REPORT

ON

STEAM-PUMPS AND PUMPING ENGINES,

BY

F. R. HUTTON, M. E.,
SPECIAL AGENT.

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PART I.

STEAM-PUMPS.

INTRODUCTORY.

A steam-pump is a steam-engine whose load is the resistance due to the work of displacing fluids under a pressure or head. Hence the distinction between the steam-pump and the pumping-engine must be entirely conventional. By common consent, the term "steam-pump" is applied to the smaller engines whose work is subsidiary to that of a large establishment. The term "pumping-engine" is restricted to those larger and more elaborate designs, where the amount of fluid to be displaced is so large that the pumping machinery becomes of primary importance. The "pump" of a water-works, of a mine, or of a sanitary enterprise then becomes a "pumping-engine".

Following this purely arbitrary and conventional division, the class of steam-pumps will be discussed first.

The class of steam-pumps naturally divides itself into three sub-classes:

A. Reciprocating pumps.

B. Rotary pumps.

C. Direct-contact pumps.

Each of these has various subdivisions, under one or the other of which all the different forms can be included.

STEAM-PUMPS AND PUMPING-ENGINES.

PART I.

Class A.—RECIPROCATING PUMPS.

The class of reciprocating steam-pumps includes all those in which there is an alternate motion of a piston in a steam-cylinder. This motion is communicated by a rod to another piston or to a plunger, which displaces the fluid that enters its cylinder through the valves at either end alternately.

For convenience of discussion, these pumps may be classified as follows:

I. Crank and fly-wheel pumps.
II. Direct-acting pumps.
III. Duplex pumps.
IV. Cam pumps.
V. Spring pumps.

The most essential differences in these pumps are caused by the differing methods for controlling and actuating the steam valves. They have many parts and features so much in common that it seems wise to note them first, and to pass afterward to the points of divergence.

All have a steam-cylinder, truly bored, and fitted with the piston upon whose alternate sides the steam is to act. To compensate for wear and for expansion, this piston has to be fitted to the bore of the cylinder by packing-rings, which shall by their elasticity prevent leakage of steam from one side of the piston to the other. In some cases, plain cast-iron rings are used in grooves in a solid piston, the elasticity of the rings themselves serving to keep the rings in contact with the bore (Fig. 49). They are turned a little too large for the bore, a diagonal cut is made at one point, and the rings are sprung in place. Other makers use steel or brass rings, similarly made (Fig. 1). Others again put a brass spring-ring inside the packing-rings proper, to force them outward (see Fig. 6), while a few use manufactured packings of some fibrous and elastic materials, such as canvas and rubber. In a few cases, also, the regular locomotive-piston principle is used (Fig. 2). The piston consists of piston and follower bolted together, the rings being forced out by elliptical springs between the arms of the spider. The springs are adjustable between jam-nuts upon studs, to vary the pressure upon the double set of rings. A few use spiral springs (Fig. 56), and steam-packed pistons are also in use (Fig. 3).

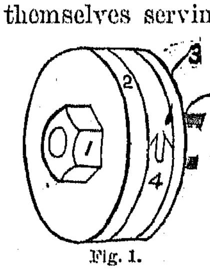

Fig. 1.

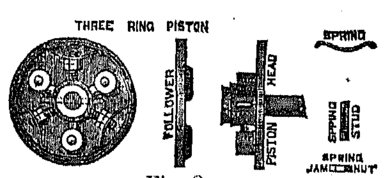

Fig. 2.

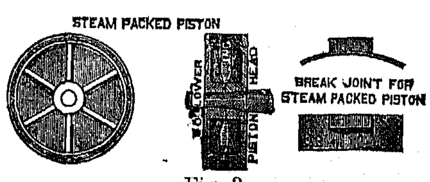

Fig. 3.

The steam-piston is secured to the piston-rod, in the great majority of cases, by a nut (Figs. 1 and 7). The end of the rod is tapered and threaded, and a nut secures all in place (Fig. 56). In a few instances the end of the rod is headed over so as to rivet the piston in place, but it is usually thought desirable to have the joint between them more easily broken.

The piston passes out through a stuffing-box in the steam-cylinder and through a similar stuffing-box into the water-cylinder. Fibrous or manufactured packing is used in these stuffing-boxes, metallic packing not having been applied upon a large scale as yet. The glands are tightened by two bolts almost universally, these bolts being so disposed that the sides of the cradle shall not interfere with the wrench which should turn the nuts upon them. For valve-stem stuffing-boxes the cap-nut over the gland is very general (Fig. 4). One or two only use that arrangement for the piston-rods.

In the water-cylinder there will be either a second piston fitting the bore (Fig. 45), or else a plunger of less diameter than the bore, fitting a gland (Fig. 54). Circumstances must determine which will be best for any given case. When the water is dirty or gritty, a piston sweeping over the silt in the bottom of the cylinder wears out both surfaces rapidly. A plunger protruding through a stuffing-box tends to free itself from solid particles, and the bore of the cylinder is untouched. A piston-pump has a small clearance volume, and therefore can lift water from a depth more rapidly than a plunger-pump, where there is much more air left in the cylinder to expand after each stroke. The plunger acting by positive displacement is well adapted for forcing under high heads and resistances. On small short-connected pumps the plunger is often single-acting, lifting and forcing alternately. In larger pumps, the water-end is in two parts, with stuffing-boxes facing each other in the opening between them (Fig. 35). The plunger moves in and out of each, driven by a rod through the inner head. This necessitates three stuffing-boxes. In another arrangement there are two plungers, connected together by rods upon the outside. The plungers enter the water-cylinder through glands at each end, and there is a partition in the middle so that the lifting and forcing may be continuous. Another plan is to have one plunger passing through a gland in this partition in the middle of the water-cylinder (Fig. 54). The piston-rod is attached to one end of the plunger, entering the water-cylinder through a stuffing-box. The two halves of this cylinder will therefore be filling and emptying alternately, producing thus a continuous flow. If elastic packing is used for the gland in the partition, it is apt to make the plunger wear small in the middle where its surface is most frequently rubbed. It is also difficult to tighten the gland if there is leakage. Some prefer an inelastic metallic ring closely fitted.

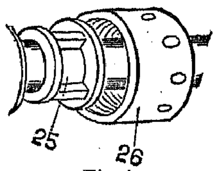

Fig. 4.

A further advantage of the plunger system is that the area of the water-plunger can be varied relatively to the area of the steam-piston without involving the change of the whole water-end of the pump. This change in relation of areas may be called for by increased or by diminished head or resistance upon the delivery. Plungers of different diameter can be introduced, and nothing but glands and stuffing-boxes need be altered. Moreover, to turn and fit the plunger and the glands when worn is much easier and cheaper than to disconnect and re-bore the cylinder. The plunger is much lighter and more portable than the cylinder and attachments, and also where resources are limited, outside turning is more feasible than inside boring. One designer combines the piston and plunger arrangement in what is known as the bucket-plunger pump (Fig. 5). The part of the piston-rod which

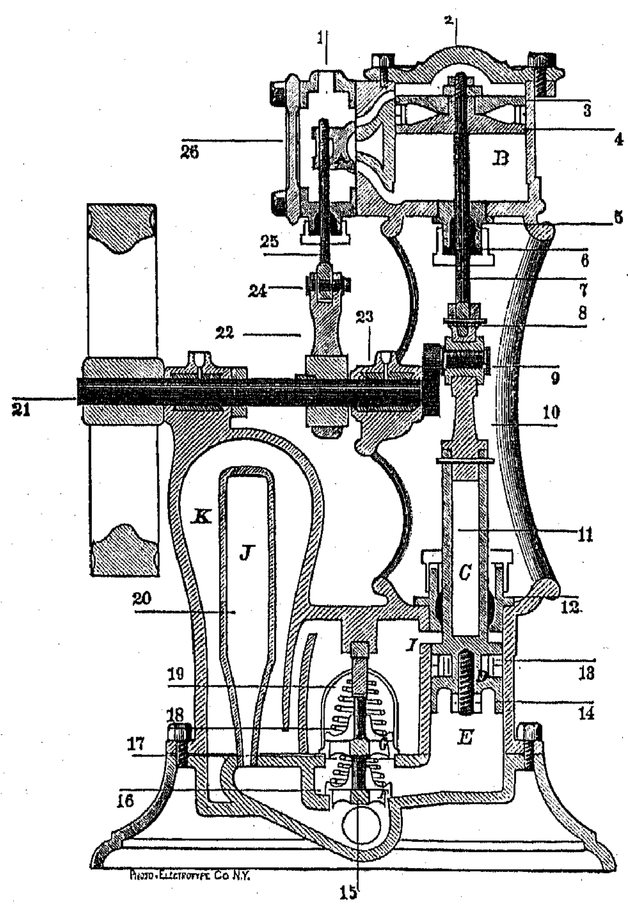

Fig. 5.

