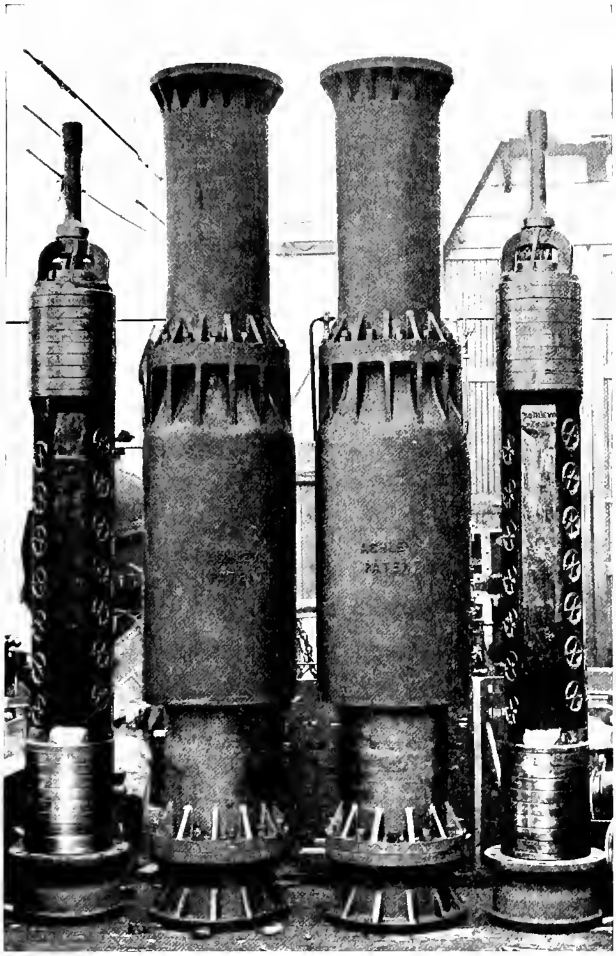


FIG. 71. THE "ASHLEY" DEEP WELL PUMP.

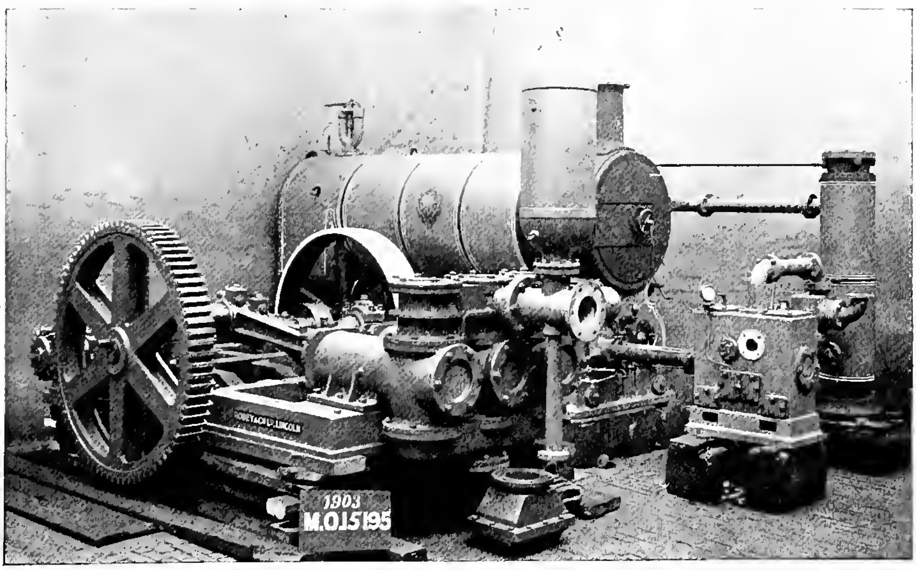


FIG. 72. PUMPING SET OF THREE-THROW PLUNGER PUMPS, LOCO BOILER AND UNDERTYPE JET CONDENSING ENGINES.

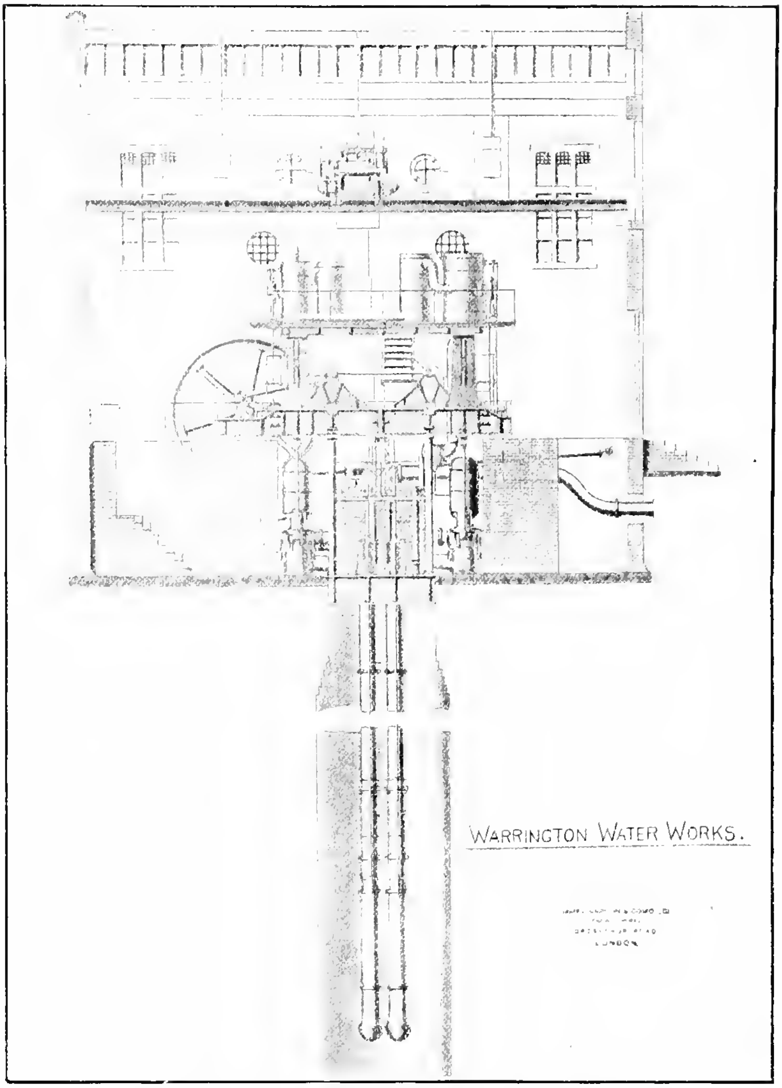


FIG. 73. TRIPLE-EXPANSION SURFACE CONDENSING RECEIVER ENGINE WITH DEEP WELL AND SURFACE PUMPS BY MESSRS. JAMES SIMPSON & CO., LTD., LONDON.

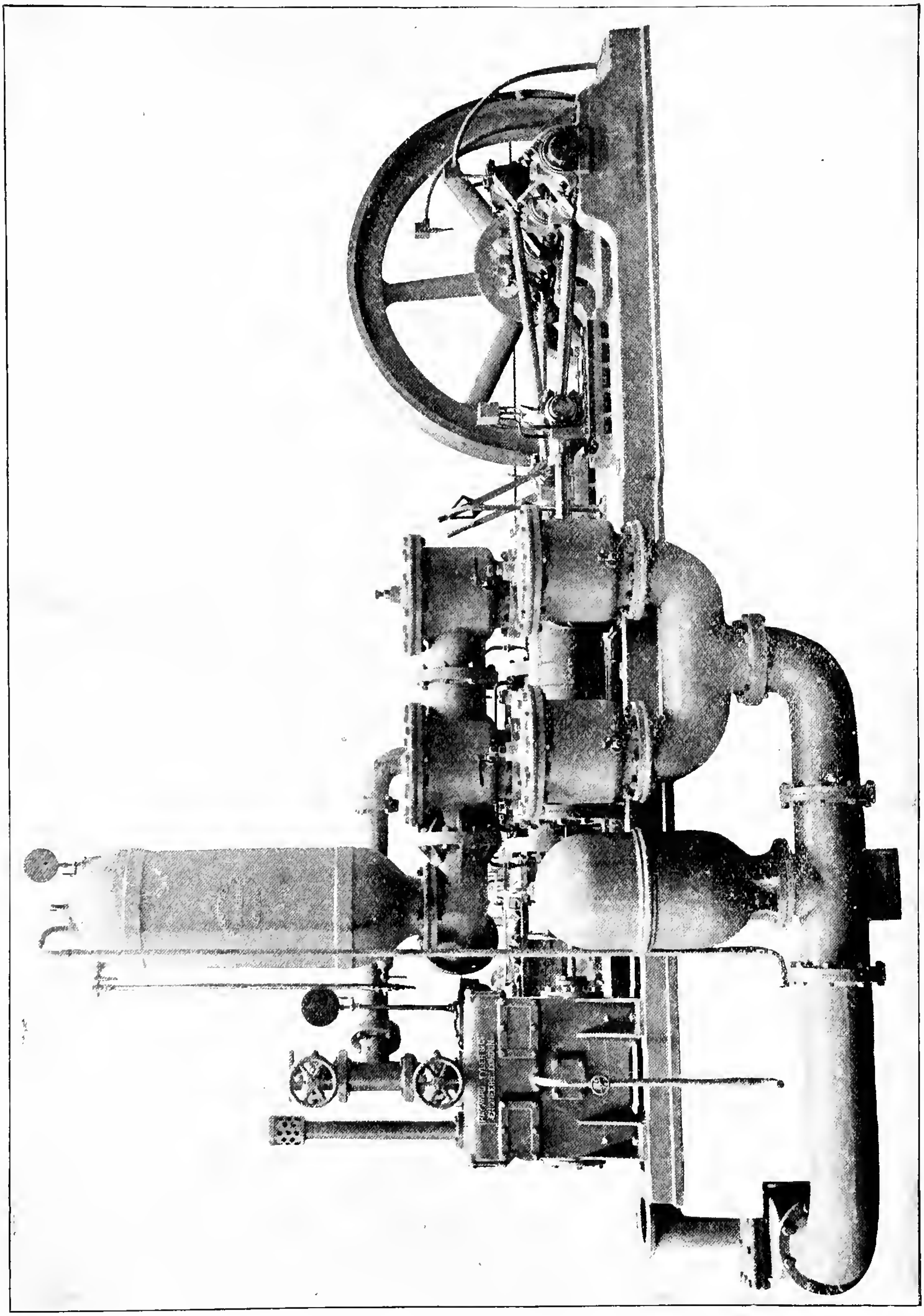


FIG. 74. HIGH PRESSURE, JET CONDENSING FLYWHEEL PUMPING ENGINE.

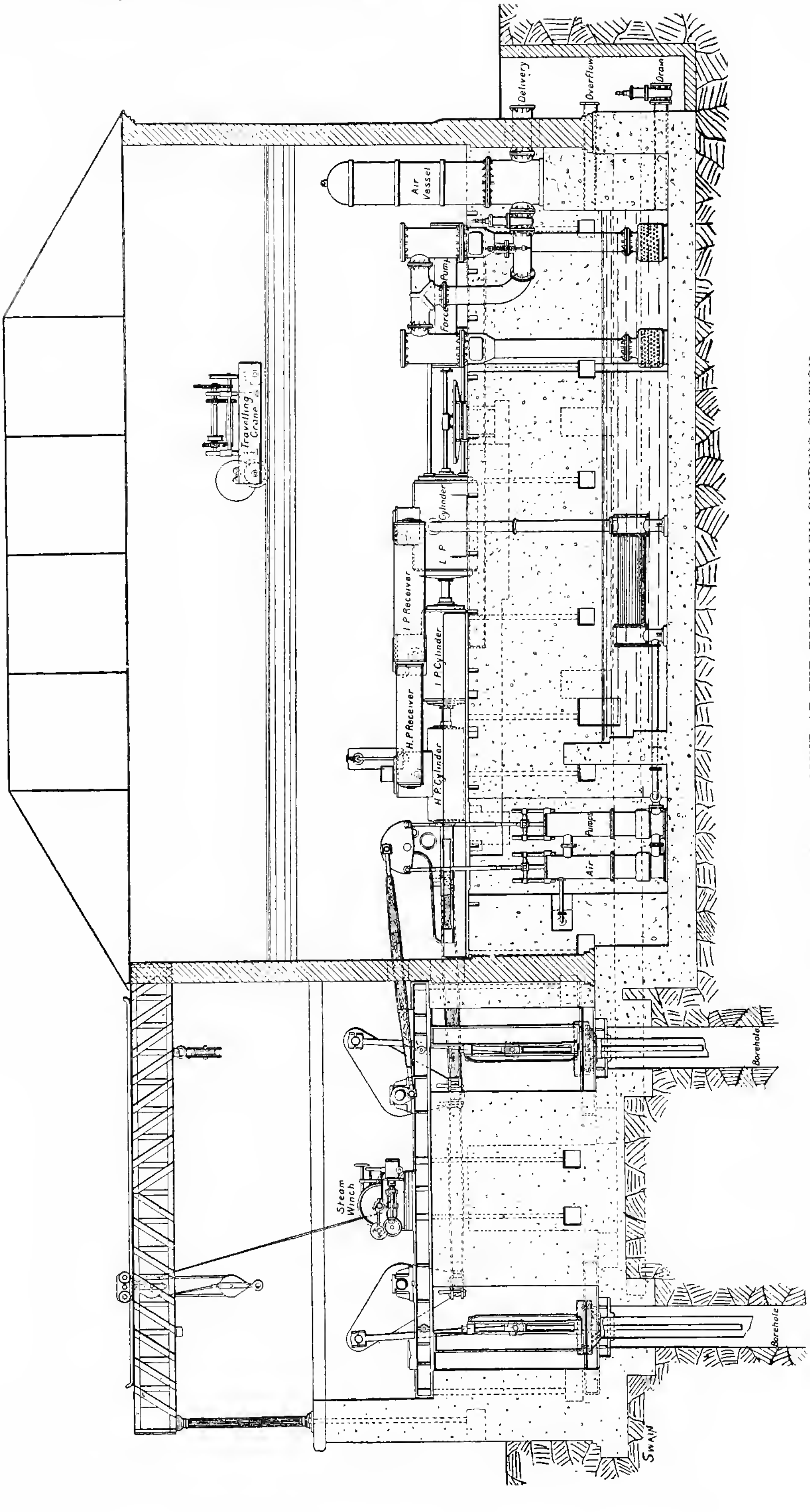


FIG. 75. TRIPLE-EXPANSION PUMPING ENGINE AT THE TRENT VALLEY PUMPING STATION.

plungers 13 in. in diameter by 18 in. length of stroke, to raise 790 gallons of water per minute to a height of 202 ft.

Warrington Waterworks, Delph Lane pumping station engines are illustrated in Fig. 73. This plant, manufactured by Messrs. James Simpson & Co., Ltd., of London, consists of a rotative triple-expansion surface-condensing receiver engine with deep-well and surface pumps. The engine is capable of pumping 3,000,000 gallons of water in 24 hours, against a total head, including friction, of 236 ft.

The high-pressure cylinder is 13 in. in diameter, the intermediate $22\frac{1}{2}$ in. in diameter, and the low-pressure 35 in. in diameter, the well bucket pumps 18 in. in diameter, and the surface plungers $17\frac{3}{4}$ in. in diameter, all having a stroke of 42 in.

The three cylinders are placed vertically, the high and intermediate being jacketed with boiler steam and the low-pressure with steam at 80 lb. per square inch through a reducing valve, the working boiler pressure being 160 lb. per square inch.

Two equilibrium receivers, fitted with tubes under boiler pressure to act as reheaters, are placed between the cylinders, the circulation in these and in the jackets being in a closed circuit.

All the cylinders are fitted with cut-off gear, that in the high-pressure being under the control of a speed governor, so arranged that if the speed of the engine varies abnormally the valves are thrown out of action and left covering the steam inlet ports, while at the same time a valve on the condenser is opened, destroying the vacuum.

The cut-offs on the low- and intermediate-pressure cylinders are adjustable by hand while the engine is running. Each individual valve is driven direct from central wrist plates by rocking levers, which are actuated by eccentrics on a counter-shaft running at the same speed as the crank-shaft and driven off it by mitre gear.

Both the high-lift and well pumps are driven through double bell-cranks and coupled together, the whole being carefully balanced.

The well pumps consist of two single-acting bucket pumps working opposite. The working-barrels are hung from the pump-head and form part of the line of rising main, so that the suction valves can be readily drawn up for examination or repair. At the pump-heads the rising mains discharge into one delivery main, which is carried into a tank on the surface.

The high-lift pumps are two vertical externally packed plunger pumps, double-acting on both suction and delivery. They draw their water from the tank into which the well pumps deliver, and discharge through the surface condenser direct into the delivery main.

A horizontal high-pressure, jet-condensing fly-wheel pumping engine, constructed for the Hitchen Urban District Council by Messrs. Hayward-Tyler and Co., is illustrated in Fig. 74. The cylinders are 12½ in. in diameter, by 24-in. stroke, and the double-acting piston pump is 10½ in. in diameter by 12-in. stroke. The capacity of the engine is 25,000 gallons per hour, against a total head of 150 ft., at an engine-speed of 200 ft. per minute and pump-speed of 130 ft. per minute. An air-vessel is placed both on the suction and delivery pipe. The air pump is of the double-acting piston type, worked by the tail rod of one of the steam cylinders. The valve boxes are bolted on to the pump cylinder, so that in case of an accident only a part of the pump has to be renewed.

The Trent Valley Pumping Station, belonging to the South Staffordshire Waterworks, is shown in side elevation, Fig. 75. It was built, under the superintendence of the Company's engineer, Mr. Ashton Hill, and assistant, Mr. A. E. Douglass, by Messrs. Hathorn, Davey and Co., Ltd.

The engine is of the horizontal triple-expansion type, having high-pressure cylinder 20 in. in diameter, intermediate-pressure cylinder 30 in. in diameter, and low-pressure cylinder 44 in. in diameter, all with a stroke of 5 ft. These cylinders are arranged tandem fashion, and actuate a pair of bore-hole pumps, each $15\frac{1}{2}$ in. in diameter, and a force pump $15\frac{3}{4}$ in. in diameter, all having a stroke the same as the engine. The bore-hole pumps are placed at a depth of 300 feet from the surface, but the yield of the bore-holes has proved so plentiful that the water level is only 67 feet from the surface. The engine was built for a head of 160 ft. on the force pump, but owing to exigencies of the water company, has for some time been delivering against a head of 325 ft., or more than twice that for which it was designed.

The engine is fitted with Mr. Davey's differential gear. This gear operates the steam valves of the engine, and is driven by water taken from the rising main, so that in case of a burst pipe the gear is thrown out of action and the steam valves closed. As an additional precaution, a throttle valve is placed on the steam pipe which, usually full open, is arranged to close automatically, either in the event of an excessive or too low pressure in the delivery mains. The engine is also fitted with a pausing gear, so that the speed can be at any moment regulated from two to fourteen strokes per minute to suit the demand of water for the time being.

The buckets and clacks are of the double-beat type. The bucket seatings consist of a gutta-percha ring of rectangular section, and it is found that both buckets and clacks run night and day for about twelve months without alteration.

The force pump, which is of the double-acting piston type, is fitted with valves of the same class as those of the bucket pumps, and with engines of this type, having a distinct pause between each stroke, these valves are found to work well.

The horizontal motion of the engine into a vertical motion of the pump buckets is obtained through Davey's high-duty attachment, which consists of a pair of angle quadrants, having the pins to which the engine and pump connecting-rods are attached so placed relatively to each other that in each stroke the engine pistons obtain a mechanical advantage over the pump bucket as the stroke is made, thus permitting a high degree of expansion without the introduction of special appliances or heavy moving parts.

This engine was tested by Mr. Douglass, the result being a duty of 122,900,000 per 1,120 lb. of steam used.

One of two sets of pumping machinery constructed by Messrs. Hayward Tyler and Co., to the order of the War Office for the water supply of hutments in Pretoria, is illustrated in Fig. 76. This plant consists of a set of treble-barrel force pumps having plungers 10 in. in diameter by 18-in. stroke. Each set is capable of raising 20,000 gallons of water per hour against a head of 450 ft. They are driven by horizontal coupled compound surface-condensing engines, having high-pressure cylinders $14\frac{1}{4}$ in. in diameter, and low-pressure cylinders $24\frac{1}{2}$ in. in diameter, both having a stroke of 32 in., running at a speed of $27\frac{1}{4}$ revolutions per minute, with a boiler pressure of 125 lb. per square inch. The engines are fitted with Meyer's variable cut-off expansion gear, and have fly-wheels 10 ft. 6 in. in diameter by 18-in. face. The surface-condenser is connected with the suction pipe of the pumps, with a by-pass and injection valve. The air pump is of the bucket-and-plunger type, worked by levers from the cross-head, as also the feed-pump.

A vertical steam engine working a double-cylinder rotary pump, termed a "Drum" pump, is illustrated in Fig. 78 and a cross-section of the pump, Fig. 77. It consists of a revolving piston *A*, moving round the drum *C*, a vacuum forming, into which the water flows from behind, and is forced by the front face of the piston. The piston *A* and the drum *C* are geared together, and the pump can be driven either way. This is a very great advantage when thick liquids or semi-liquids are dealt with, as the suction pipe can, by reversing the action, be made into delivery and emptied of the liquid. *E* is the suction and *F* the delivery branches, or vice versa, according to

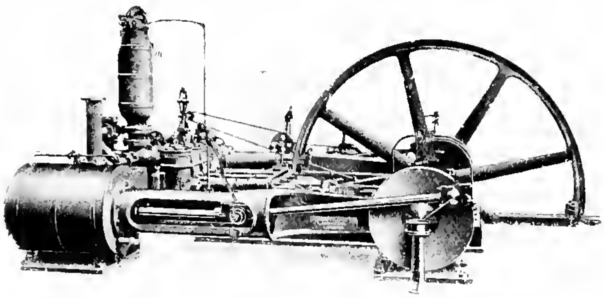


FIG. 76. COMPOUND SURFACE CONDENSING ENGINE DRIVING TREBLE-BARREL FORCE PUMPS.

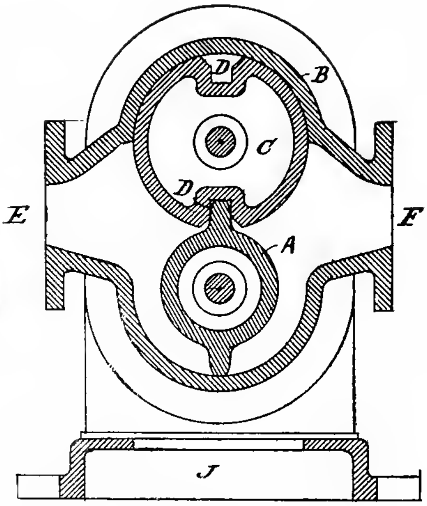


FIG. 77. CROSS-SECTION OF DOUBLE CYLINDER ROTARY PUMP.

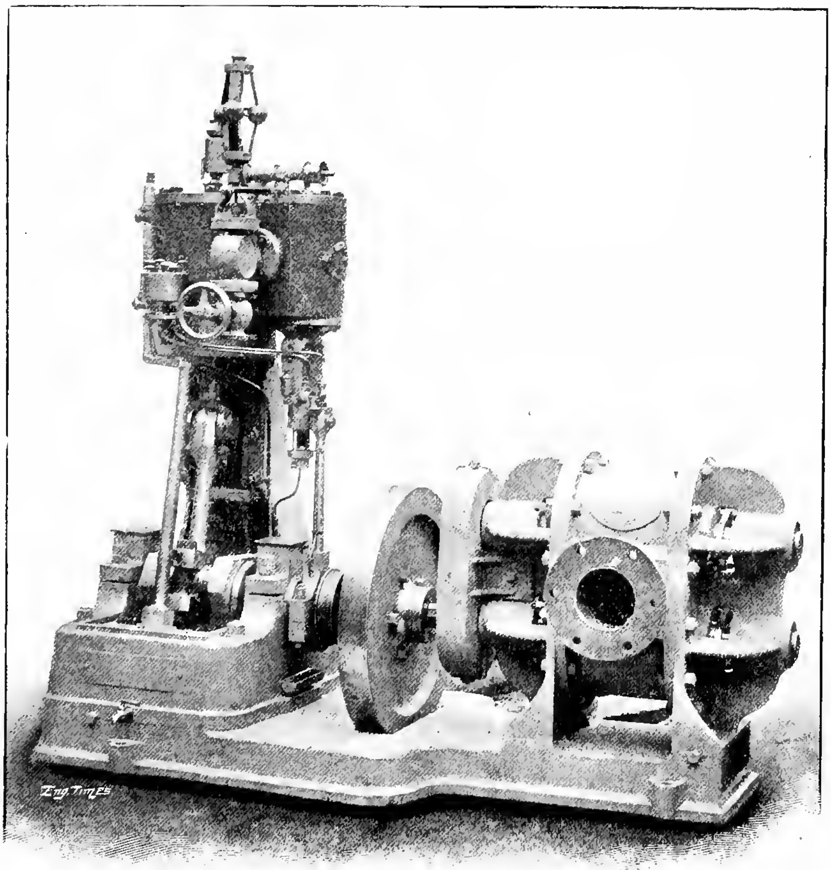


FIG. 78. DOUBLE CYLINDER ROTARY "DRUM" PUMP.

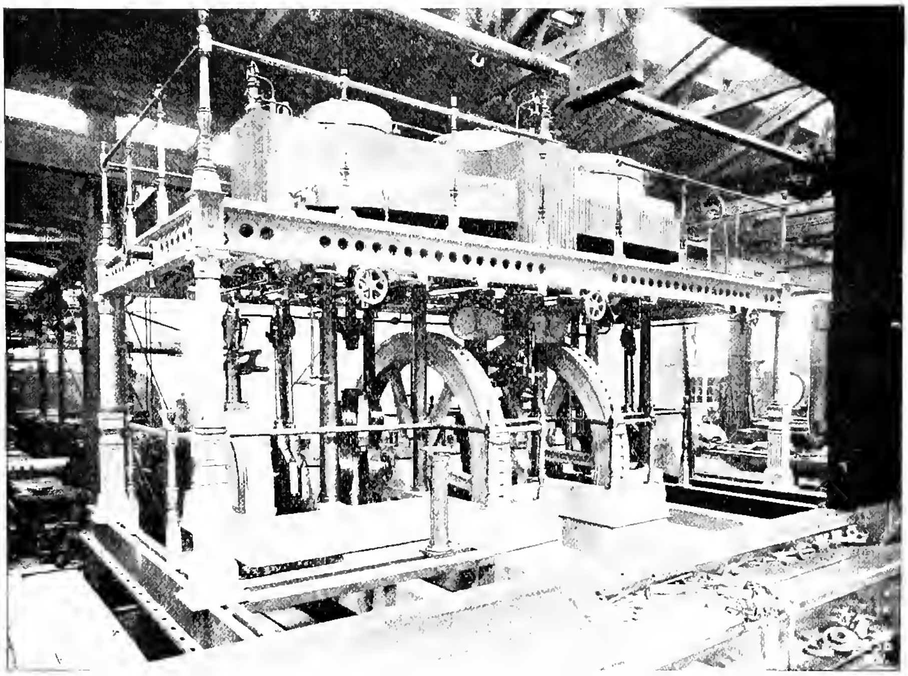


FIG. 79. TRIPLE-EXPANSION PUMPING ENGINES AT THE LEICESTER CORPORATION WATERWORKS.

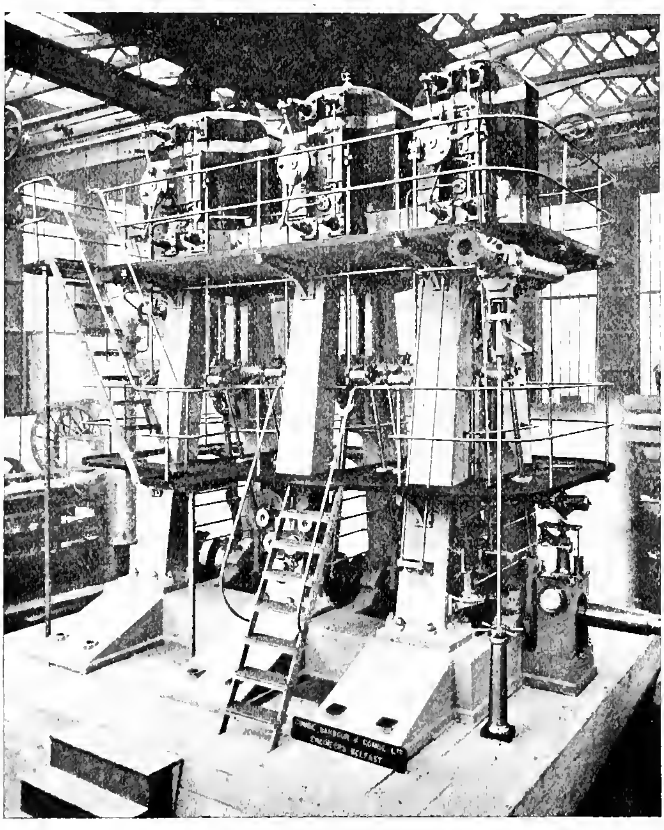


FIG. 80. TRIPLE-EXPANSION PUMPING ENGINE AT THE NOTTINGHAM CORPORATION WATERWORKS.

the way the pump is running. *J* is the bed-plate, on to which the engine and pump are secured.