enters the cylinder is a plunger of one-half the area of the piston. The whole volume of the cylinder is filled from the suction upon the upward stroke of the piston. Upon the downward stroke, this water is discharged through the delivery valve. The upper end of the working barrel is in direct communication with the delivery-passages, so that one-half the capacity of the cylinder enters above the piston around the plunger, the other half only being forced into the pipes. On the upward stroke the piston displaces the water above it, and fills again below. The pump is therefore single-acting in sucking, but double-acting in forcing. It delivers one-half the capacity of the cylinder at each stroke. To accomplish a similar purpose, and at the same time to avoid any change of direction of the currents of water, is the object of the tubular pump shown in Figs. 6 and 7. At the extreme left is the

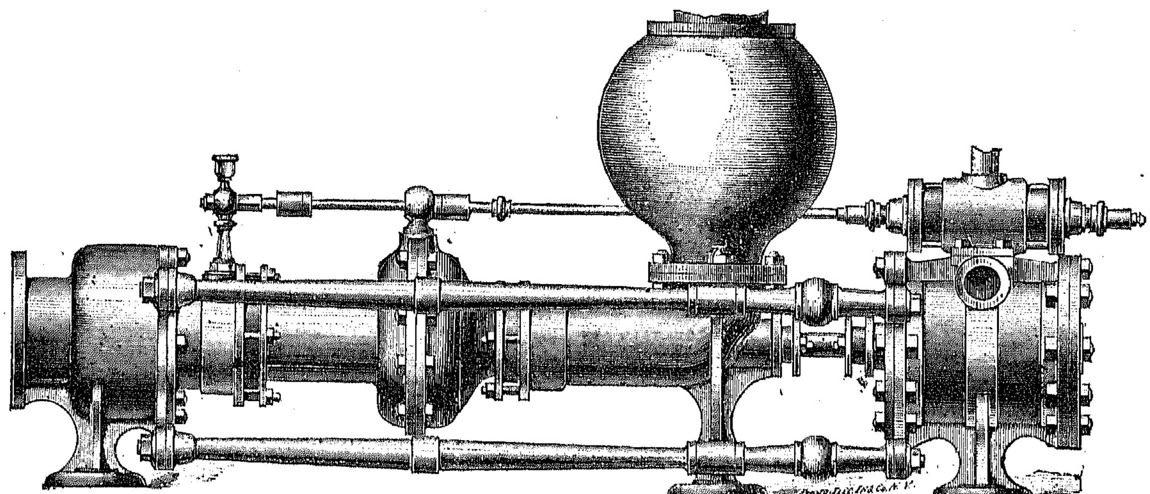

Fig. 6.

large foot-valve on the suction-pipe, through which the fluid enters and fills the large hollow plunger A, up to the central valve. Upon the return of this plunger the central valve is opened and the fluid passes into the smaller tube B. The capacity of B is one-half that of A, and hence the excess must pass out through the discharge-pipe.

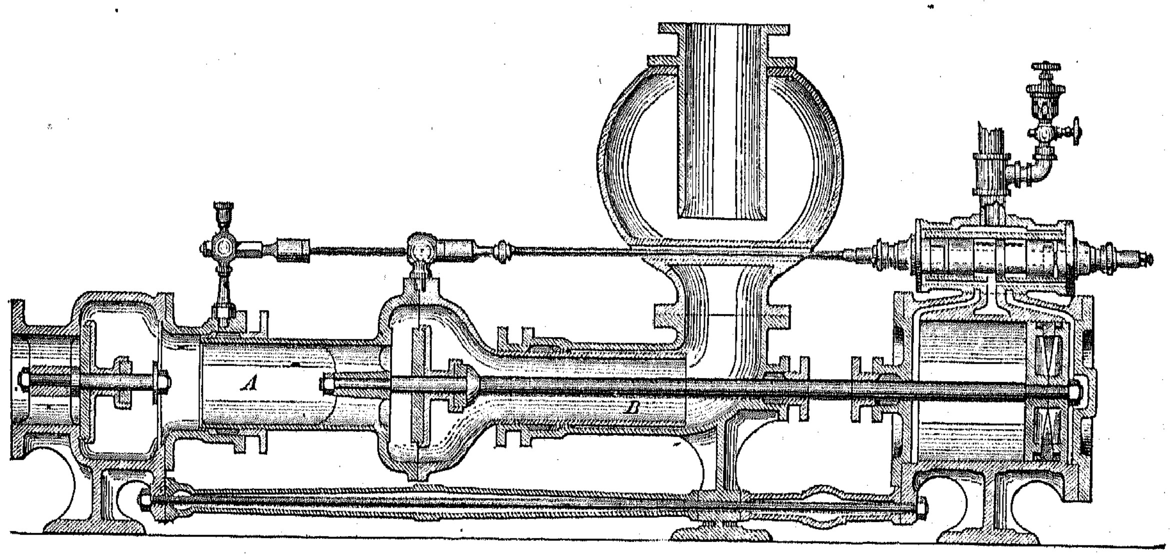

Fig. 7.

Upon repeating the first stroke, the volume of the smaller tube B is again displaced while the larger tube is being filled. Hence the capacity of the pump at each stroke is that of the smaller reciprocating tube.

For the packing of water-pistons, either cup-leathers (Fig. 8), square rubber (Fig. 9), or some of the patent

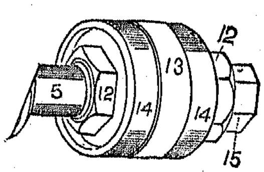

Fig. 8.

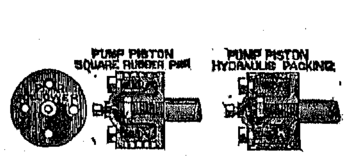

Fig. 9a.

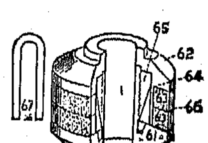

Fig. 9b.

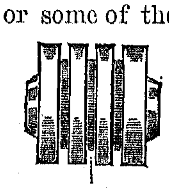

Fig. 9c.

packings are preferred. Brass rings are sometimes used, especially for hot water or acid pumps, and in many cases simple grooves are turned upon the surface of the piston (Fig. 9*c*). These grooves fill with the fluid being pumped, and prevent any leakage from one side to the other during a stroke. This form of piston depends upon the principle that a fluid leaking into the first groove through the small passage between piston and bore must there accumulate pressure before it will leak into the second groove through a similar small passage. The groove, being relatively large, requires an appreciable time to fill, and the piston will have made its stroke before all grooves are filled, and leakage begins into the suction side. For the plunger stuffing-boxes, elastic fibrous or manufactured packings are preferred.

There must be two sets of water-valves at each end of the cylinder of a double-acting pump. One set must open upon the lifting-stroke at each end, and the other set must open upon the forcing-stroke. With respect to their position relatively to the barrel there are four types of practice. In one case they are put at the side of the cylinder (Fig. 49), in the second upon the top (Fig. 10), in the third upon the ends, and lastly on both top and bottom. The

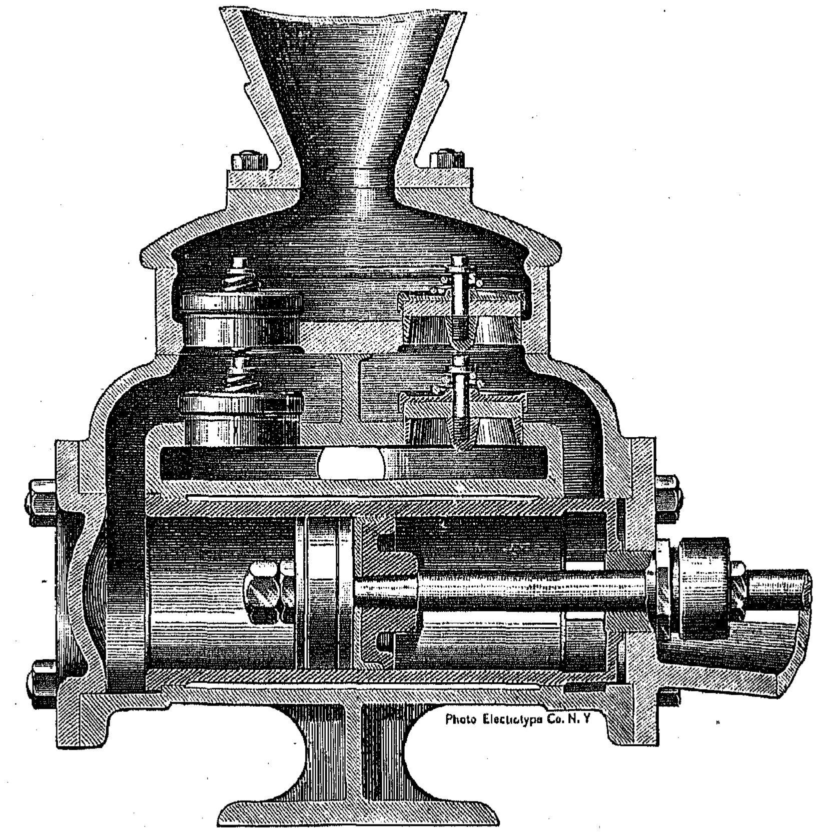

Fig. 10.

suction-valves are nearly always put directly under the delivery-valves (Fig. 10). The space between the two connects with the pump-barrel at each end, and a partition separates the sets which act on the forward and backward strokes. There is but one design having the valves in the cylinder-heads (Fig. 46). A great deal of attention has been paid to the matter of removable bonnets to permit easy access to the water-valves for cleaning and repair. In the forms where the valves are upon the side of the cylinder and the stroke is short, the whole side of the casing can be taken off (Fig. 49), being secured by stud-bolts and nuts. The bonnet and chamber surfaces are faced and the bonnet is recessed, so that a joint may be made water-tight without a gasket or other form of packing. Where the stroke is longer, the bonnets are often faced disks opposite each pair of valves, secured by studs like a cylinder-head. In one form the valves are in tubular chambers at each end, which can be opened by taking off their lids (Fig. 35). These lids are either screwed plugs or bolted covers.

Where the valves are on the top of the cylinder there must be differences according to the construction. In many forms the suction-valves are in a flat plate directly above the cylinder. Upon this plate fits a box. The delivery-valves seat upon a partition in this box, and over all fits the cap of the pump carrying the air-chamber. In other forms a plate for the seating of the delivery-valves covers the solid box in which are the suction-valves, and the cap fits close upon the plate (Fig. 32). In another type the seatings for both sets of valves are cast with the cylinder, and the lower valves and removable seats are put in place through the upper plate (Fig. 42). The cap, as before, fits on this top plate. This, of course, avoids one joint. In any of these latter cases the removal of the whole cap permits access to the valves. It is held down by tapped studs and nuts, or else in newer practice by eye-bolts, which swing out and down out of the way when the nuts are loosened (Fig. 34). The bolts and nuts cannot be mislaid or lost, as none are removed altogether from pump or bolts, and the nuts need be unscrewed but a little to release the cap. An especial point with regard to these bonnets is that they shall permit access to the valves without causing interference with the piping to or from the pumps. In the larger pumps with this type of water-end, separate bonnets are called for, because of the size and weight of the caps.

It is practically universal to use inserted valve-seats for the water-valves (Fig. 10). These seats are brass gratings fitted to the casting of the cylinder either by being screwed, keyed, or forced into place, or else are held in place upon a ground surface by a cage or the valve-spindle. The practice of screwing in the seat is objected to on the ground of the tendency of such seats to work loose, permitting corrosion of the threads. Forcing or driving them in place is more usual, the castings being bored with a slight taper. In a few cases, after screwing or forcing the seat into place, a taper pin or key is driven in to prevent loosening from the shocks of the valves and water. There are advantages in favor of the ground-joint with cage or spindle to hold the seat in place. The valves must be over each other. After the lower seat and valve and spring are in place a brass cage is put over the valve, guiding the spindle (if any is used) and resting upon the seat outside of the valve. This open cage is held in place by the bottom of the seat of the upper valve, and is thus kept from moving. This upper valve-seat is kept down by a similar cage, which is held from rising either by a key driven between the cage and a boss on the casing (Fig. 5), or else by the end of a bolt tapped through the casing from the outside (Fig. 56). Where, as is frequently the case, this bolt is in the center of the bonnet, the removal of the bonnet loosens all the valves and seats and permits easy inspection or renewal, whether the defect be of valve or of seat. This replacing of a seat cannot be so readily done in other arrangements. In some forms the seats are held in place by a spindle which enters a step in the lower seat, and has a collar or shoulder to secure the upper seat (Fig. 49). Some secure the lower seat, and have the shouldered spindle screw into the center of the lower seat, thus confining the upper. The valves are then independent of the cap.

Rubber is used almost universally for the valves themselves in cold-water pumps. Many purchasers prefer brass for valves in hot water, but a large number of makers are using a rubber composition made for this purpose, and especially hard and resistant to heat. The small rubber valves are simple disks with a hole in the center through which passes the stationary guiding spindle (Fig. 12). This spindle is often a simple brass bolt, screwing into the seat. Its head serves as abutment for a spiral brass or steel spring which presses upon the top of the valve to prevent it from rising too high and to close it promptly. Where there are cages there need be no spindle, or if there are shoulders upon a long spindle they may receive the thrust of the springs. In some of the larger valves the back of the valve is reinforced by a metallic plate or grating to receive the greater pressure of the spring and to stiffen the valve. The back of the valve is either specially shaped to retain this plate, or else the valves are moulded around it by the manufacturer.

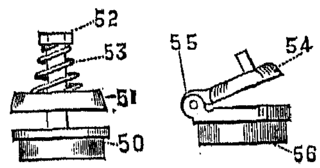

Fig. 12.

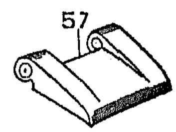

Fig. 13.

Brass valves have their guiding spindles cast with them, sliding in a caging either above or below the valves, or both. There are very few makers who use any other form of valve. Two use a hinged valve of rubber with metallic backing (Fig. 13), and one uses square prisms guided by the walls of the casing (Fig. 36). There is a wide divergence of practice with respect to the area of the valve-openings relatively to the piston-area. In some cases the valve-area is only one-third of the piston-area for low-speed pumps. In other patterns the valve-area is one-half, six-tenths, or two-thirds of the piston-area. The newest practice where patterns have been changed and improved is to give a valve-area equal to that of the piston or even greater, especially in pumps for high speed. This avoids the high velocity and pressure through the valves, permitting a less lift, and causing less jar in the seating. It is also more certain that the barrel will be filled at each stroke.

There is no less divergence with respect to the number and the diameters of the single valves which make up the aggregate area. Some use several small valves, three inches in diameter or less, while others prefer a few valves of large diameter, using eight-inch valves in some cases. There are advantages connected with each system. A disk-valve can be shown, by a simple calculation, to be able to discharge its maximum quantity when it has risen from its seat a distance equal to its radius. Then the area of the cylindrical opening between valve and seat will be equal to the area of the circular opening of the seat. In theory, therefore, a large valve should lift farther from its seat than a small one if the passage of the water is not to be impeded. But a high lift of water-valves means a loss of efficiency from leakage before the valves close; and also there will be violent shocks from the blow of the valve as it is brought up against its seat by the outrushing water. These shocks will loosen all joints and wear out all connections. High lifts of valves are, therefore, to be avoided to insure quiet working, and this is to be attained by the use of small valves where the lift can be very much reduced without loss. The small valves on the suction side act as a strainer to prevent large obstructions from reaching the cylinder, where they might do great harm.

On the other hand the use of few valves reduces the number of parts in a pump, reduces the amount of space required for the valves in the water-end, permits easy and direct access to all valves when the bonnets are removed, and diminishes the chances for leakage of valves by diminishing their number.

Average practice for small pumps will be found to favor one or two valves for suction and for delivery at each end of the cylinder, of a diameter suited to the capacity of the pump, lifting from three-sixteenths of an inch to five-eighths, according to size and speed of the piston.

The air-chamber is an almost universal feature of the water-end of a steam-pump. The only exceptions are found in a few boiler feed-pumps, where the resistance to the plunger is an elastic tension of steam, and in some of the forms of plunger mining-pumps. The function of the air-chamber is to serve as an elastic cushion to start gradually the motion of the water-column from rest, and also to keep up the flow steadily from the delivery-pipe by the expansion of the imprisoned air.

Upon horizontal pumps the air-chamber is carried upon the top of the water-chamber, either cast as part of the lid of the valve-chest (Fig. 37) or bolted or screwed to it (Figs. 10 and 45). When screwed to the lid it is often made of copper. There is, however, great variety in form, from the cast- or wrought-iron cylinder with rounded or flat top (Fig. 14) to the spherical globe (Fig. 46). The prevailing form is the conical with a rounded top (Fig. 47), passing into an elongated pear-form in some designs. This form is easy to secure to the cap, and offers a larger water-surface to the inclosed air. In the designs where the valves are reached through bonnets, the delivery-pipes start from the base or the neck of the chamber. Where the whole cap is removed, the pipes have to be connected to outlets from the cylinder casting below the joint with the valve casing, otherwise a pipe-joint must be unmade in order to obtain access to the valves. An air-chamber on the suction-pipe (or a vacuum-chamber, as it is often called) is sometimes added, where the mass of water in the suction-pipe is considerable (Fig. 38). This will be the case with high lifts, or where there are long reaches of horizontal pipe through which water passes to the pump. The vacuum-chamber will also be judicious where the water is delivered to the pump under a head or at high speed. Its object is to bring to rest the moving mass of water when the suction-valves close, without jar to pipes or valves. The inertia of the column is arrested gradually by the air-cushion in the vacuum-chamber instead of expending itself all at once in a blow against the valves. Hence it would seem that the most expedient place for this chamber would be close to the valves, and in a prolongation of the direction toward which the water was moving when the valves closed. In this situation it will be most efficient. Very often, however, this chamber is simply a long plugged nipple from a T in the suction-pipe and at some distance from the valves. One maker casts the bonnets and walls of the suction volume of the water-end with large recesses in them (Fig. 17). These are filled with air, and being close to the valves would appear to be very efficient for the purpose intended.