This pump is very useful for boiler feeding or for forcing water against moderate pressures. The delivery is continuous and steady.

The engine is designed for quick and continuous running, and is fitted with "Pickering's" patent governor, self-acting lubrication, and a massive fly-wheel. This pump is manufactured by the Drum Engineering Co., Bradford, England.

The Leicester Corporation Waterworks pumping engine at Swithland Reservoir Pumping Station, is illustrated in Fig. 79. This engine is of the vertical triple-expansion type, built and erected by Messrs. Combe Barbour, branch of Fairbairn, Lawson, Combe, Barbour, Ltd., Belfast, Ireland. It has a high-pressure cylinder 17 in. in diameter, intermediate cylinder 27 in. in diameter, and a low-pressure cylinder 44 in. in diameter, all having a stroke of 3 ft. The cylinders are steam jacketed, and the engine is fitted with Corlis valves placed in the cylinder heads. The normal speed of the engine is 25 revolutions per minute. Each cylinder works a plunger-pump direct, the plungers being 12¼ in. in diameter, and a stroke of 3 ft. The suction pipe is 21 in. in diameter, and the delivery pipe or rising main 20 in. in diameter by 5,700 ft. long, and the total head to which the water has to be raised from the suction level in the source to the end of the rising main is 487 ft. The surface condenser has a cooling area of 300 ft. The steam pressure is 120 lb. per square inch.

The pumps deliver 2,000,000 gallons of water per 24 hours, and from a test by the corporation's engineer, during a trial of 12 hours' duration on November 27, 1903, it was found that the engine developed a mean of 135 indicated horse-power. The horse-power of water lifted was 115·79, giving a mechanical efficiency of 85·77 per cent. Total water pumped was 900,228 gallons, and the steam used per indicated horse-power per hour was 12·65 lb., the steam pressure being 121 lb. per square inch.

The pumping engine for the Nottingham Corporation for the Boughton Pumping Station is shown in Fig. 80, and the pumps underneath the engine-house floor are illustrated in Fig. 81. It was built by the same firm as the last example.

The engines are of the vertical triple-expansion type, fitted with slide valve gear. The high-pressure cylinder is 15 in. in diameter, the intermediate 24 in. in diameter and the low-pressure cylinder 39 in. in diameter, all having a stroke of 3 ft.

The main pumps are three in number, have plungers 12½ in. in diameter by 3 ft. length of stroke, running at 30 revolutions per minute, with a steam pressure of 140 lb. per square inch, when they deliver 2,000,000 gallons per 24 hours.

The air pump is 18½ in. in diameter by 16-in. stroke. The surface condenser has 512 tubes, giving a total cooling surface of 700 square feet. At the official test of this engine the efficiency, i.e. the pump horse-power divided by the indicated horse-power, worked out to 92 per cent., and the condensed steam passing through the engine

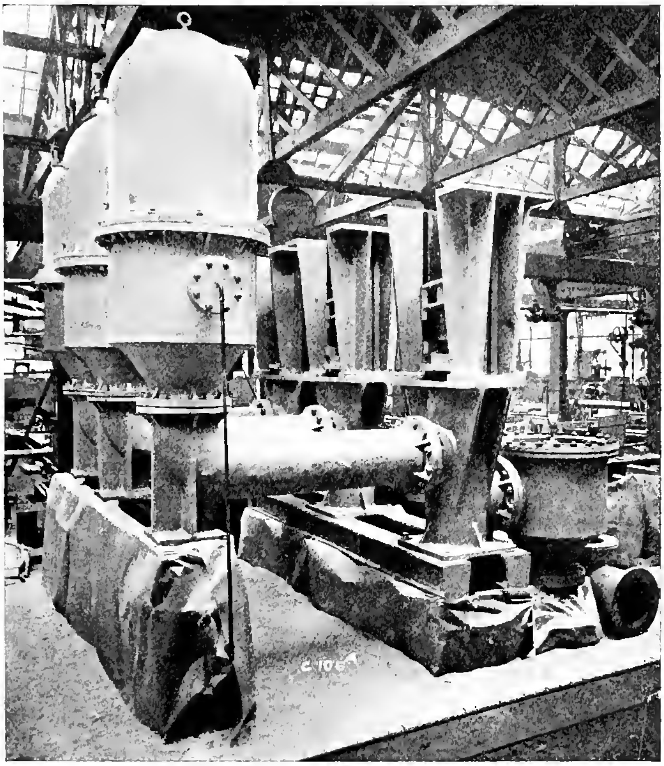


FIG. 81. PLUNGER PUMPS AT THE NOTTINGHAM CORPORATION WATERWORKS.

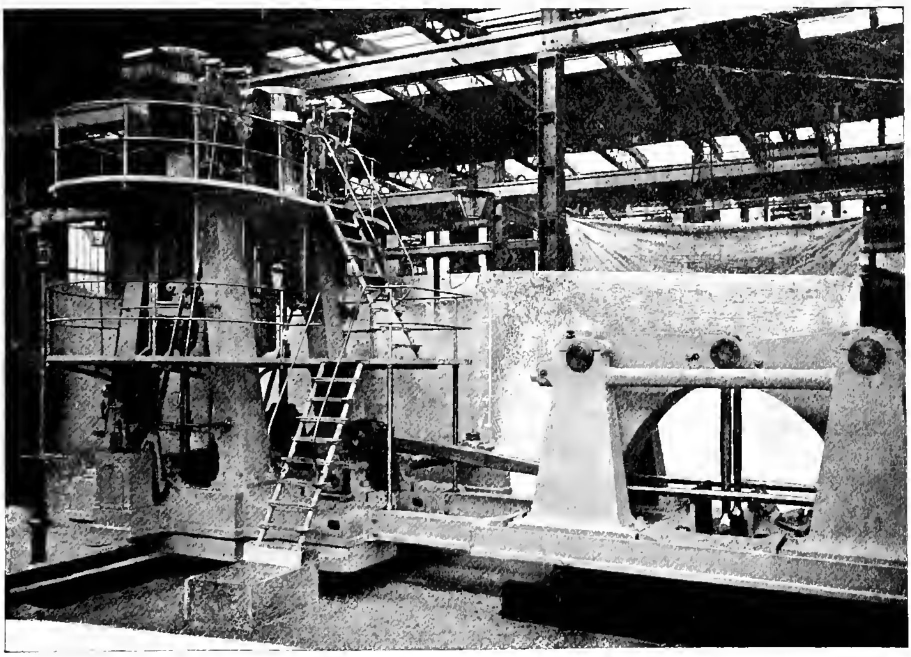


FIG. 82. VERTICAL COMPOUND PUMPING ENGINES WORKING TWO "ASHLEY" DEEP WELL PUMPS.

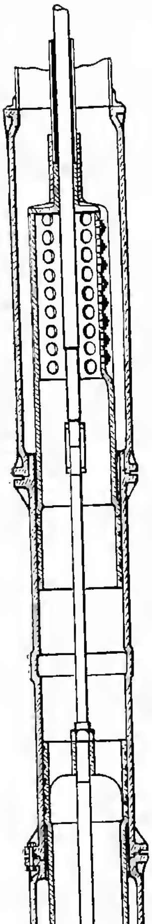


FIG. 83.
THE "ASHLEY CONCERTINA" DEEP WELL PUMP.

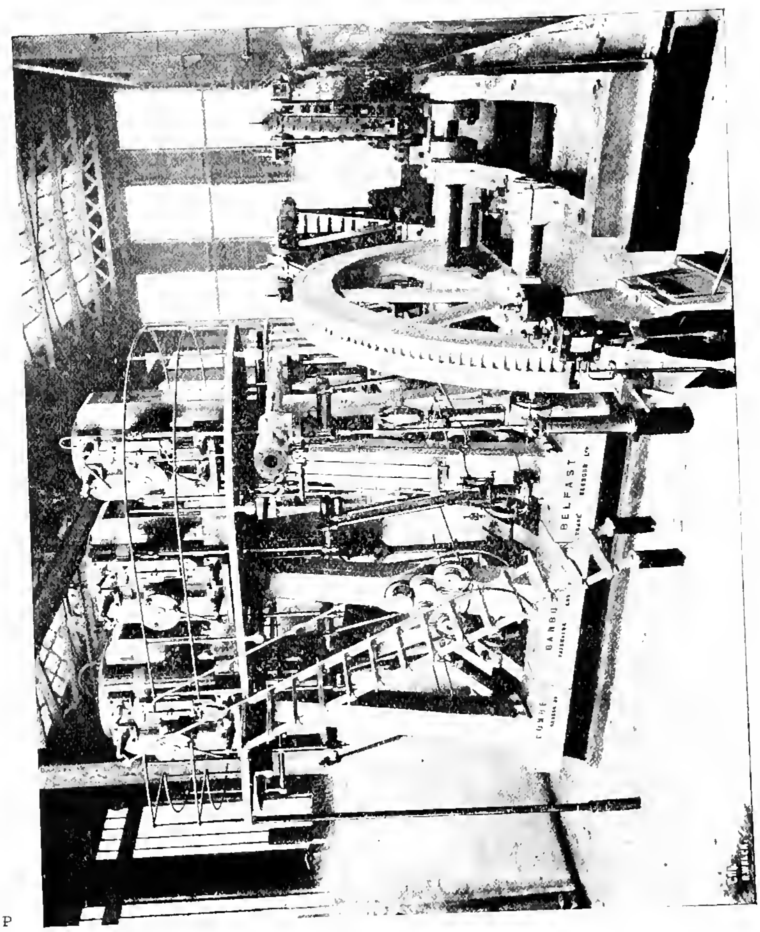


FIG. 84. PUMPING ENGINE AND GEAR FOR EAST LONDON WATERWORKS.

amounted to 13·6 lb. per indicated horse-power per hour.

The whole of the engine and pumps weighed 109 tons 10 cwt.

William B. Bryan, Esq., the chief engineer to the East London Waterworks Company was the consulting engineer.

Another engine erected by the same firm for the Gainsborough Urban District Council is illustrated in Fig. 82. Percy Griffith, Esq., was the engineer. It is of the vertical compound type, having a high-pressure cylinder 20 in. in diameter, and a low-pressure cylinder 40½ in. in diameter, both having a stroke 3 ft. in length. The steam is distributed by means of Corlis valves, placed in the cylinder heads.

This engine works the surface pumps placed immediately below the engine, delivering 60,000 gallons of water per hour, to a reservoir 150 ft. higher. These pumps are 14 in. in diameter, by 3-ft. stroke, running normally at 15 revolutions per minute.

The two deep-well pumps are of the "Ashley concertina" type. This type was adopted, because it was required to obtain the greatest possible quantity of water from the bore-hole. For this reason a double-acting pump, i.e. the pump that can deliver the full capacity of the barrel in both up- and down-stroke was selected. One of the best types of bore-hole pumps capable of doing this is known as the "concertina" or "bellows" type. In these pumps there are two buckets working in one barrel, each operated by separate rods and working in opposite directions, so that when one is going up the other is going down, and vice versa, and are thus double-acting and balanced. The great objection to this type of pump as hitherto made is that, as the buckets move away from each other, and the space between them is being filled with suction water, the area through the valve on the bottom bucket is not sufficient to allow the pump being worked much more than the speed of an ordinary single-bucket pump of the same diameter and stroke. Assuming that in an ordinary pump of this "concertina" type the suction valve is, say, 50 per cent. of the barrel, and the mean bucket speed 120 ft. per minute, then the water must flow through the valve at a mean velocity of 480 ft. per minute, which is, of course, excessive, the result being that pumps of this type constructed in the ordinary way must be made to run one half the speed of an ordinary one, and will then only discharge very little, if any, more than the single-bucket pump.

By adopting the "Ashley concertina" pump, as illustrated in sectional elevation, Fig. 83, an unlimited number of suction valves can be put in and the water passages all made of large area, so that a double-bucket pump of this class can be run at nearly the same speed as a single-bucket pump of the same diameter and stroke, and discharge nearly twice as much water, having a continuous flow, and be perfectly balanced at all water levels.

The bottom bucket rod is solid and worked by the *L*-bob shown on the left hand side in Fig. 82, and the top bucket rod is hollow, worked outside the solid rod, and is actuated by the right hand side *L*-bob.

These pumps are placed in the bore-holes, 300 ft. below the engine house floor, lifting up the 60,000 gallons per hour. The buckets are 19 in. in diameter by 3-ft. stroke, making 15 revolutions or 30 double strokes per minute worked by a counter shaft and *L*-bobs. This shaft is driven by a helical pinion 5 ft. in diameter keyed on to the engine crank shaft, gearing into a helical wheel 10 ft. in diameter, both having a pitch of 3¼ in.

The suction pipe for the force pumps is 15 in. in diameter and the delivery pipe 14 in. in diameter.

The surface condenser has 300 ft. of cooling surface.

The pumping engine illustrated in Fig. 84 was manufactured and erected by Messrs. Combe Barbour, for the East London Waterworks Company, under the supervision of William B. Bryan, Esq., Engineer in Chief. It is of the vertical triple-expansion surface-condensing type, having 12½-in. high-pressure cylinder, 20¼-in. intermediate and 33-in. low-pressure cylinder, all having a stroke of 2 ft. 6 in. The cylinders are provided with Corlis valves fitted in the cylinder heads. The normal speed of the engine is 56 revolutions per minute, with a steam pressure of 150 lb. per square inch. This is equal to about 171 indicated horse-power.

The engines and pumps are capable of discharging 2¼ million gallons of water per 24 hours into a main 42 in. in diameter, and against a total head from bottom of well of 300 ft.

This engine is actuating two sets of "Ashley" patent bucket pumps through spur gearing and rocking levers. The buckets are 20½ in. in diameter by 3 ft. 6 in. stroke; these pumps lifting the water from a well 200 ft. deep, and delivering it against a pressure of 100 ft. into the 42-in.

main, all the water passing through the surface condenser. The pump shaft runs at a speed of 16·1 revolutions per minute. Four of "Ashley" pumps stand upon the bottom of the well, and lift their water to the surface of the ground only, while the other two stand in another well similar in depth, and are fitted with plungers to lift the water to a height of 80 ft. above the surface of the ground, a total lift of 280 ft.

Pulsating Steam Pumps

THE Pulsometer, manufactured by the Pulsometer Engineering Co., Ltd., Reading, England, is illustrated in sectional elevation, Fig. 85. This appliance for raising water consists of a single casting, which is composed of two chambers, *A A*, joined side by side with tapering necks bent towards each other, and surmounted by another casting, called the neck, *J*, fitted and bolted to it, in which the two passages terminate in a common steam chamber, wherein the ball-valve *I* is fitted so as to be capable of oscillation between seats formed in the junction. Downwards, the chambers *A A* are connected with the suction passage *C*, wherein the suction-valves *E E* are arranged. A delivery box, common to both chambers and leading to the delivery pipe, is provided, in which are fitted the delivery-valves *F F*. The air-vessel *B* communicates with the suction. In this example, india-rubber disc-valves are shown. *G G* are guards which regulate the amount of opening of the valves *E E*. Small air-valves are screwed into the cylinders and air-vessel for admission of air.

The pump being filled with water, either by pouring water through the plug-holes in the chamber, or by drawing the charge, the steam is admitted through the steam pipe *K*—by opening to a small extent the stop-valve—passes down that side of the neck which is left open to it by the position of the steam ball *I*, and passes upon the small surface of water in the chamber which is exposed to it, depressing it without any agitation, and consequently with but very slight condensation, and driving it through the discharge opening and valve into the rising-main. The moment that the level of the water is as low as the horizontal orifice which leads to the discharge, the steam blows through with a certain amount of violence, and being brought into intimate contact with the water in the pipe leading to the delivery valve-box, an instantaneous condensation takes place, and a vacuum is in consequence so rapidly formed in the just emptied chamber, that the steam ball is pulled over into the seat opposite to that which it had occupied during the emptying of the chamber, closing its upper orifice and preventing the further admission of steam, allowing the vacuum to be completed; water rushes in immediately through the suction pipe, lifting the suction-valve *E*, and rapidly fills the chamber *A* again. Matters are now in exactly the same state in the second chamber *A*. The air-cocks are introduced to prevent the too rapid filling of the chamber on low lifts and for other purposes, and a very little practice will enable any unskilled workman or boy so to set them by the small nut, that the best effect may be produced.

A pulsometer with a vertical boiler mounted on a pair of wheels is illustrated in Fig. 86. This arrangement is very useful where the pumping machinery is wanted for temporary purposes only, as it is readily moved from place to place. It is also suitable as a fire engine for moderately high buildings. They are sometimes mounted on four wheels when desired.

There are an endless variety of purposes for which the pulsometer can be applied. One arrangement of one at a tin mine is shown in Fig. 87. The capacity of this pulsometer was 28,000 gallons of water per hour. The lift on which these pumps work varies, of course, but the usual height is 60 to 70 ft. In this example the pump was placed at the surface, but they are frequently placed down in the workings.

Another design of pulsating steam pump, invented and patented by Mr. John B. Foxwell, is manufactured by the Waterspout Engineering Co., Manchester, England. This is illustrated by the reproduction from a photograph, Fig. 88, and enlarged sectional elevation of valve and valve-chest, Fig. 89, and enlarged end view of valve-chest, Fig. 90. The valve *A* is self-adjusting to its seat. It is of annular shape, with two faces parallel to each other. It is loosely supported on an oscillating saddle *B*, which fits into the groove *C*, formed between the two faces of the valve, and is embraced by the projecting arms *D* and *D*, to prevent it rolling or moving away, and missing its face. By this arrangement a double or duplex movement of the valve is obtained, thus enabling it to oscillate be-

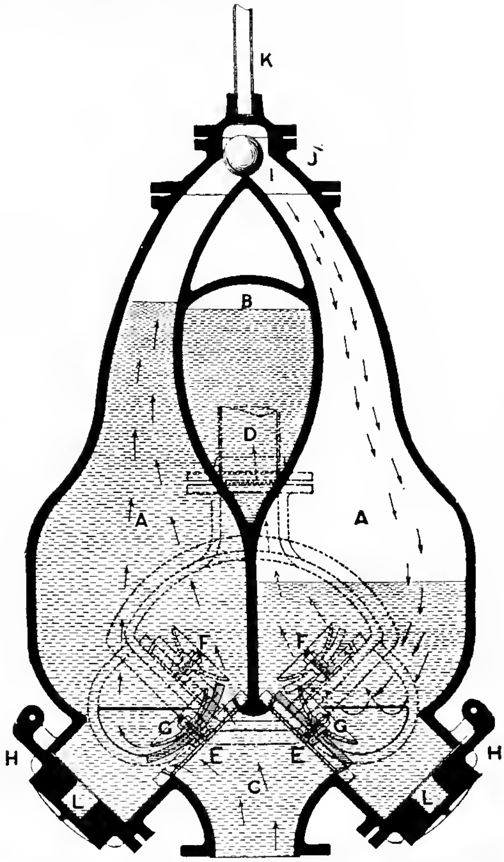


FIG. 85. SECTIONAL VIEW OF THE PULSOMETER STEAM PUMP.

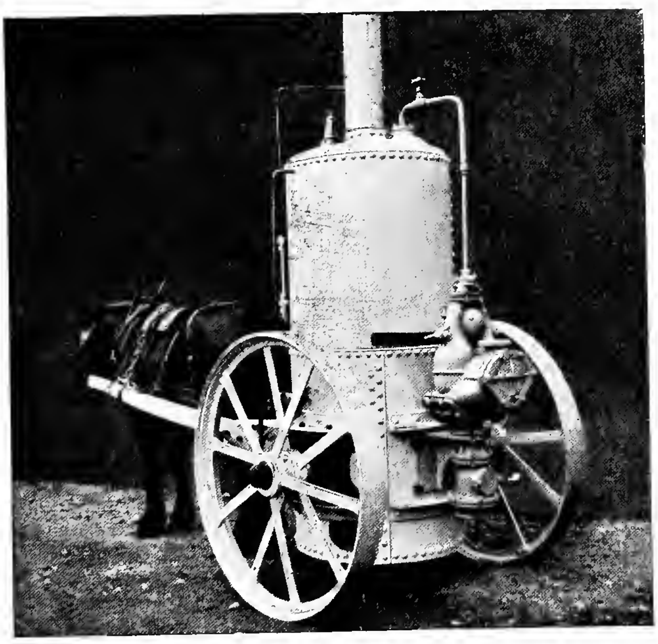


FIG. 86. PORTABLE PULSOMETER PUMP AND BOILER.

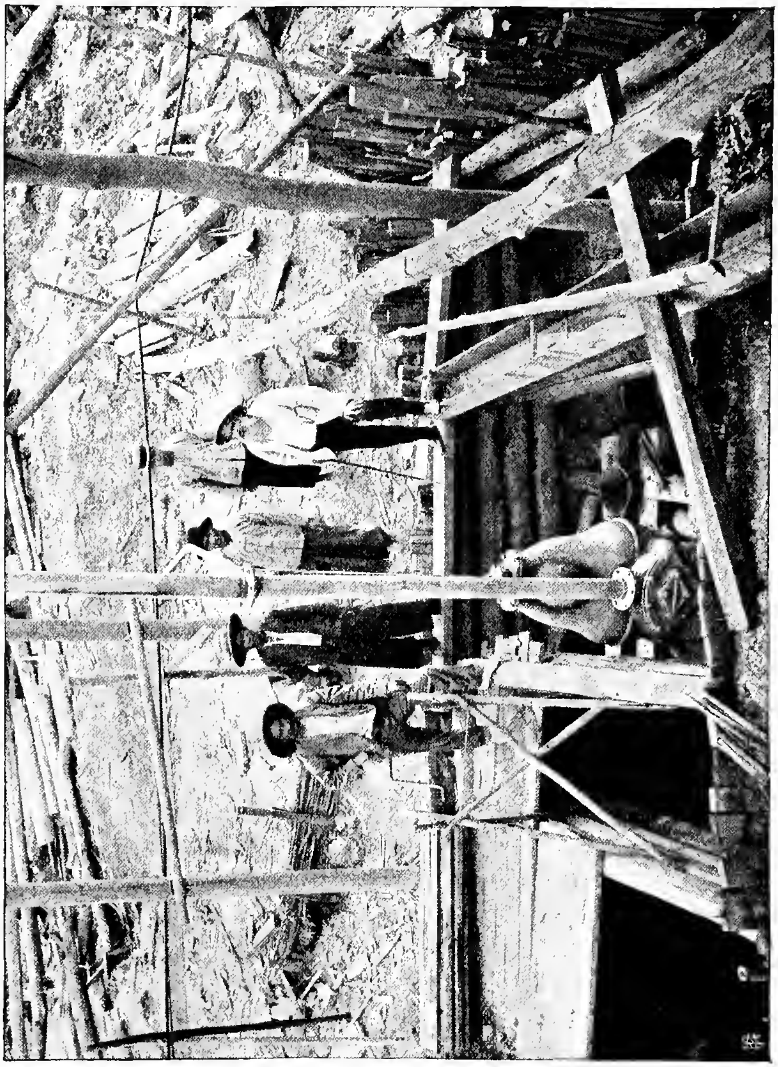


FIG. 87. VIEW SHOWING PULSOMETER PUMP WORKING IN A TIN MINE.

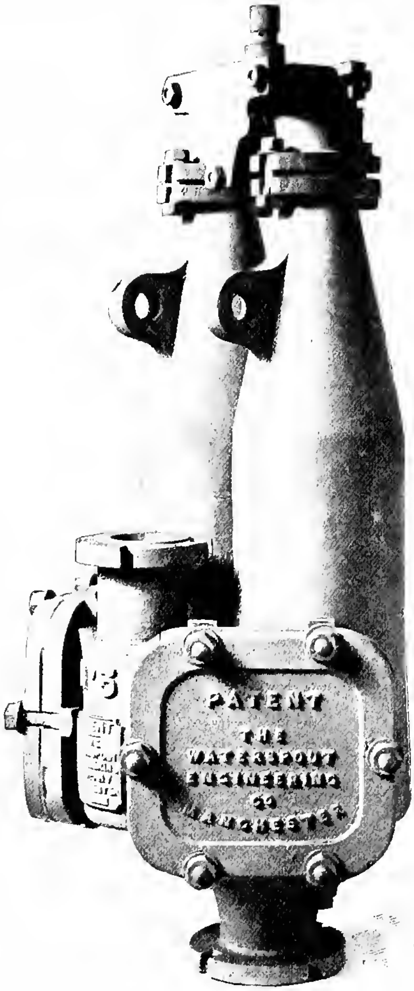


FIG. 88. THE "WATERSPOUT" PULSATING STEAM PUMP.

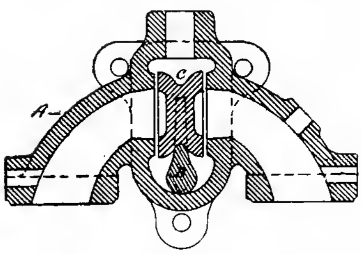


FIG. 89. VALVE AND VALVE CHEST.

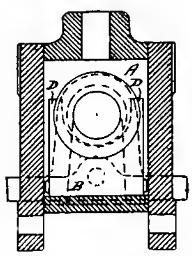


FIG. 90. END VIEW OF VALVE CHEST.

THE "WATERSPOUT" PUMP.

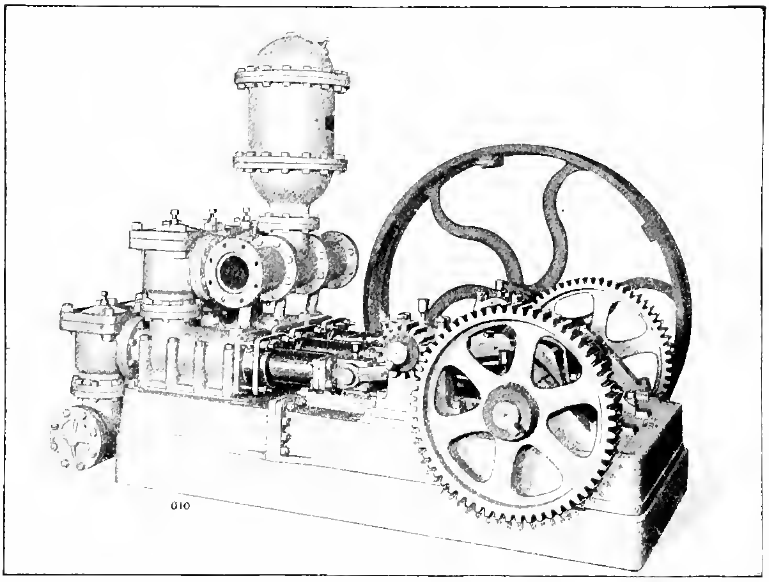


FIG. 91. HIGH LIFT PUMP, 200 TO 600 FEET HEAD, FITTED WITH ROPE PULLEY.

tween the two valve seatings, so as to close the whole area of the steam-port at the same time, or immediately adjust itself to the seating; also a more regular and even wear over the surface of the valve facings, and the adjustment or alteration of the position thereof to compensate for wear. The other part is almost identical with that of the "Pulsometer," so that it would only be waste of time and space to give a description.

Rope and Belt Driven Pumps

FIG. 91 shows a set of high-lift pumps designed for lifts between 200 and 600 ft. head driven with rope gear. It is manufactured by Messrs. E. Scott and Mountain, Ltd. To reduce the length of the bed-plate the driving shaft is placed above the connecting-rods between the pump crank-shaft and the pumps. The crank-shaft is fitted with a spur-wheel on each end, gearing into the pinions on the driving shaft, to prevent torsional strain as much as possible on the crank-shaft. The pump design is good, in fact it would be difficult to make any improvement upon it.