Certain modifications are made upon the typical forms to adapt the pumps for special duties. The usual relation of areas of steam-piston to water-piston is as one is to three or four, for tank or general purposes. This will be varied according to the head against which the pump is to work. For air-pumps the ratio will often be reversed. For acid or mine waters, a removable lining will be used in the water-end of brass composition, or copper, or other non-corrodible metal. This lining is secured in place in a variety of ways. In some cases it is cast with a flange at one end, of which the holes fit over the studs in the cylinder-flange, and the cover holds all in place. Ports in the bore of the lining permit the water to pass into the passages to the valves at each end. It is important in this arrangement to have the studs equidistant, in order that the lining may be revolved in place so as to expose a fresh part to the wear of the grit on the bottom by the piston. Another arrangement is to secure the lining to the inner head (Fig. 10). A boss threaded on the outside passes through the head, and a nut and gasket on the outside clamp the lining to the head. The boss forms the stuffing-box for the main rod. The other end of the lining abuts against a counter-bore near the outer cylinder cover. Still another way is to insert a plain cylinder, and after it is in place to expand it by blows from a hammer upon the bore. This pening stretches the inner skin, enlarging the diameter and making the contact with the iron very close. For plunger-pumps this needs no further treatment, but for piston-pumps the bore is trued out by a very light cut, which does not go sufficiently deep to release the strain of the skin.

Further minor modifications will be called for by special industries. To pump active acids will require a pump entirely of composition; to pump ammonia demands a pump entirely of iron. Often an air- and water-pump will both be driven by the same piston-rod. Several makers have put upon the market a vacuum-pump in which the acting piston is a surface of water which is alternately raised and lowered by the protrusion and withdrawal of a plunger working below the surface. Pressure-pumps for transmitting and storing power for hydraulic machinery, and oil-line pumps, also demand certain departures from the conventional forms to fit them for the requirements of their several duties.

1.—CRANK AND FLY-WHEEL PUMPS.

This type of pump results very directly from the desire to adapt the ordinary steam-engine for pumping purposes. The cross-head, connecting-rod, and crank of the typical engine are retained (or what may replace them), and the pumping-piston is secured to a direct or indirect prolongation of the steam-piston rod.

This form of pump has several advantages. The living force stored in the fly-wheel will carry the reciprocating parts past the centers, and therefore the ordinary slide-valve can be used on the steam-cylinder. Moreover, the valve can be driven positively by an eccentric on the rotating shaft. There will, therefore, be no danger at ordinary speeds of the "stalling" of the pump with the valve covering both steam-ports. The valve also is not liable to fail to operate because small steam-passages have become clogged by gummed lubricant. A second advantage is that the pump-stroke is of positive length. The throw of the crank determines the travel of the pistons, and hence there is no necessity for large percentages of clearance to prevent an overstroke from injuring the cylinder-heads. The whole length of the pump-barrel must be swept through at every stroke. This avoids the losses of efficiency due to partial strokes which are occasionally made by pumps whose stroke is controlled by steam only. This type of pump can also be run very fast for the same reasons. A third advantage is that the fly-wheel and attachments serve as a reservoir for work imparted to them during the first half of a stroke which must be given out during the latter half. Hence the steam can be worked expansively in the cylinder, from which results a saving of fuel.

Moreover, by the use of the slide-valve controlled by an eccentric or crank, the steam is gradually admitted to the piston as the port-opening increases. By this means is avoided some of the shock of impact of steam upon the piston-head, and the pump reciprocates more quietly. Also, the simplicity of the valve-gear reduces the number of its parts, and renders it intelligible to a man of limited resources and reparable by him in case of injury.

Again, the less velocity of the water-piston at the beginning and at the end of a stroke permits the water-valves to seat themselves with less jar than when the piston starts from rest with its full velocity.

The disadvantages of the fly-wheel pump are—

First, that it cannot be made to run very slowly. There must be a sufficient number of strokes per minute to keep the rate of the fly-wheel from falling below a certain minimum, or else the pump will stall.

Secondly, the inertia of the fly-wheel will carry forward the reciprocating parts, and the water-column crashing through any obstruction which may have come in by the water-passages. Fracture of some part is very likely to result.

A third objection to this form of pump is the varying velocity imparted to the water column by the varying velocity of a piston whose motion is controlled by a uniformly-revolving crank. There will be irregularity of flow, and consequent strain upon the forcing-pipe as a result of this.

Moreover, the pump will not start itself from rest when "centered", or on the dead-points, or when the steam-valve covers both parts. The fly-wheel must be turned over by hand in this case, which makes it necessary that the pump be in an accessible place.

The valve for distributing steam to the two ends of the steam-cylinder is the plain flat slide-valve in nearly all cases. In one or two designs the valve is of the balanced type, to relieve the pressure upon the seat. Usually, however, the valve-area is small and balancing is thought unnecessary. When balanced, the valve is of the piston form. The valve-seat is put either upon the top or upon the side of the steam-cylinder in horizontal pumps. There are advantages in having the steam-chest upon the side, first, because the condensed water in the cylinder will escape naturally into the exhaust-passage through the ports, and, secondly, because the valve-rod enters the stuffing-box in the plane of the crank-shaft, so that no rock-shaft is required to transmit motion from the eccentric. The relief of condensation into the exhaust avoids the use of drip-cocks with either their multiple connections to drains or else their "sloppiness". One of the vertical pumps accomplishes the same purpose by using steam passages of unequal length (Fig. 28). The valve-stem is usually guided by the stuffing-box alone. In the pumps with short connections (Fig. 5) the eccentric-rod is usually cast as part of the strap, and connects with the valve-stem by a pin-joint. The strap is made wide and solid. Where rocker-arms are used, they are either levers of the third order, pivoted at one end (Fig. 14), moved by the eccentric in the middle, while the valve-rod is attached to the free end, or else they are levers of the first order, the eccentric-arm hanging down and the valve-arm pointing up (Fig. 18). In two cases the rock-shaft passes into the chest through a stuffing-box, and moves the valve inside by a finger (Figs. 16 and 22). There is but one case of a long guided valve-stem.

These fly-wheel pumps are made both horizontal and vertical. There are several types of arrangement of parts of the horizontal pump, of which Fig. 14 illustrates one design. The steam and water piston-rods are in the same

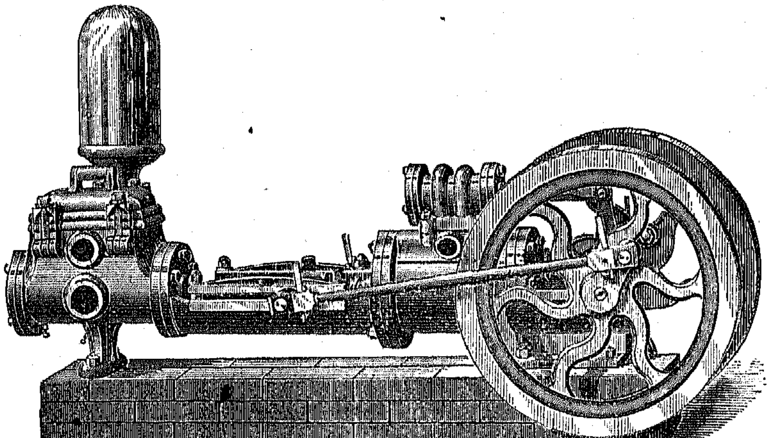

Fig. 14.

line, and are connected together by being keyed into a horizontal cross-head between the two cylinders. This cross-head slides between guides, and is quite long at right angles to the rods. The ends are turned to serve as cross-head pins for the ends of two connecting-rods. These latter connect to crank-pins upon the spokes of two overhanging fly-wheels upon a shaft behind the steam-cylinder. The slide-valve is driven by an eccentric in the middle of the shaft, from which motion is carried to the valve-stem by a rocking arm pivoted below. The

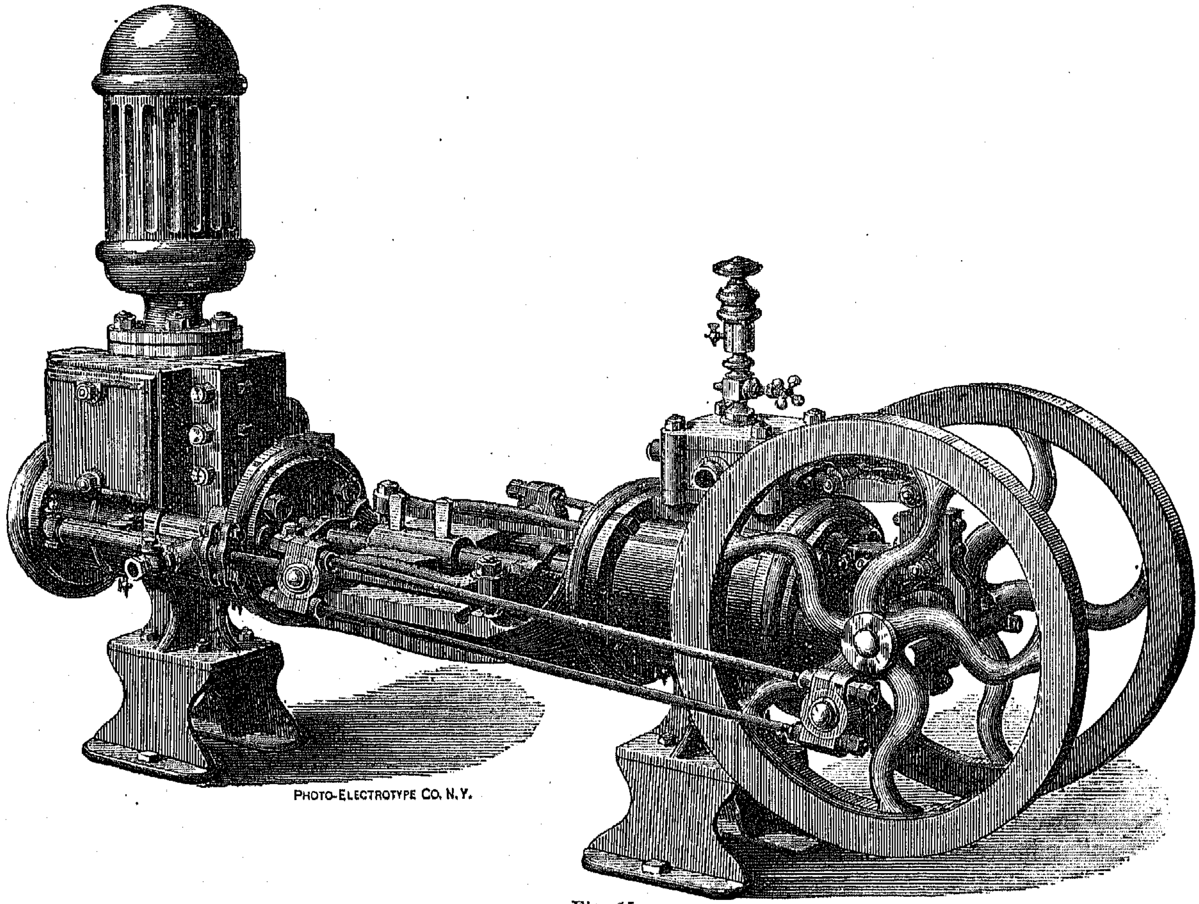

Fig. 15.

disadvantage of this arrangement is that access to the rear head of the steam-cylinder can only be had by taking that end of the pump apart. A similar design is shown by Fig. 15. The valve is worked by a yoke-motion.

Fig. 16 shows a modification of these designs.

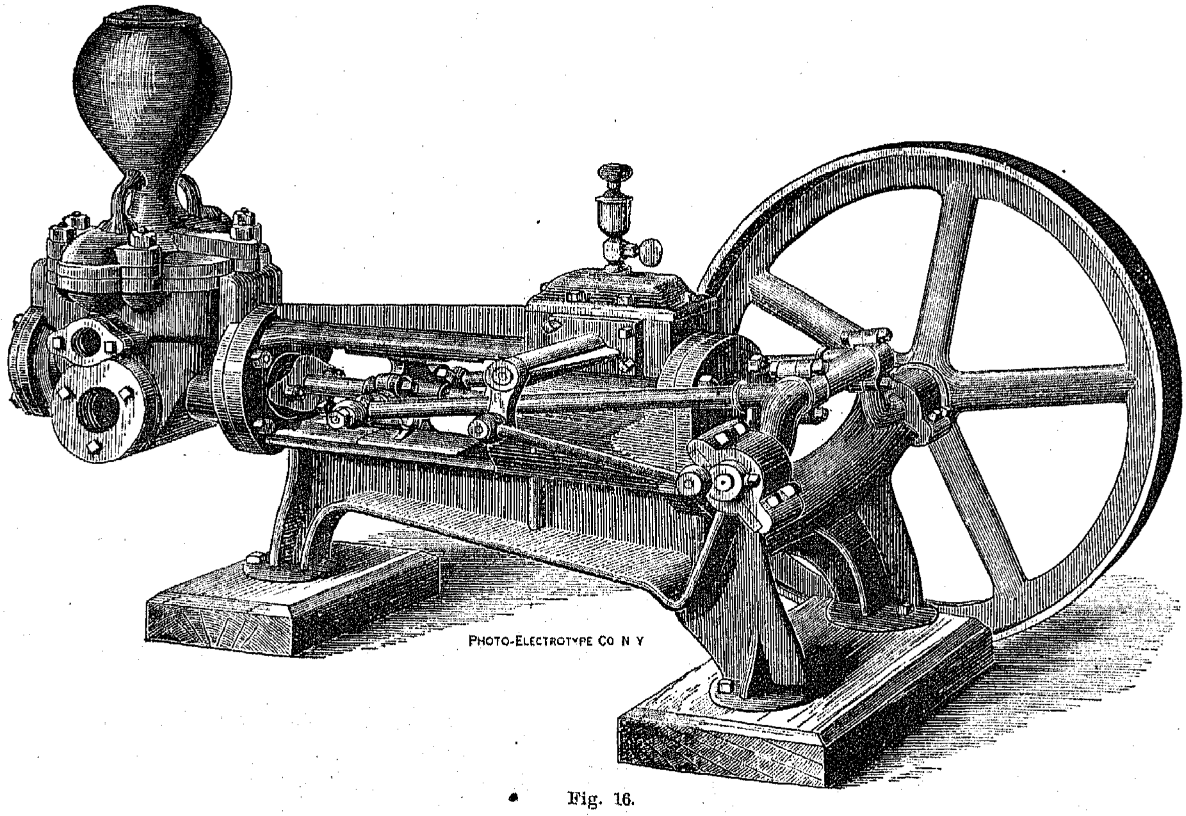

Fig. 16.

A second design is illustrated by Fig. 17. The two fly-wheels are keyed on a shaft which is carried upon the cradle between the two cylinders. The long cross-head is at the back of the steam-cylinder, driven by a

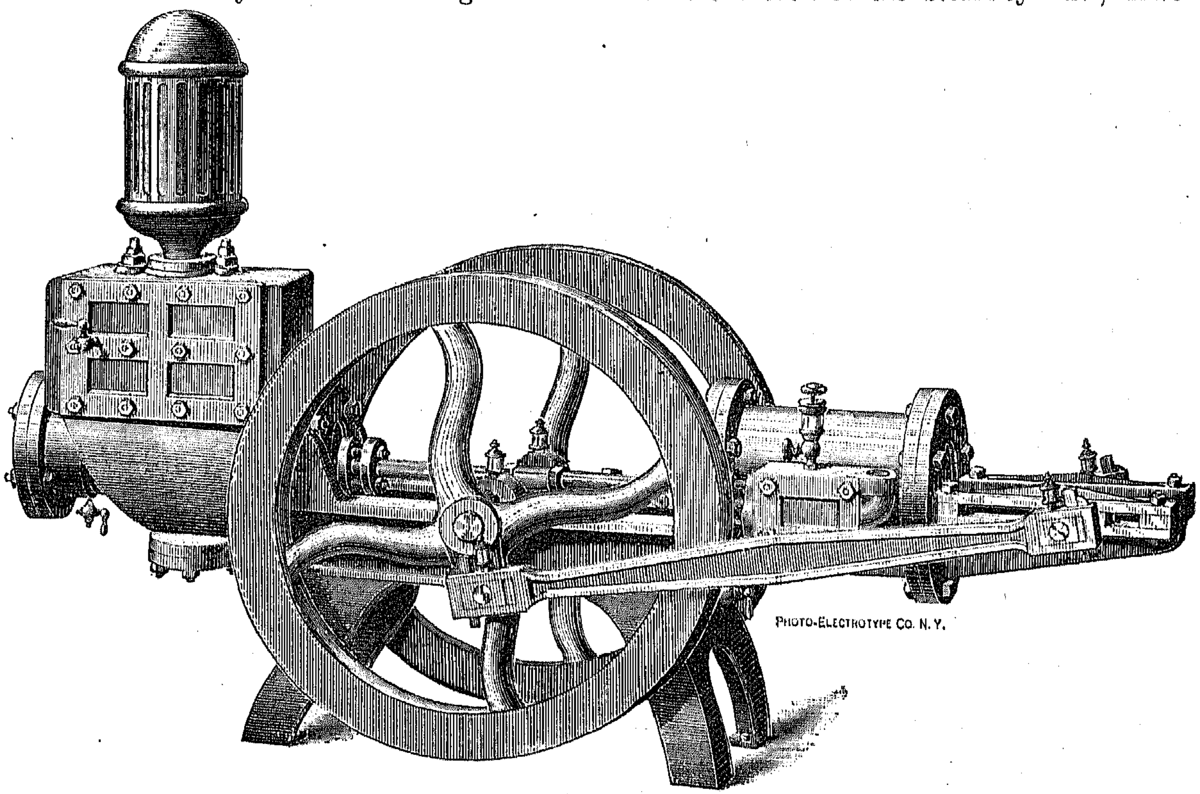

Fig. 17.