A belt-driven pump of a novel design, with an arrangement by means of which the length of the stroke of the pump can be altered whilst the pumps are running, is made by Messrs. Hayward-Tyler and Co. of London. It has pump barrels $2\frac{1}{2}$ in. in diameter by 6 in. stroke, and is capable of delivering 500 gallons per hour against a boiler pressure of 80 lb. per square inch. The crank connecting-rods are permanently secured to a rock arm provided with a slide in which the pump connecting-rod cross-heads can be moved, by that means altering the stroke of the pump pistons or plungers, as the case may be. This pump is also made to be electrically driven.

The " Haste " inertia pump is shown in sectional elevation, Fig. 92. This pump consists of a hollow plunger, working through two glands and stuffing-boxes, one of which is formed in the suction-pipe, and one in the delivery-pipe or rising-main. At the centre of the length of the plunger is fitted a valve, made of " Dermatine " in such a manner that the beating surface is guided on a spindle secured to a cross-piece in the sides of the plunger, the ribs being tapered top and bottom so as to minimise the friction of the water flowing through.

The plunger being reciprocating at a high speed, by any motor, the valve is closed on the up-stroke, and imparts so high velocity to the water in the delivery-pipe that the inertia of this water maintains a continuous discharge through the down-stroke of the plunger, so that in practice the flow of water is continuous, hence no pressure air-vessel is required. This pump has a discharge varying from 416 to 123 per cent., according to the head against which the pump is working, the area for the passage of the liquid being the same as in the bore of the plunger.

A general view of a belt-driven " Haste " inertia pump is illustrated in Fig. 93.

These pumps are manufactured by the Haste Pump Company, London, England.

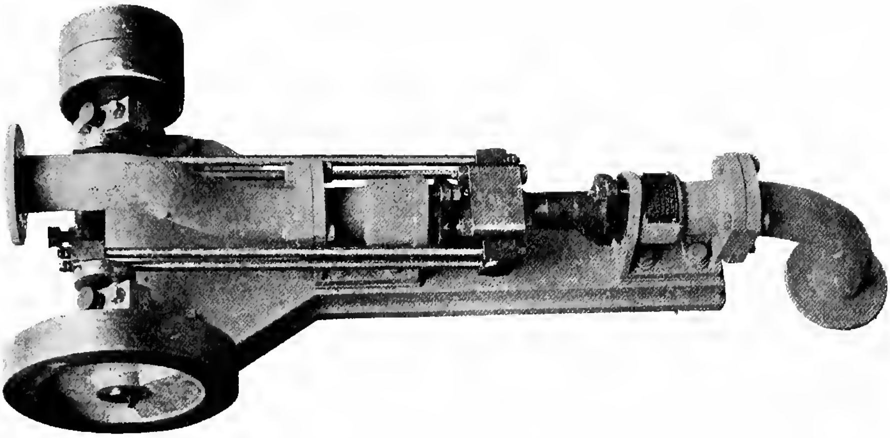


FIG. 93. BELT-DRIVEN HASTE INERTIA PUMP.

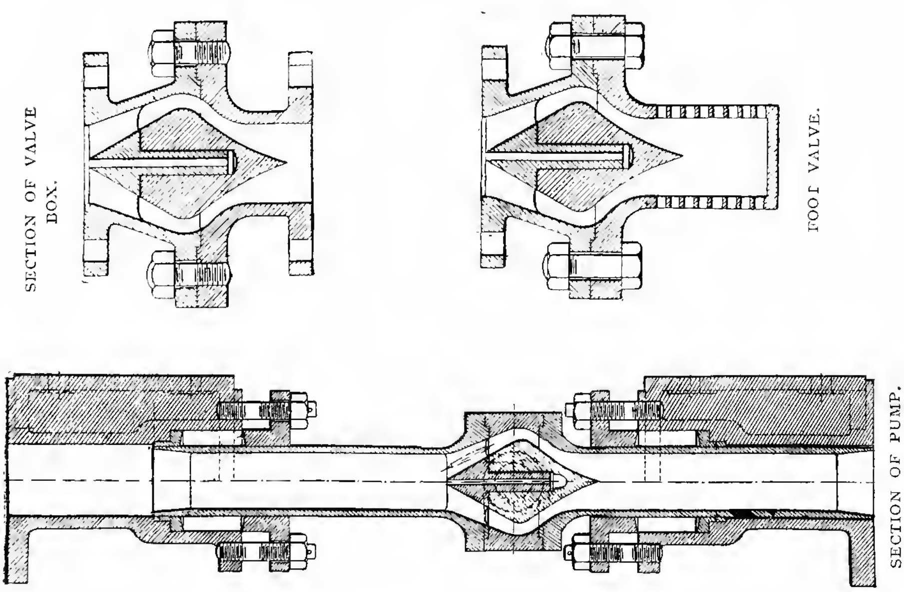


FIG. 92. THE HASTE PATENT PUMP.

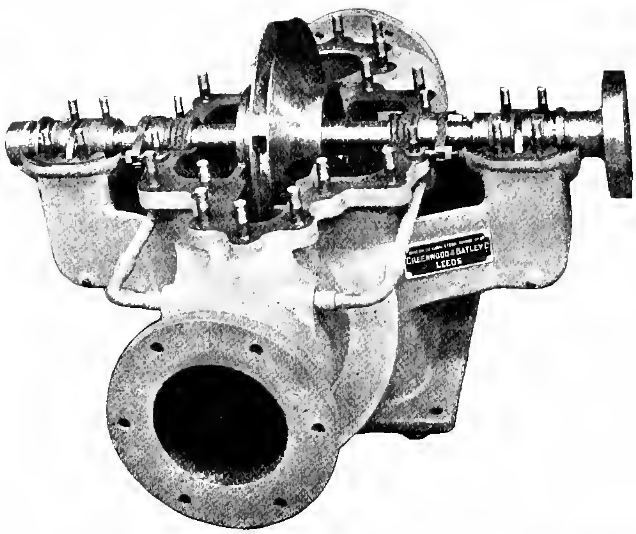


FIG. 94. VIEW SHOWING DETAILS OF DE LAVAL CENTRIFUGAL PUMP.

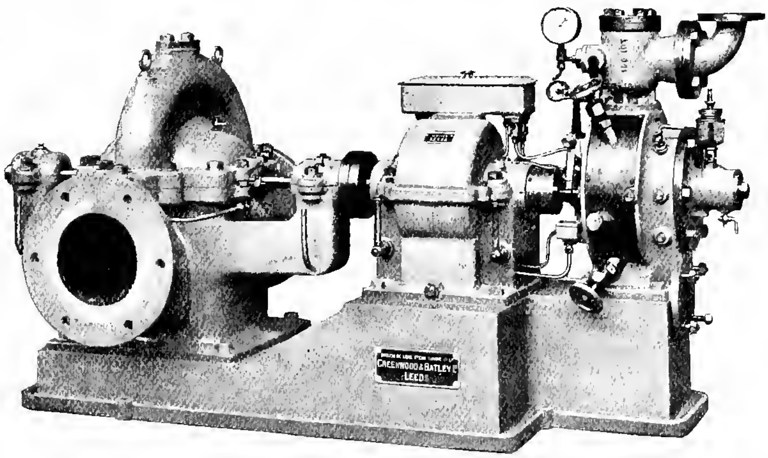


FIG. 95. 15 B.H.P. DE LAVAL PATENT STEAM TURBINE PUMP (capacity : 550 imperial galls. per min. Head : 60 feet).

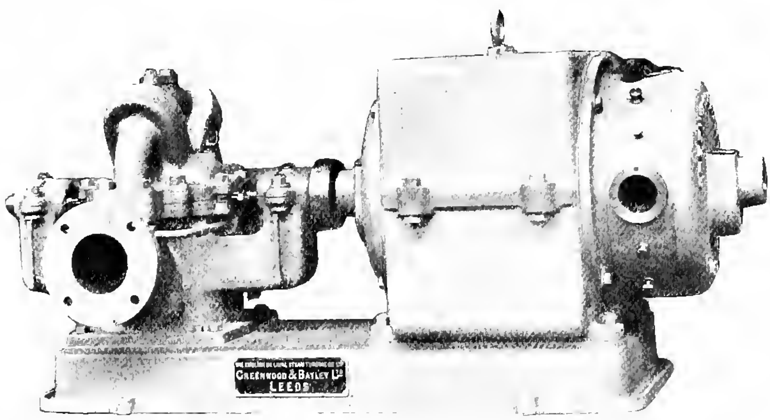


FIG. 96. 8 B.H.P. DE LAVAL PATENT ELECTRIC MOTOR PUMP (capacity : 350 imperial galls. per min. Head : 50 feet).

English De Laval Patent Centrifugal Pumps.

The English De Laval Patent Centrifugal Pumps illustrated in Figs. 94 to 97 are specially designed for working in combination with high-speed steam turbines and electric motors, but they are also designed for lower speeds, suitable for belt drive or for working in combination with slow-speed engines or motors.

These pumps are made in standard sizes to work against heads of from 20 feet up to 300 feet, but special pumps for practically any head up to 1,000 feet are also constructed.

The special characteristic of the De Laval Centrifugal Pumps, viz., their high speed, which is greatly in excess of anything previously known in connection with centrifugal pumps, is a mechanical problem which has been solved partly by an improvement in the construction of the wheel and packing boxes of the pump, including their lubricating arrangements, and partly by paying the greatest attention to the execution of all the movable parts. The high rate of speed has made it possible to reduce the diameter of the pump wheel, and consequently the frictional resistance of the pump has been greatly lowered.

It is claimed by the makers that this circumstance has made it possible to obtain with the De Laval Pumps an efficiency considerably in excess of the results generally obtained with centrifugal pumps.

Owing to the high speed, the dimensions and weight of the De Laval pumps are small when compared with their capacity.

A special feature of the De Laval Pumps is their oiling arrangement. All bearings are self-oiling and entirely separated from the packings, thus making it impossible for any oil to get into the water dealt with by the pumps.

All parts are made interchangeable, and to gauge, and therefore repairs can be very quickly made. Those parts where a close running fit is required are provided with interchangeable rings of bronze, which can be easily replaced in case they are worn.

The pump cases are divided horizontally, making it possible to inspect the interior of the pump and make repairs without disturbing the suction and discharge pipes.

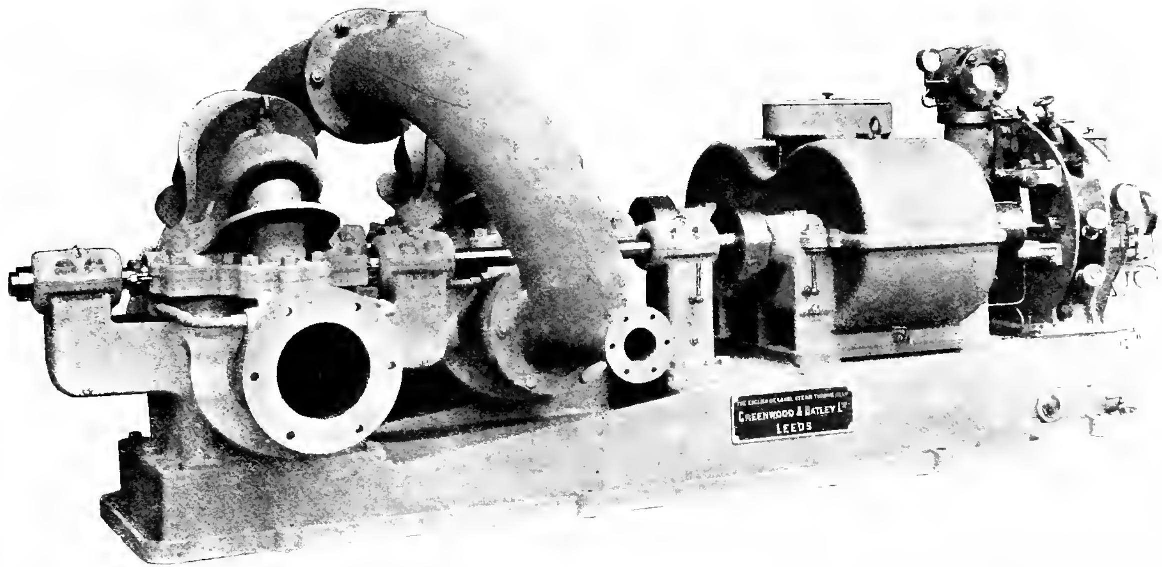


FIG. 97. 150 B.H.P. DE LAVAL PATENT STEAM TURBINE SERIES PUMP (capacity: 1,400 imperial galls. per min. Head: 240 feet or 104 pounds per sq. in.), MADE BY THE ENGLISH DE LAVAL STEAM TURBINE CO., LTD., LEEDS

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Bibliography of Books on Pumps and Pumping Engines Published in Great Britain

"Centrifugal Pumps, Turbines, and Water Motors," by Charles H. Innes. (Technical Publishing Company, Manchester.)

"Construction of Pump Details," by Philip R. Björling. (E. & F. N. Spon, London.)

"Hydraulic Motors and Turbines," by G. R. Bodmer. (Whittaker & Co., London.)

"Hydraulic Power and Hydraulic Machinery," by Henry Robinson. (Charles Griffin & Co., London.)

"Hydraulic Rams, their Construction and Management," by J. Wright Clarke. (B. T. Batsford, London.)

"Manual of Civil Engineering," by W. J. Macquorn Rankin. (Charles Griffin & Co., London.)

"Mine Drainage," by Stephen Michell. (Crossby, Lockwood & Son, London.)

"Principles, Construction and Application of Pumping Machinery," by Henry Davey. (Charles Griffin & Co., London.)

"Pumps and Pump Motors," by Philip R. Björling. (E. & F. N. Spon, London.)

"Pumps and Pumping," by M. Powis Bale. (Crossby, Lockwood & Son, London.)

"Pumps and Pumping Machinery," by F. Colyer. (E. & F. N. Spon, London.)

"Pump Fitter's Guide for Calculating and Fixing Pumps," by J. Eldridge. (E. & F. N. Spon, London.)

"Pumps: their Construction and Management," by Philip R. Björling. (P. S. King & Son, London.)

"Pumps: their Principles and Construction," by Wright Clarke. (B. T. Batsford, London.)