prolongation of the steam piston-rod through the back head. The same arrangement of outside connecting-rods is here used, and the slide-valve on the side of the steam-cylinder is driven directly from the eccentric. From the necessity of having the piston-rod cross the fly-wheel shaft, it will be seen that the dead-point of the cranks does

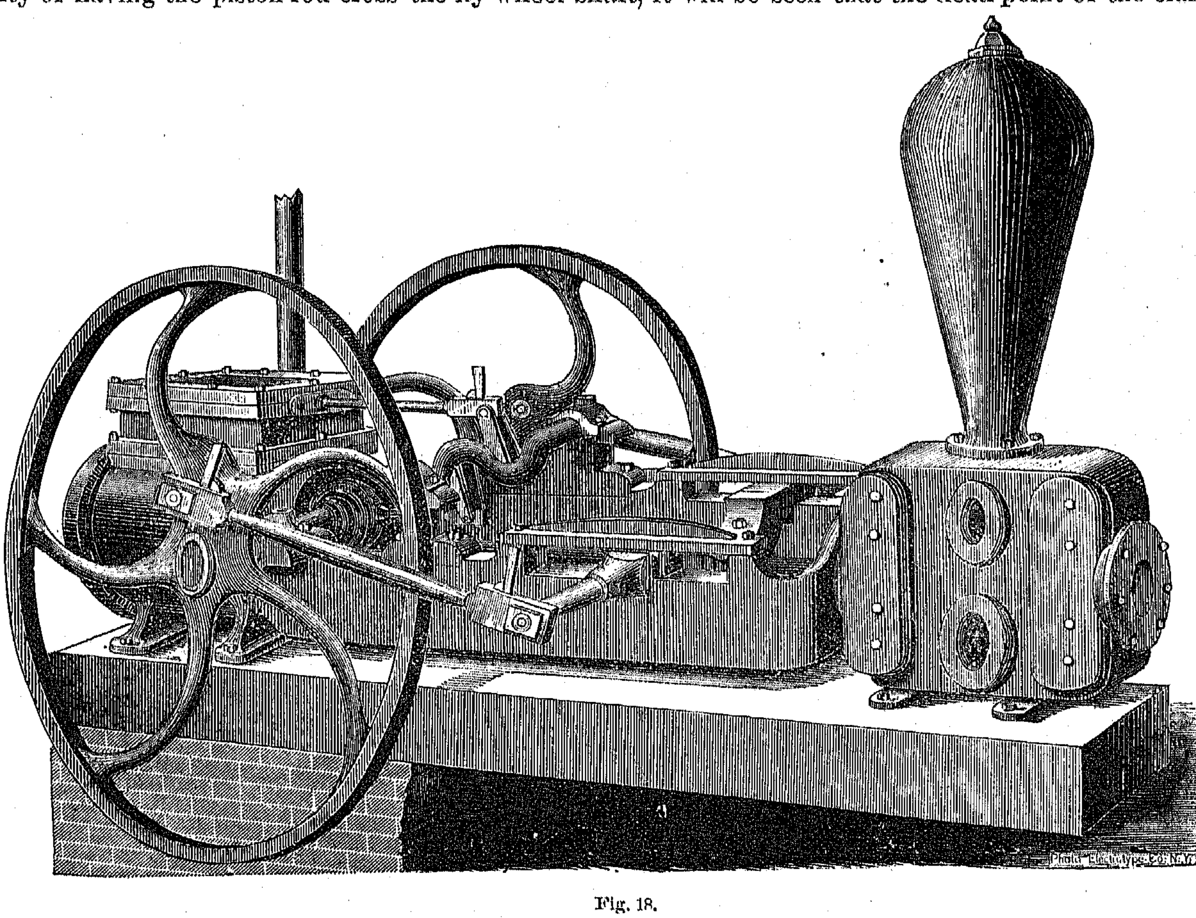

Fig. 18.

not coincide with the end of the piston-stroke, and consequently the danger of stalling is diminished at low speeds. This advantage is common to all pumps which have this feature.

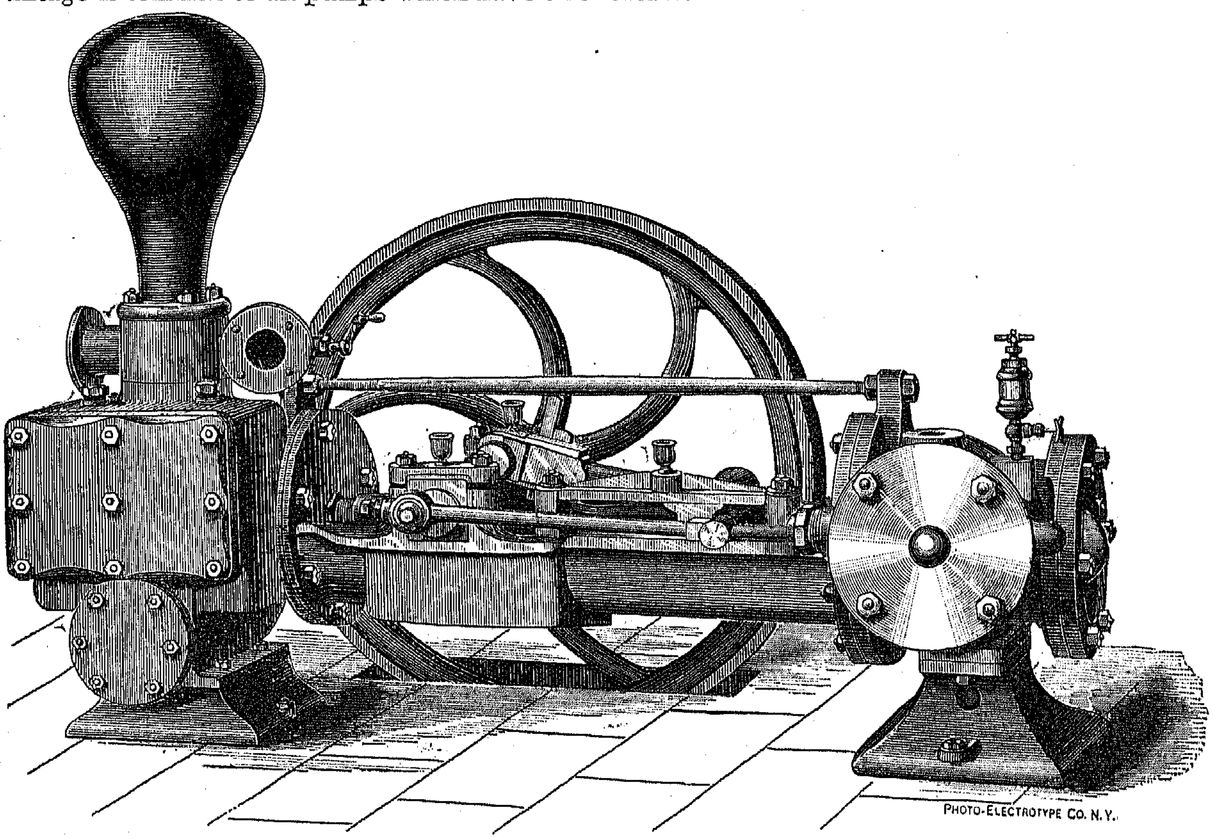

Fig. 19.

In the next type, shown in Fig. 18, both cross-head and fly-wheel shaft are between the cylinders. The continuous piston-rod passes below the shaft, and the valve is driven through a rock-shaft and arms. This arrangement permits easy access to the cylinders.