Directory of Manufacturers of Pumps and Pumping Engines in Great Britain

Abbot, John, & Co.	Park Works, Gateshead-on-Tyne.
Adamson, Daniel, & Co . . .	Dukinfield, Manchester.
Allen, W. H., Son & Co. . . .	Queen's Engineering Works, Bedford.
Bailey, W. H., & Co., Ltd. . .	Albion Works, Salford, Manchester.
Baker Blower Engineering Co. .	Stanley Works, Sheffield.
Bamford, C. F.	Goldington Avenue, Bedford.
Barclay, Sons & Co., Andrew . .	Caledonia Works, Kilmarnock, N.B.
Batchelor, R. D.	73, Queen Victoria Street, London, E.C.
Beaumont's Pump Works . .	Stockport, Lancs.
Bellis & Morcom, Ltd.	Birmingham.
Berry, Henry, & Co.	Croydon Works, Hunslet, Leeds, Yorks.
Bever, Dorling & Co., Ltd. . .	Bowling Iron Works, Bradford, Yorks.
Boby, Robert	Bury St. Edmunds.
Bracket, F. W., & Co.	Hythe Bridge Works, Colchester.
Braithwaite, H., & Co. . . .	Swinegate, Leeds, Yorks.
Braithwaite, Isaac, & Son . .	Kendal.
Brazil, Holborow & Straker, Ltd. .	Vulcan Ironworks, Bristol.
Brotherhood, Peter	Belevdere Road, Westminster, London, S.W.
Buxton & Thornley	Burton-on-Trent.
Cadle, C.	Wellington Quay, Dublin.
Cameron, John	Oldfield Road Ironworks, Salford.
Campbell & Calderwood . . .	Soho Engine Works, Paisley, N.B.
Campbell Gas Engine Co., Ltd. .	Halifax, Yorks.
Capell, R. L.	Northampton.
Carruthers, J. H. & Co. . . .	Polmadie Ironworks, Hamilton Street, Polmadie, Glasgow, N.B.
Chaplin, Alex., & Co.	Gowan, Glasgow, N.B.
Cherry, John, & Sons	Pump Works, Beverley, Yorks.
Clarke, Chapman & Co., Ltd. . .	Victoria Works, Gateshead-on-Tyne.
Clay Cross Co.	Clay Cross, near Chesterfield.

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Coalbrookdale Co., Ltd. . . .	Coalbrookdale, Shropshire.
Cochrane, John	Barrhead, N.B.
Coles, H. J.	London Crane Works, Derby.
Combe, Barber, Ltd.	Belfast.
Corlett Electrical Engineering Co., Ltd.	Wigan, Lancs.
Craig, A. F., & Co., Ltd. . . .	Caledonia Engine Works, Paisley, N.B.
Crossley Brothers, Ltd. . . .	Openshaw, Manchester.
Crossley, Geo., Ltd.	Albion Ironworks, Cleckheaton, Yorks.
Crow, Harvey & Co.	Park Ironworks, Glasgow, N.B.
Daglish, Robert, & Co., Ltd. . .	St. Helens, Lancs.
Davey, Paxman & Co., Ltd. . .	Standard Ironworks, Colchester.
Dempster, Moore & Co. . . .	Robertson Street, Glasgow, N.B.
Denison, Thos., & Co.	West Street, Leeds, Yorks.
Douglas & Grant	Kircaldy, N.B.
Drum Engineering Co.	Bradford, Yorks.
Duke & Ockenden	Littlehampton, Sussex.
Drysdale & Co.	Bon Accord Engine Works, Glasgow, N.B.
East Ferry Road Engineering Works Co., Ltd..	Millwall, London, E.
Easton & Co., Ltd.	Broad Sanctuary Chambers, Westminster, London, S.W.
Edwards Air Pump Syndicate, Ltd.	Crown Court, Old Broad Street, London, E.C.
Electrical Construction Co. . .	New Broad Street, London, E.C.
Ellison, W. T., & Co., Ltd. . .	Irlam, Manchester.
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Fraser & Chalmers, Ltd. . . .	Erith and London Wall Buildings, London, E.C.
Gimson & Co.	Vulcan Road, Leicester.
Glenfield & Kennedy, Ltd . .	Kilmarnock, N.B.
Goddard, Massey & Warner . .	Nottingham.
Greenwood & Batley, Ltd. . .	Albion Works, Leeds, Yorks.
Gunther, W., & Sons	Central Works, Oldham, Lancs.
Gwynnes, Ltd.	81, Cannon Street, London, E.C.
Hall, J. P., & Sons, Ltd. . . .	London Road, Peterborough.
Hartnell Wilson, & Co., Ltd. . .	Volt Works, Leeds, Yorks.
Haslam Foundry and Engineering Co., Ltd.	Derby.

Haste Patent Pump Co.	Crown Court, Old Broad Street, London.
Hathorn, Davey & Co., Ltd. . .	Sun Foundry, Leeds, Yorks.
Hayward-Tyler & Co., Ltd. . .	90, Whitecross Street, London, E.C.
Heenan & Froude, Ltd. . . .	Aston, Birmingham, and Manchester.
Hindley, E. S.	Bourton, Dorset.
Holden & Brook, Ltd.	Gorton, Manchester.
Hole & Roberts	Warminster, Wilts.
Hornsby, Richard, & Sons, Ltd. .	Grantham.
Howes, S., & Co.	64B, Mark Lane, London, E.C.
Hughes & Lancaster	47, Victoria Street, Westminster, London, and Ruabon.
Isca Foundry Co.	Newport, Mon.
Isler, C., & Co.	Bear Lane, Southwark, London, S.E.
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King, R. A., & Co.	St. Enoch's Square, Glasgow, N.B.
Kirkaldy, John, Ltd.	Leadenhall Street, London, E.C.
Lancaster & Tonge, Ltd. . . .	Pendleton, Manchester.
Leadbeater & Gill	Holbeck Lane, Leeds, Yorks.
Lee, Howl & Co., Ltd.	Tipton, Staffs.
Llewellyn & Cubitt	Rhondda Engine Works, Pentre, Glam.
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Marshall, Sons & Co., Ltd. . .	Gainsborough.
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Matthews, William, E., & Co. . .	Moston Lane, Manchester.
Mavor & Coulson, Ltd. . . .	Broad Street, Glasgow, N.B.
Merryweather & Sons, Ltd. . .	Long Acre, London, W.C.
Middleton, Robert	Sheepscar Foundry, Leeds, Yorks.
Millar, J. S. & Son	Annan, N.B.
Mills, Edwin, & Son	Aspley Ironworks, Huddersfield, Yorks.
Mills, Geo., & Co.	Radcliffe, near Manchester.
Mirrless, Watson & Co., Ltd. . .	Scotland Street, Glasgow, N.B.
Morland, Richard, & Sons, Ltd. .	Old Street, London, E.C.
Mumford, A. G.	Culver Works, Colchester.
Musgrave Brothers	Crown Point Foundry, Leeds, Yorks.
Neill, W., & Son, ...	St. Helens Junction, Lancs.
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Potter, A. C., & Co.	Lant Street, Borough, London, S.E.
Prachitt Brothers	Carlisle.
Pulsometer Engineering Co., Ltd. .	Reading, Berks.
Ransomes & Rapier, Ltd. . .	Waterside Works, Ipswich.
Reader, E., & Sons, Ltd. . . .	Nottingham.
Richards, R., & Co.	Upper Ground Street, London, S.E.
Rimington Brothers, ...	Abbey Street, Carlisle.
Roberts, E., & H., Ltd. . . .	Deanshanger Ironworks, Stony Stratford, Bucks.
Roberts, J. & S., Ltd.	West Bromwich.
Robey & Co., Ltd.	Globe Works, Lincoln.
Roger, R., & Co., Ltd. . . .	Stockton-on-Tees.
Royce, Ltd.	Manchester.
Ruston, Proctor, & Co., Ltd. . .	Lincoln.
Samuelson & Co., Ltd. . . .	Banbury, Oxon.
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Saunderson, H. B., & Co., Ltd. .	Elstow Works, Bedford.
Scott, Ernest, & Mountain, Ltd. .	Close Works, Newcastle-on-Tyne.
Shore & Sons	Albion Foundry, Etruria, Stoke-on-Trent.
Siebe, Gorman & Co.	Westminster Bridge Road, London, S.E.
Simons, W., & Co., Ltd. . . .	Renfrew, N.B.
Simpson, James, & Co., Ltd. . .	London and Newark-on-Trent.
Slee, John, & Co.	Earlstown, Lancs.
Smith, John, & Co.	Grove Works, Carshalton, Surrey.
Spenser, W. H., & Co.	Hitchin, Herts.
Stannah, J.	Skin Market Place, Bankside, London, S.E.
Stewart, D., & Co. (1902), Ltd. .	London Road Ironworks, Glasgow, N.B.
Sykes, Henry, Ltd.	Bankside, London, S.E.
Tangyes, Ltd.	Cornwall Works, Birmingham.
Thom, John G.	Canal Works, Patricroft, Manchester.
Thomas & Son	Broad Street, Worcester.
Thwaites Brothers, Ltd. . . .	Bradford, Yorks.
Tickle Brothers	Vulcan Foundry, Wigan, Lancs.
Titt, John Wallis	Warminster, Wilts.
Uskside Engineering and Rivet Co., Ltd.	Newport, Mon.
Valor & Co., Ltd.	Birmingham.
Vauxhall Ironworks Co., Ltd. .	Wandsworth, London, S.W.
Vosper & Co., Ltd.	Portsmouth.

Waller, George, & Son . . .	Stroud, Gloucester.
Waterspout Engineering Co. . .	North Parade, Parsonage, Manchester.
Watson, Henry, & Sons . . .	High Bridge Works, Newcastle-on-Tyne.
Warner, R., & Co.	Queen Victoria Street, London, E.C.
Weir, G. & J., Ltd.	Cathcart, Glasgow, N.B.
Willcox, W. H. & Co. . . .	Southwark Street, London, S.E.
Williams, T. C., & Sons, Ltd. .	Reading, Berks.
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Acid Pumps.

Bailey, W. H., & Co.	Albion Works, Salford, Manchester.
Evans, Joseph, & Sons	Wolverhampton.
Hayward-Tyler & Co.	90, Whitecross Street, London, E.C.

Air Pumps.

Bailey, W. H., & Co.	Albion Works, Salford, Manchester.
Coalbrookdale Ironworks	Coalbrookdale, Shropshire.
Davey, Paxman & Co., Ltd.	Colchester.
Edwards' Air Pump Co., Ltd.	3, Crown Court, Old Broad Street, London, E.C.
Evans, Joseph, & Sons	Wolverhampton.
Fairbairn, Lawson, Combe, Barber, Ltd.	52, Lime Street, London, E.C.
Fraser & Chalmers, Ltd.	3, London Wall Buildings, London, E.C.
Galloways, Ltd.	Knott Mill, Manchester.
Hathorn, Davey & Co., Ltd.	Sun Foundry, Leeds, Yorkshire.
Hayward-Tyler & Co.	90, Whitecross Street, London, E.C.
Marshall, Sons & Co.	Gainsborough.
Pearn, F., & Co., Ltd.	West Gorton, Manchester.
Roby & Co., Ltd.	Lincoln.
Tangyes, Ltd.	Birmingham.

Ammoniacal Liquor Pumps.

Evans, Joseph, & Sons.	Wolverhampton.
Hayward-Tyler & Co.	90, Whitecross Street, London, E.C.
Haslam Foundry and Engineering Co., Ltd.	Derby.

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Batchelor, R. D.	73, Queen Victoria Street, London, E.C.
Beck & Co.	130, Great Suffolk Street, Southwark, London, S.E.
Duke & Ockenden	Littlehampton and London.
Evans, Joseph, & Sons	Wolverhampton.
Hayward-Tyler & Co.	90, Whitecross Street, London, E.C.
Isler, C., & Co.	Bear Lane, Southwark Street, London, S.E.
Le Grand & Sutcliffe	125, Bunhill Row, London, E.C.
Matthews, Thomas	Pendleton, Manchester.
Richards, R., & Co.	Upper Ground Street, Blackfriars, London, S.E.
Stone & Co.	Deptford, London, S.E.

ASHLEY PUMP.

Glenfield and Kennedy, Ltd.	Kilmarnock, N.B.

BELT DRIVEN PUMPS.

Bailey, W. H., & Co.	Albion Works, Salford, Manchester.
Berry, H., & Co., Ltd.	Hunslet, Leeds, Yorkshire.
Brackett, F. W., & Co.	Hythe Bridge Works, Colchester.
Duke & Ockenden,	Littlehampton and London.
Edwards' Air Pump Syndicate, Ltd.	3, Crown Court, Old Broad Street, London, E.C.
Evans, Joseph, & Sons	Wolverhampton.
Fielding & Platt, Ltd.	Gloucester.
Fraser & Chalmers, Ltd.	3, London Wall Buildings, London, E.C.
Haste Pump Co., Ltd.	3, Crown Court, Old Broad Street, London, E.C.
Hathorn, Davey & Co.	Sun Foundry, Leeds, Yorkshire.
Hayward-Tyler & Co.	90, Whitecross Street, London, E.C.
Leeds Engineering & Hydraulic Co., Ltd.	Cross Stamford Street, Leeds, Yorkshire.
Merryweather & Sons, Ltd.	Greenwich Road, London, S.E.
Musgrave Brothers.	Crown Point Foundry, Leeds, Yorkshire.

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Rice & Co., Ltd.	Elland Road, Leeds, Yorkshire.
Scott, Ernest, & Mountain, Ltd.	Close Works, Newcastle-on-Tyne.
Tangyes, Ltd.	Birmingham.
Tannett, Walker & Co., Ltd. .	Hunslet, Leeds, Yorkshire.
Thwaites Brothers, Ltd. . . .	Thornton Road, Bradford, Yorkshire.
Warner, R., & Co.	97, Queen Victoria Street, London, E.C.

Boiler Feed Pumps.

Bailey, W. H., & Co., Ltd. . .	Albion Works, Salford, Manchester.
Cameron, J., Ltd.	Oldfield Road, Salford, Manchester.
Carruthers, J. H., & Co. . . .	Polmadie Works, Glasgow, N.B.
Clarke, Chapman, & Co., Ltd. .	Gateshead-on-Tyne.
Coalbrookdale Ironworks . . .	Coalbrookdale, Shropshire.
Cochrane, John.	Barrhead, N.B.
Dempster, Moore & Co., Ltd. . .	49, Robertson Street, Glasgow, N.B.
Drum Engineering Co. . . .	27, Charles Street, Bradford, Yorkshire.
Evans, Joseph, & Sons . . .	Wolverhampton.
Hall, J. P., & Sons, Ltd. . . .	Peterborough.
Haste Patent Pump Co., Ltd. .	3, Crown Court, Old Broad Street, London, E.C.
Hayward-Tyler & Co. . . .	90, Whitecross Street, London, E.C.
Hindley, E. S., & Sons . . .	Bourton, Dorsetshire.
Mumford, A. G.	Culver Street, Colchester.
Owens, S., & Co.	Whitefriars Street, London, E.C.
Pearn, E., & Co., Ltd.	West Gorton, Manchester.
Shore, T., & Sons	Etruria, Stoke-on-Trent.
Tangyes, Ltd.	Birmingham.
Tinker Brothers	Wigan, Lancashire.
Vauxhall Ironworks Co., Ltd. .	Wandsworth Road, London, S.W.
Warner, R., & Co.	97, Queen Victoria Street, London, E.C.
Weir, G. & J., Ltd.	Cathcart, Glasgow, N.B.
Westinghouse Brake Co., Ltd. .	York Road, King's Cross, London, N.
Willcox, W. H., & Co., Ltd. . .	23, Southwark Street, London, S.E.
Wilson, Alex.	172, Fenchurch Street, London, E.C.

Wilson, J. H., & Co.	Sandhills, Liverpool.

Bore-Hole Pumps.

Batchelor, R. D.	73, Queen Victoria Street, London, E.C.
Duke & Ockenden	Littlehampton and London.
Hayward-Tyler & Co.	90, Whitecross Street, London, E.C.
Isler, C., & Co.	Bear Lane, Southwark Street, London, S.E.
Le Grand & Sutcliffe	125, Bunhill Row, London, E.C.
Mather & Platt, Ltd.	Salford, Manchester.
Matthews, Thomas	Pendleton, Manchester.
Richards, R., & Co.	Upper Ground Street, Blackfriars, London, S.E.

Bucket Pumps.

Bailey, W. H., & Co., Ltd. . . .	Albion Works, Salford, Manchester.
Barkley, Andrew, Sons & Co., Ltd.	Kilmarnock, N.B.
Beck & Co., Ltd.	130, Great Suffolk Street, Southwark, London, S.E.
Clay Cross Co.	Clay Cross, near Chesterfield.
Davey, Paxman & Co., Ltd. . .	Colchester.
Duke & Ockenden	Littlehampton and London.
Edwards' Air Pump Syndicate, Ltd.	3, Crown Court, Old Broad Street, London, E.C.
Evans, Joseph, & Sons . . .	Wolverhampton.
Fairbairn, Lawson, Combe, Barber, Ltd.	52, Lime Street, London, E.C.
Fraser & Chalmers, Ltd. . . .	3, London Wall Buildings, London, E.C.
Glenfield & Kennedy, Ltd. . .	Kilmarnock.
Hathorn, Davey & Co. . . .	Sun Foundry, Leeds, Yorkshire.
Isca Foundry & Engineering Co.	Newport, Mon.
Isler, C., & Co.	Bear Lane, Southwark Street, London, S.E.
Jessop & Appleby Brothers, Ltd.	Leicester.
Le Grand & Sutcliffe	125, Bunhill Row, London, E.C.
Lilleshall Co., Ltd.	Oakengates, Shropshire.
Mather & Platt, Ltd.	Salford, Manchester.
Merryweather & Sons, Ltd. . .	Greenwich Road, London, S.E.
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Perry, T., & Sons, Ltd. . . .	Bilston, Staffordshire.

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Stone & Co.	Deptford, London, S.E.
Uskside Engineering Co., Ltd.	Newport, Mon.

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Cherry, John, & Sons	Pump Works, Beverley, Yorkshire.
Davey, Paxman & Co., Ltd.	Colchester.
De Laval Steam Turbine Co., Ltd.	84, Armley Road, Leeds, Yorkshire.
Drysdale & Co.	Bon Accord Engine Works, Glasgow, N.B.
Gilkes, G., & Co., Ltd.	Kendal.
Greenwood & Batley, Ltd.	Armley Road, Leeds, Yorkshire.
Gunther, W., & Sons	Central Works, Oldham, Lancashire.
Gwynnes, Ltd.	81, Cannon Street, London, E.C.
Mather & Platt, Ltd.	Salford, Manchester.
Parsons, C. A., & Co.	Heaton Works, Newcastle-on-Tyne.
Ransome, A., & Co., Ltd.	Newark-on-Trent.
Ransomes & Rapier, Ltd.	Waterside Ironworks, Ipswich.
Robey & Co., Ltd.	Lincoln.
Ruston, Proctor & Co., Ltd.	Lincoln.
Tangyes Limited	Birmingham.
Thwaites Brothers, Ltd.	Thornton Road, Bradford, Yorkshire.

CHEMICAL PUMPS.

Bailey, W. H., & Co., Ltd.	Albion Works, Salford, Manchester.
Evans, Joseph, & Sons	Wolverhampton.
Hayward-Tyler & Co.	90 Whitecross Street, London, E.C.

COMPRESSED AIR PUMPS.

Bailey, W. H., & Co., Ltd.	Albion Works, Salford, Manchester.
Evans, Joseph, & Sons	Wolverhampton.
Hathorn, Davey & Co., Ltd.	Sun Foundry, Leeds, Yorkshire.
Hayward-Tyler & Co.	90, Whitecross Street, London, E.C.
Tangyes Limited	Birmingham.

CLASSIFIED LIST OF MANUFACTURERS

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Glenfield & Kennedy, Ltd.	Kilmarnock, N.B.
Mather & Platt, Ltd.	Salford, Manchester.

DEEP-WELL PUMPS.

Bailey, W. H., & Co., Ltd.	Albion Works, Salford, Manchester.
Barclay, Andrew, Sons & Co., Ltd.	Kilmarnock, N.B.
Batchelor, R. D.	73, Queen Victoria Street, London, E.C.
Beck & Co., Ltd.	130, Great Suffolk Street, Southwark, London, S.E.
Campbell Gas Engine Co., Ltd.	Halifax, Yorkshire.
Duke & Ockenden	Littlehampton and London.
Evans, Joseph, & Sons	Wolverhampton.
Glenfield & Kennedy, Ltd.	Kilmarnock, N.B.
Haste Patent Pump Co., Ltd.	3, Crown Court, Old Broad Street, London, E.C.
Hathorn, Davey & Co., Ltd.	Sun Foundry, Leeds, Yorkshire.
Hayward-Tyler & Co.	90, Whitecross Street, London, E.C.
Hornsby, R., & Sons,	Grantham.
Isca Foundry & Engineering Co.	Newport, Mon.
Isler, C., & Co.	Bear Lane, Southwark Street, London, S.E.
Jessop & Appleby Brothers, Ltd.	Leicester.
Le Grand & Sutcliffe	125, Bunhill Row, London, E.C.
Lilleshall Co., Ltd.	Oakengates, Shropshire.
Mather & Platt, Ltd.	Salford, Manchester.
Moreland, Richard, & Son,	Old Street, London, E.C.
Perry, T., & Sons, Ltd.	Bilston, Staffordshire.
Stothert & Pitt, Ltd.	Bath.
Uskside Engineering Co., Ltd.	Newport, Mon.
Warner, R., & Co.	97, Queen Victoria Street, London, E.C.
Willcox, W. H., & Co., Ltd.	23, Southwark Street, London, S.E.

DIAPHRAGM PUMPS.

Duke & Ockenden	Littlehampton and London.
Evans, Joseph, & Sons	Wolverhampton.

DIRECT-ACTING STEAM PUMPS.

Bailey, W. H., & Co., Ltd.	Albion Works, Salford, Manchester.

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Berry, H., & Co., Ltd.	Hunslet, Leeds, Yorkshire.
Bever, Dorling & Co.	Bowling Ironworks, Bradford, Yorkshire.
Carruthers, J. H., & Co., Ltd.	Polmadie Works, Glasgow, N.B.
Chaplin, Alex., & Co.	Govan, Glasgow, N.B.
Clarke, Chapman & Co., Ltd.	Gateshead-on-Tyne.
Coalbrookdale Ironworks	Coalbrookdale, Shropshire.
Cochrane, John	Barrhead, N.B.
Cole, Marchant & Morley, Ltd.	Prospect Foundry, Bradford, Yorkshire.
Evans, Joseph, & Sons	Wolverhampton.
Fielding & Platt, Ltd.	Gloucester.
Hall, J. P., & Sons, Ltd.	Peterborough.
Haste Patent Pump Co., Ltd.	3, Crown Court, Old Broad Street, London, E.C.
Hathorn, Davey & Co., Ltd.	Sun Foundry, Leeds, Yorkshire.
Hayward-Tyler & Co.	90, Whitecross Street, London, E.C.
Hindley, E. S., & Sons	Bourton, Dorsetshire.
Merryweather & Sons, Ltd.	Greenwich Road, London, S.E.
Mumford, A. G.	Colchester.
Owens, S., & Co.	Whitefriars Street, London, E.C.
Pearn, F., & Co., Ltd.	West Gorton, Manchester.
Shore, T., & Sons	Etruria, Stoke-on-Trent.
Tangyes Limited.	Birmingham.
Warner, R., & Co.	97, Queen Victoria Street, London, E.C.
Weir, G. & J., Ltd.	Cathcart, Glasgow, N.B.
Westinghouse Brake Co., Ltd.	York Road, King's Cross, London, N.

DONKEY PUMPS.

Bailey, W. H., & Co., Ltd.	Albion Works, Salford, Manchester.
Belliss & Morcom, Ltd.	Ledsom Street, Birmingham.
Brazil, Holborow & Straker, Ltd.	Vulcan Works, Bristol.
Cameron, John, Ltd.	Oldfield Road, Salford, Manchester.
Carruthers, J. H., & Co., Ltd.	Polmadie Works, Glasgow, N.B.
Chaplin, Alex., & Co.	Govan, Glasgow, N.B.
Clarke, Chapman, & Co., Ltd.	Gateshead-on-Tyne.
Coalbrookdale Ironworks	Coalbrookdale, Shropshire.
Cole, Marchant & Morley, Ltd.	Prospect Works, Bradford, Yorkshire.

Coles, H. J.	London Crane Works, Derby.
Crow, Harvey & Co.	Park Grove Ironworks, Glasgow.
Dempster, Moore & Co. . . .	49, Robertson Street, Glasgow, N.B.
Dodman, A., & Co.	King's Lynn.
Drum Engineering Co. . . .	27, Charles Street, Bradford, Yorkshire.
Evans, Joseph, & Sons . . .	Wolverhampton.
Hall, J. P., & Sons, Ltd. . . .	Peterborough.
Hayward-Tyler & Co.	90, Whitecross Street, London, E.C.
Hindley, E. S., & Sons	Bourton, Dorsetshire.
Mumford, A. G..	Culver Street, Colchester.
Pearn, F., & Co., Ltd.	West Gorton, Manchester.
Shore, T., & Sons	Etruria, Stoke-on-Trent.
Tangyes Limited	Birmingham.
Tinker Brothers	Wigan, Lancashire.
Toward, T., & Co.	9, St. Lawrence, Newcastle-on-Tyne.
Vauxhall Ironworks Co., Ltd. .	Wandsworth Road, London, S.W.
Vosper & Co., Ltd.	Portsmouth.
Warner, R., & Co.	97, Queen Victoria Street, London, E.C.
Weir, G. & J., Ltd.	Cathcart, Glasgow, N.B.
Westinghouse Brake Co., Ltd. .	York Road, King's Cross, London, N.
Willcox, W. H., & Co., Ltd. . .	23, Southwark Street, London, S.E.
Wilson, Alex.	172, Fenchurch Street, London, E.C.
Wilson, J. H., & Co., Ltd. . .	Sandhills, Liverpool.

Driven Tube-Well Pumps.

Duke & Ockenden.	Littlehampton and London.
Hayward-Tyler & Co.	90, Whitecross Street, London, E.C.
Isler & Co.	Bear Lane, Southwark Street, London, S.E.
Le Grand & Sutcliffe	125, Bunhill Row, London, E.C.
Mather & Platt, Ltd.	Salford, Manchester.
Matthews, Thomas	Pendleton, Manchester.
Matthews, William, & Co. . . .	Kluff Road, Manchester.

Duplex Diaphragm Pumps.

Duke & Ockenden	Littlehampton and London.

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Duplex Pumps.

Arrol, Sir W., & Co., Ltd.	Dalmarnock Ironworks, Glasgow, N.B.
Bailey, W. H., & Co.	Albion Works, Salford, Manchester.
Bever, Dorling & Co.	Bowling Ironworks, Bradford, Yorkshire.
Brazil, Holborow & Straker, Ltd.	Vulcan Works, Bristol.
Carruthers, J. H., & Co., Ltd.	Polmadie Works, Glasgow, N.B.
Coalbrookdale Ironworks	Coalbrookdale, Shropshire.
Cole, Marchant & Morley, Ltd.	Prospect Foundry, Bradford, Yorkshire.
Evans, Joseph, & Sons	Wolverhampton.
Fielding & Platt, Ltd.	Gloucester.
Hayward-Tyler & Co.	90, Whitecross Street, London, E.C.
Hindley, E. S., & Sons	Bourton, Dorsetshire.
Mumford, A. G.	Culver Street, Colchester.
Pearn, F., & Co.	West Gorton, Manchester.
Tangyes Limited.	Birmingham.

Electrically Driven Pumps.

Bailey, W. H., & Co., Ltd.	Albion Works, Salford, Manchester.
Barclay, Andrew, Sons & Co., Ltd.	Kilmarnock, N.B.
Clarke, Chapman & Co., Ltd.	Gateshead-on-Tyne.
Evans, Joseph, & Sons	Wolverhampton.
Fraser & Chalmers, Ltd.	3, London Wall Buildings, London, E.C.
Gwynnes Limited	81, Cannon Street, London, E.C.
Hathorn, Davey & Co., Ltd.	Sun Foundry, Leeds, Yorkshire.
Hartnell, W., & Co., Ltd.	Volt Works, Leeds, Yorkshire.
Hayward-Tyler & Co.	90, Whitecross Street, London E.C.
Jackson, P. R., & Co., Ltd.	Manchester.
Mather & Platt, Ltd.	Salford, Manchester.
Merryweather & Sons, Ltd.	Greenwich Road, London, S.E.
Pearn, F., & Co., Ltd.	West Gorton, Manchester.
Scott, Ernest, & Mountain, Ltd.	Close Works, Newcastle-on-Tyne.
Tangyes Limited	Birmingham.
Warner, R., & Co.	97, Queen Victoria Street, London, E.C.