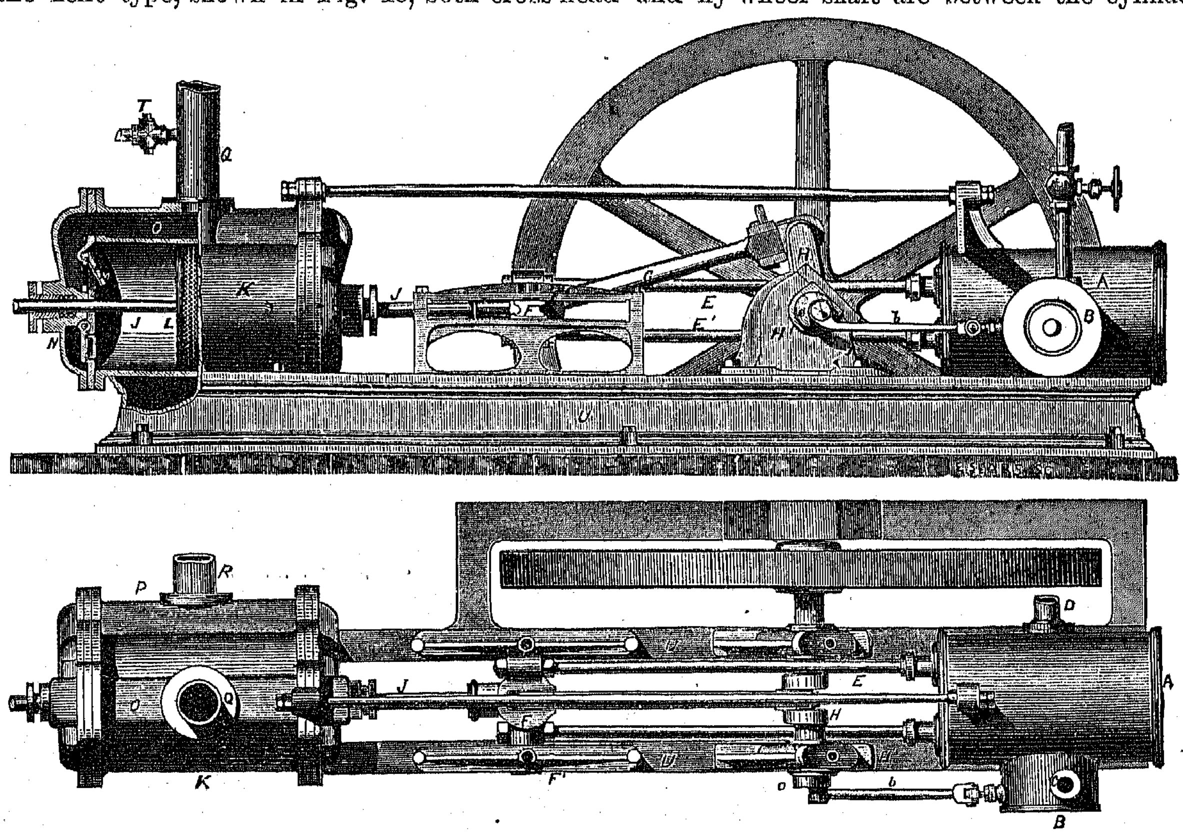

Fig. 20.

A modification of this type, using only one fly-wheel, and with the mechanism inside the cradle, is shown in Fig. 19. The cross-head is guided upon one side only, the double crank revolving at the side of the piston-rod, which passes under the shaft. A short connecting-rod unites the crank to the cross-head, and the valve is driven from a crank-pin on the end of the fly-wheel shaft.

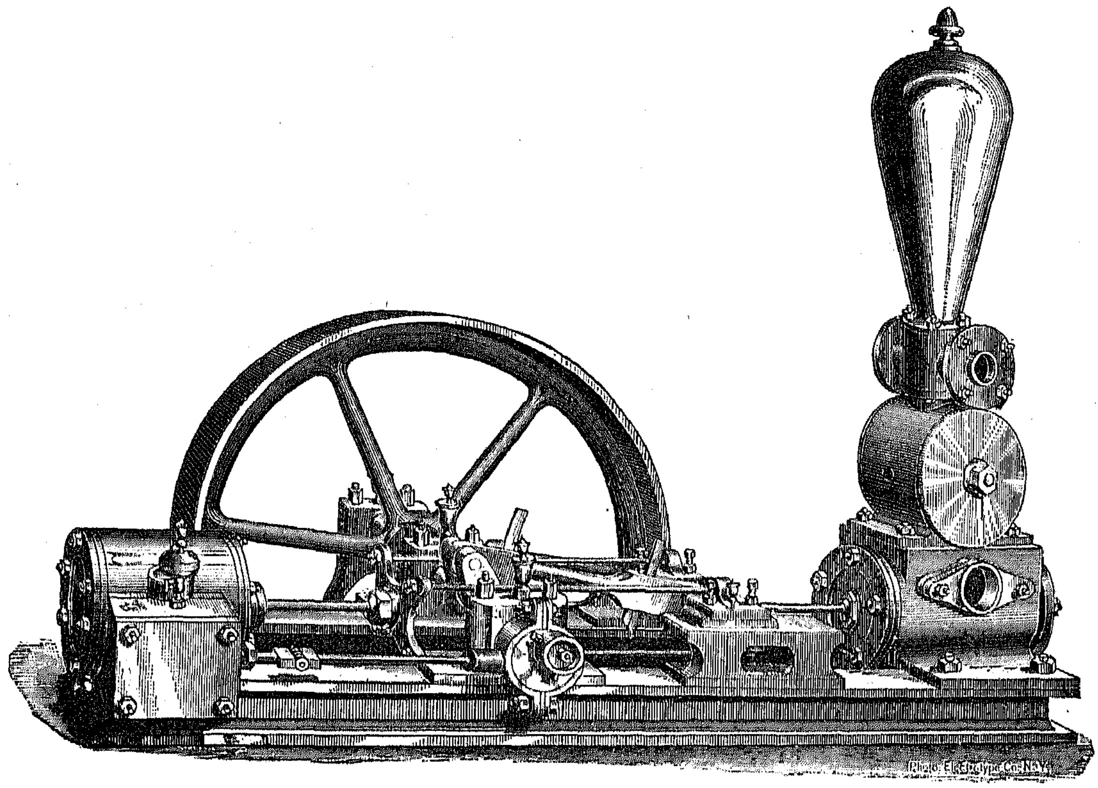

Fig. 21.

Fig. 20 shows a modification of this form, suggested by the engines for some screw-vessels. There are two steam piston-rods connected to the guided cross-head, one above and one below the center-line and far enough apart

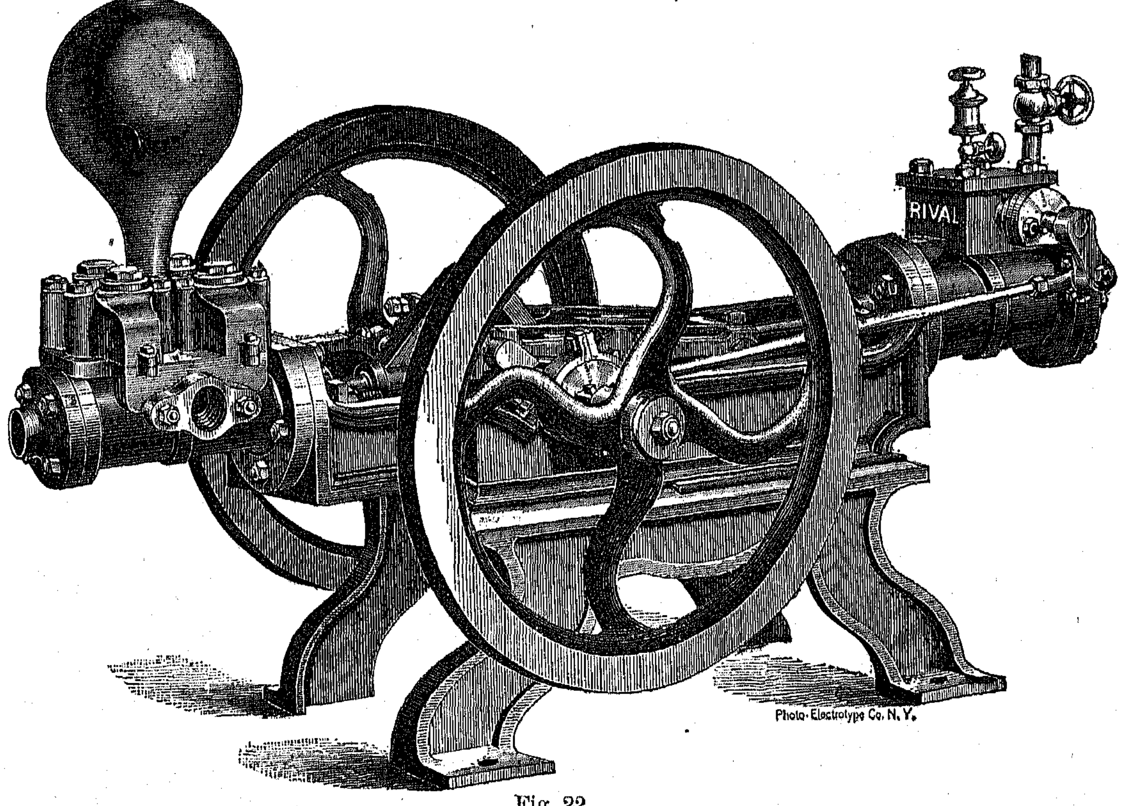

Fig. 22.

to permit the crank to revolve between them. The fly-wheel shaft has three bearings, and the valve is driven directly.

In the design shown in Fig. 21 the steam piston-rod bears a spider of four arms, which is connected to the guided cross-head by four long bolts or rods. This leaves an open space for the double crank and for the connecting-rod between the pairs of rods.