Geared Pumps.

Bailey, W. H., & Co., Ltd.	Albion Works, Salford, Manchester.

Barclay, Andrew, Sons & Co., Ltd.	Kilmarnock, N.B.
Beck & Co., Ltd.	130, Great Suffolk Street, Southwark, London, S.E.
Belliss & Morcom, Ltd. . . .	Ledsam Street, Birmingham.
Berry, H., & Co., Ltd.	Hunslet, Leeds, Yorkshire.
Braxil, Holborow, & Straker, Ltd.	Vulcan Works, Bristol.
Bumstead & Chandler . . .	Hednesford, Staffordshire.
Caird & Rayner	777, Commercial Road, London, S.
Caledonian Engineering & Shipbuilding Co.	Preston, Lancashire.
Campbell Gas Engine Co., Ltd. .	Halifax, Yorkshire.
Chaplin, Alex., & Co.	Govan, Glasgow, N.B.
Clarke, Chapman & Co., Ltd. .	Gateshead-on-Tyne.
Coalbrookdale Ironworks . . .	Coalbrookdale, Shropshire.
Dodman, A., & Co., Ltd. . . .	King's Lynn.
Dudbridge Ironworks	Stroud, Gloucestershire.
Duke & Ockenden	Littlehampton and London.
Evans, Joseph, & Sons . . .	Wolverhampton.
Fairbairn, Lawson, Combe, Barber, Ltd.	52, Lime Street, London, E.C.
Fielding & Platt, Ltd. . . .	Gloucester.
Fraser & Chalmers, Ltd. . . .	3, London Wall Buildings, London, E.C.
Galloways, Limited	Knott Mill, Manchester.
Glamorgan Engineering Co., Ltd.	Swansea.
Glenfield & Kennedy, Ltd. . .	Kilmarnock, N.B.
Greenwood & Batley, Ltd. . .	Albion Works, Leeds, Yorkshire.
Hanna, Donald & Wilson . . .	Paisley, N.B.
Hartnell, W., & Co., Ltd. . . .	Volt Works, Leeds, Yorkshire.
Haste Patent Pump Co., Ltd. .	3, Crown Court, Old Broad Street, London, E.C.
Hathorn, Davey & Co., Ltd. . .	Sun Foundry, Leeds, Yorkshire.
Hayward-Tyler & Co.	90, Whitecross Street, London, E.C.
Hornsby, R., & Sons, Ltd. . .	Grantham.
Hughes & Lancaster.	47, Victoria Street, Westminster, London, S.W.
Hunter & English	Bow, London, E.
Jackson, P. R., & Co., Ltd. . .	Manchester.
Jessop & Appleby Brothers, Ltd.	Leicester.
Leeds Engineering & Hydraulic Co.	Cross Stamford Street, Leeds, Yorkshire.
Mather & Platt, Ltd.	Salford, Manchester.
Merryweather & Sons, Ltd. . .	Greenwich Road, London, S.E.
Owens, S., & Co.	Whitefriars Street, London, E.C.

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Parsons, C. A., & Co.	Heaton Works, Newcastle-on-Tyne.
Pearn, F., & Co., Ltd.	West Gorton, Manchester.
Piercy & Co.	Broad Street Engine Works, Birmingham.
Reader, E., & Sons, Ltd. . . .	Nottingham.
Renshaw, W. R., & Co., Ltd. . .	Phœnix Works, Stoke-on-Trent.
Rice & Co., Ltd.	Elland Road, Leeds, Yorkshire.
Robey & Co., Ltd.	Lincoln.
Roger, R., & Co., Ltd.	Stockton-on-Tees.
Scott, Ernest, & Mountain, Ltd.	Close Works, Newcastle-on-Tyne.
Simons, W., & Co., Ltd.. . .	Renfrew, N.B.
Tannett, Walker & Co., Ltd. . .	Hunslet, Leeds, Yorkshire.
Uskside Engineering Co., Ltd. .	Newport, Mon.
Warner, R., & Co.	97, Queen Victoria Street, London, E.C.
West Hydraulic Engineering Co., Ltd.	23, College Hill, London, E.C.

Haste Pump.

Haste Patent Pump Co., Ltd. .	3, Crown Court, Old Broad Street, London, E.C.

Hand Pumps.

Bailey, W. H., & Co., Ltd. . .	Albion Works, Salford, Manchester.
Baker's Patent Appliances Co., Ltd.	Melrose Street Works, Scarborough.
Beck & Co., Ltd.	130, Great Suffolk Street, Southwark, London, S.E.
Coalbrookdale Ironworks, Ltd. .	Coalbrookdale, Shropshire.
Evans, Joseph, & Sons . . .	Wolverhampton.
Hayward-Tyler & Co.	90, Whitecross Street, London, E.C.
Tangyes Limited	Birmingham.
Willcox, W. H., & Co., Ltd. . .	23, Southwark Street, London, S.E.

Hot Air Engine Pumps.

Bailey, W. H., & Co., Ltd. . .	Albion Works, Salford, Manchester.
Hayward-Tyler & Co.	90, Whitecross Street, London, E.C.

Inertia Pumps.

Haste Patent Pump Co., Ltd. .	3, Crown Court, Old Broad Street, London, E.C.

MULTIPLE DIAPHRAGM PUMPS.

Duke & Ockenden	Littlehampton and London.

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Bailey, W. H., & Co., Ltd. . .	Albion Works, Salford, Manchester.
Barclay, Andrew, Sons & Co., Ltd.	Kilmarnock, N.B.
Beck & Co., Ltd.	130, Great Suffolk Street, Southwark, London, S.E.
Berry, H., & Co., Ltd.	Hunslet, Leeds, Yorkshire.
Bever, Dorling & Co.	Bowling Ironworks, Bradford, Yorkshire.
Cameron, J., Ltd.	Oldfield Road, Salford, Manchester.
Campbell Gas Engine Co., Ltd. .	Halifax, Yorkshire.
Carruthers, J. H., & Co., Ltd. . .	Polmadie Works, Glasgow, N.B.
Chaplin, Alex., & Co.	Govan, Glasgow, N.B.
Clarke, Chapman, & Co., Ltd. .	Gateshead-on-Tyne.
Coalbrookdale Ironworks . . .	Coalbrookdale, Shropshire.
Cochrane, John	Barrhead, N.B.
Fairbairn, Lawson, Combe, Barber, Ltd.	52, Lime Street, London, E.C.
Fielding & Platt, Ltd. . . .	Gloucester.
Fraser & Chalmers, Ltd. . . .	3, London Wall Buildings, London, E.C.
Grange Ironworks	Durham.
Haste Patent Pump Co., Ltd. .	3, Crown Court, Old Broad Street, London, E.C.
Hathorn, Davey & Co., Ltd. . .	Sun Foundry, Leeds, Yorkshire.
Hayward-Tyler & Co.	90, Whitecross Street, London, E.C.
Hindley, E. S., & Sons	Bourton, Dorsetshire.
Jackson, P. R., & Co., Ltd. . .	Salford Rolling Mills, Manchester.
Leeds Engineering and Hydraulic Co.	Cross Stamford Street, Leeds, Yorkshire.
Lilleshall Co., Ltd.	Oakengates, Shropshire.
Mather & Platt, Ltd.	Salford, Manchester.
Moreland, Richard, & Son . .	Old Street, London, E.C.
Mumford, A. G.	Culver Works, Colchester.
Owens, S., & Co.	Whitefriars Street, London, E.C.
Pearn, F., & Co., Ltd.	West Gorton, Manchester.
Perry, T., & Sons, Ltd. . . .	Bilston, Staffordshire.
Robey & Co., Ltd.	Lincoln.
Scott, Ernest, & Mountain, Ltd.	Close Works, Newcastle-on-Tyne.
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Tangyes Limited.	Birmingham.
Thwaites Brothers, Ltd.	Thornton Road, Bradford, Yorks.
Uskside Engineering Co., Ltd.	Newport, Mon.
Vauxhall Ironworks Co., Ltd.	Wandsworth Road, London, S.W.
Warner, R., & Co.	97, Queen Victoria Street, London, E.C.
Willcox, W. H., & Co., Ltd.	23, Southwark Street, London, S.E.
Wilson, Alex.	172, Fenchurch Street, London, E.C.

PETROLEUM PUMPS.

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Hayward-Tyler & Co.	90, Whitecross Street, London, E.C.

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Bailey, W. H., & Co., Ltd.	Albion Works, Salford, Manchester.
Ellison, W. T., & Co., Ltd.	Manchester.
Evans, Joseph, & Sons	Wolverhampton.
Holden & Brooke, Ltd.	Sirius Works, Manchester.
Pulsometer Engineering Co., Ltd.	Reading and London.
Waterspout Engineering Co., Ltd.	Manchester.

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Duke & Ockenden	Littlehampton and London.

QUADRUPLE SEMI-ROTARY PUMPS.

Duke & Ockenden	Littlehampton and London.
Evans, Joseph, & Sons	Wolverhampton.

QUICKSILVER PUMPS.

Fraser & Chalmers, Ltd.	3, London Wall Buildings, London, E.C.

RAM PUMPS (*see* PLUNGER PUMPS).

ROPE DRIVEN PUMPS.

Bailey, W. H., & Co., Ltd.	Albion Works, Salford, Manchester.
Barclay, Andrew, Sons, & Co., Ltd.	Kilmarnock, N.B.

Campbell Gas Engine Co., Ltd. .	Halifax, Yorkshire.
Clarke, Chapman & Co., Ltd. .	Gateshead-on-Tyne.
Dudbridge Ironworks	Stroud, Gloucestershire.
Evans, Joseph, & Sons . . .	Wolverhampton.
Fielding & Platt, Ltd.	Gloucester.
Fraser & Chalmers, Ltd. . . .	3, London Wall Buildings, London, E.C.
Haste Patent Pump Co., Ltd. .	3, Crown Court, Old Broad Street, London, E.C.
Hathorn, Davey & Co., Ltd. . .	Sun Foundry, Leeds, Yorkshire.
Hayward-Tyler & Co.	90, Whitecross Street, London, E.C.
Pearn, F., & Co., Ltd.	West Gorton, Manchester.
Scott, Ernest, & Mountain, Ltd.	Close Works, Newcastle-on-Tyne.
Tangyes Limited.	Birmingham.
Uskside Engineering Co., Ltd. .	Newport, Mon.

ROTARY PUMPS.

Bailey, W. H., & Co., Ltd.. . .	Albion Works, Salford, Manchester.
Brackett, F. W., & Co. . . .	Hythe Bridge Works, Colchester.
Drum Engineering Co.	27, Charles Street, Bradford, Yorkshire.
Evans, Joseph, & Sons	Wolverhampton.

SEMI-ROTARY PUMPS.

Evans, Joseph, & Sons . . .	Wolverhampton.

SEWAGE PUMPS.

Barclay, Andrew, Sons & Co., Ltd.	Kilmarnock, N.B.
Davey, Paxman, & Co., Ltd. .	Colchester.
Fairbairn, Lawson, Combe, Barber, Ltd.	52, Lime Street, London, E.C.
Hathorn, Davey, & Co., Ltd. .	Sun Foundry, Leeds, Yorkshire.
Lilleshall Co., Ltd.	Oakengates, Shropshire.
Mather & Platt, Ltd.	Salford, Manchester.
Simpson, James, & Co., Ltd. .	Grosvenor Road, London, S.W.

SINKING PUMPS.

Bailey, W. H., & Co., Ltd. . .	Albion Works, Salford, Manchester.
Evans, Joseph, & Sons	Wolverhampton.
Hayward-Tyler & Co.	90, Whitecross Street, London, E.C.

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Pearn, F., & Co., Ltd.	West Gorton, Manchester.
Tangyes Limited	Birmingham.

SLIME PUMPS.

Coalbrookdale Ironworks . . .	Coalbrookdale, Shropshire.
Evans, Joseph, & Sons . . .	Wolverhampton.
Hayward-Tyler & Co.	90, Whitecross Street, London, E.C.

SLUDGE PUMPS (*see* SLIME PUMPS).

SPRAY PUMPS.

Bailey, W. H., & Co., Ltd. . .	Albion Works, Salford, Manchester.
Duke & Ockenden	Littlehampton.

SYPHON PUMPS.

Batchelor, R. D.	73, Queen Victoria Street, London, E.C.
Duke & Ockenden	Littlehampton and London.
Isler, C., & Co.	Bear Lane, Southwark Street, London, S.E.
Titt, James Wallis	Warminster.
Warner, R., & Co.	97, Queen Victoria Street, London, E.C.

TUBE WELL PUMPS (*see* ARTESIAN WELL PUMPS).

BAR PUMPS (*see* AMMONIACAL LIQUOR PUMPS).

TRIPLEX DIAPHRAGM PUMPS.

Duke & Ockenden	Littlehampton and London.

TWO AND THREE THROW PUMPS.

Bailey, W. H., & Co., Ltd. . .	Albion Works, Salford, Manchester.
Beck & Co., Ltd.	130, Great Suffolk Street, Southwark, London, S.E.
Evans, Joseph, & Sons . . .	Wolverhampton.
Hayward-Tyler & Co.	90, Whitecross Street, London, E.C.
Jackson, P. R., & Co., Ltd. . .	Salford, Manchester.
Pearn, F., & Co., Ltd.	West Gorton, Manchester.
Scott, Ernest, & Mountain . .	Close Works, Newcastle-on-Tyne.

Tangyes Limited	Birmingham.
Warner, R., & Co..	97, Queen Victoria Street, London, E.C.

WALL PUMPS.

Bailey, W. H., & Co., Ltd. . .	Albion Works, Salford, Manchester.
Evans, Joseph, & Sons . . .	Wolverhampton.
Hayward-Tyler & Co.	90, Whitecross Street, London, E.C.

WATER WHEEL PUMPS (*see* WIND MOTOR PUMPS).

WELL PUMPS (*see* ARTESIAN WELL PUMPS).

WIND MOTOR PUMPS.

Duke & Ockenden	Littlehampton and London.
Picking, Hopkins & Co. . . .	Arnold Works, Bow, London, E.
Titt, James Wallis.	Warminster.

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