Another form is shown by Fig. 22. Here the cylinders are at the ends of the cradle, and the two piston-rods are keyed to the ends of an open forging, the crank-shaft traversing the opening. The forging is so shaped that

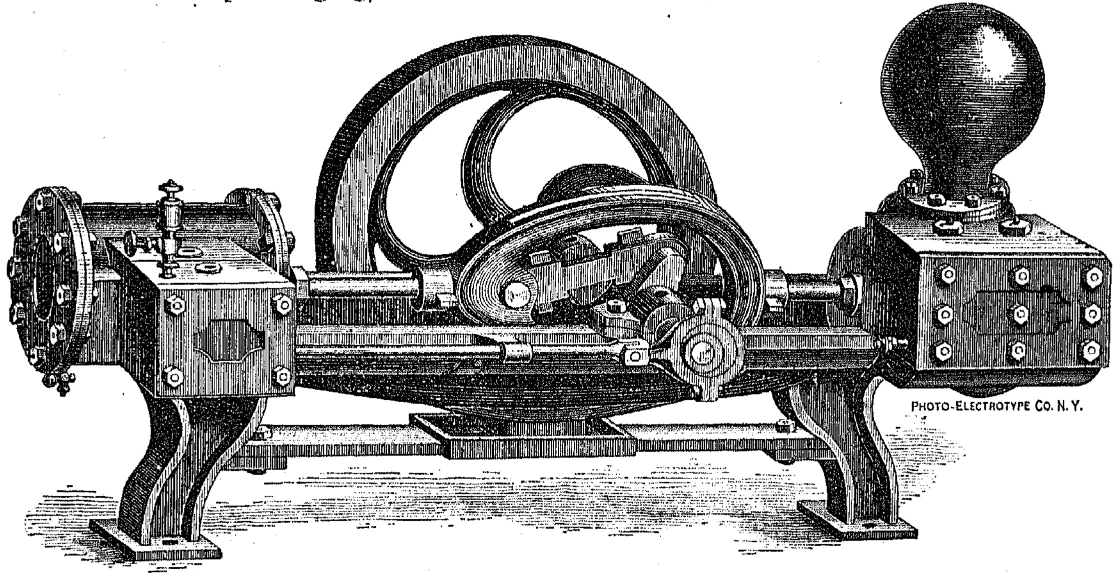

Fig. 23.

cranks on the shaft will clear its sides, these cranks being driven by two connecting-rods from a short guided cross-head keyed on the steam-rod. This arrangement permits a short bed-casting, the cylinders being bolted to the ends. A modification of this again is shown by Fig. 23, where the yoke is lengthened and receives an egg-shape for the opening. In a slot in the smaller end is pinned a short connecting-rod, which drives a crank revolving in

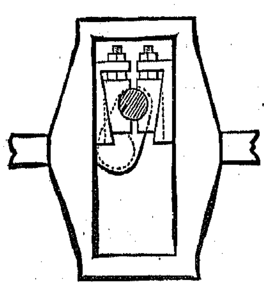

Fig. 24.

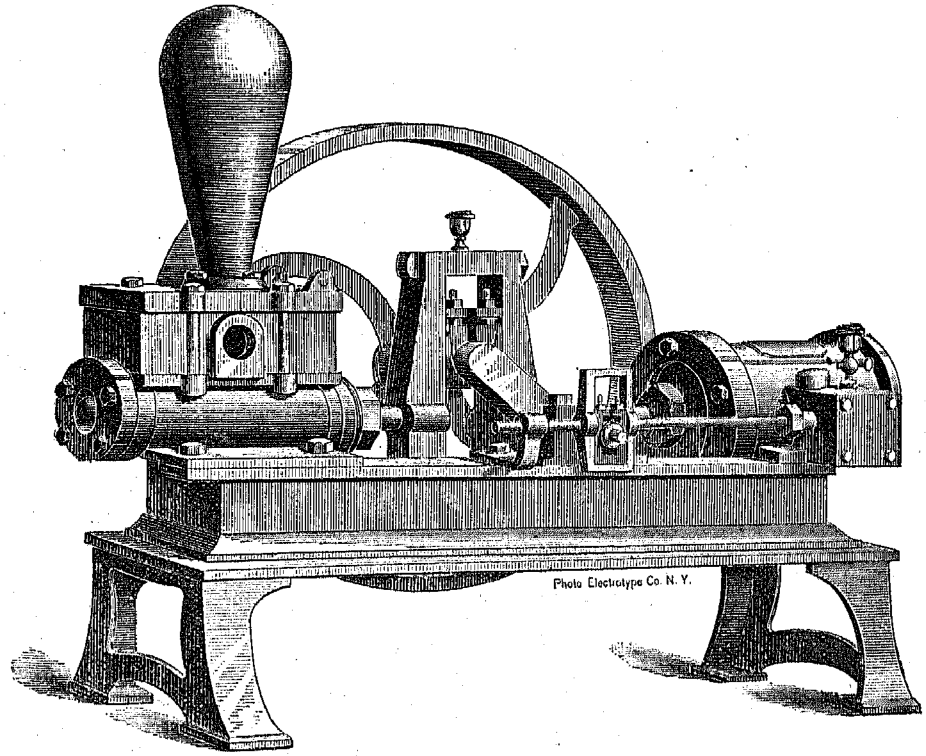

Fig. 25.

the opening of the yoke. The yoke is supported and guided by a slide below the cradle, an arrangement which permits easy and thorough lubrication.

In the remaining type of horizontal pump, which is preferred by several makers, the connecting-rod disappears. The reciprocating motion of the piston-rod is transformed to rotary motion for the fly-wheel shaft by the well-known device shown in Figs. 24, 25, and 26. The two rods are screwed or keyed to the two halves of a solid or bolted yoke, between whose inner parallel faces slides a block, enveloping the pin of a double crank. The vertical components in the motion of the crank are taken up in the yoke, while the pistons appropriate only the horizontal

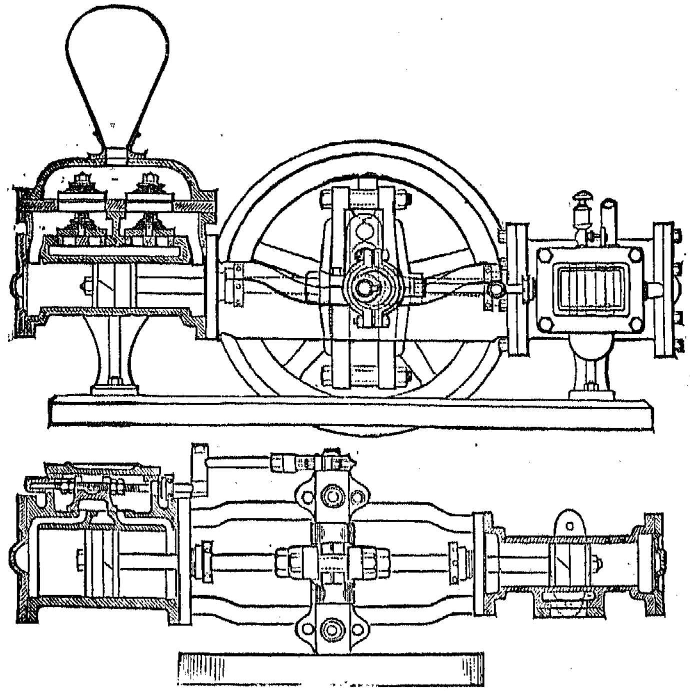

Fig. 26.

motion. Hence the pistons move as though controlled by a connecting-rod of infinite length. There would be a practical loss from friction if much power had to be given out at the crank, but as the only duty is to rotate the

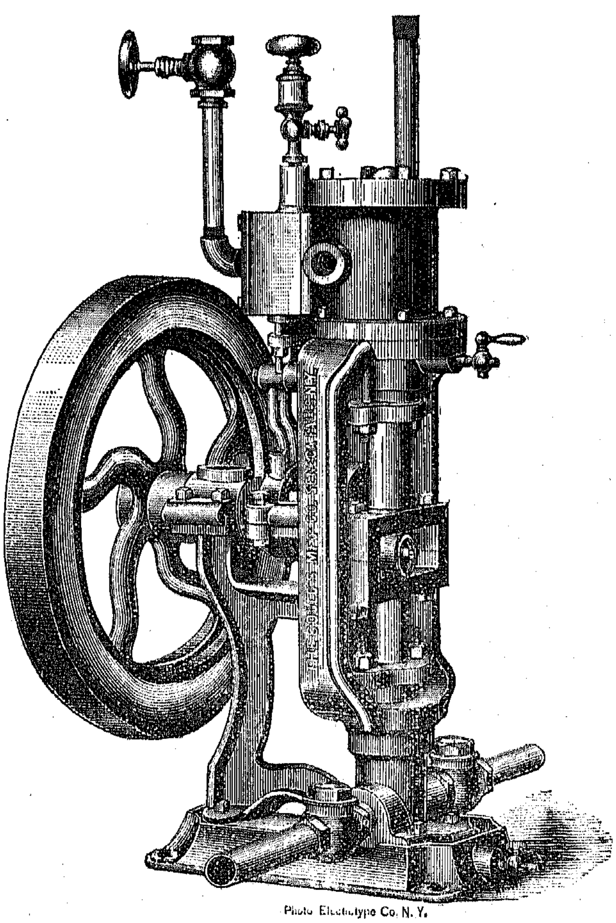

Fig. 27.

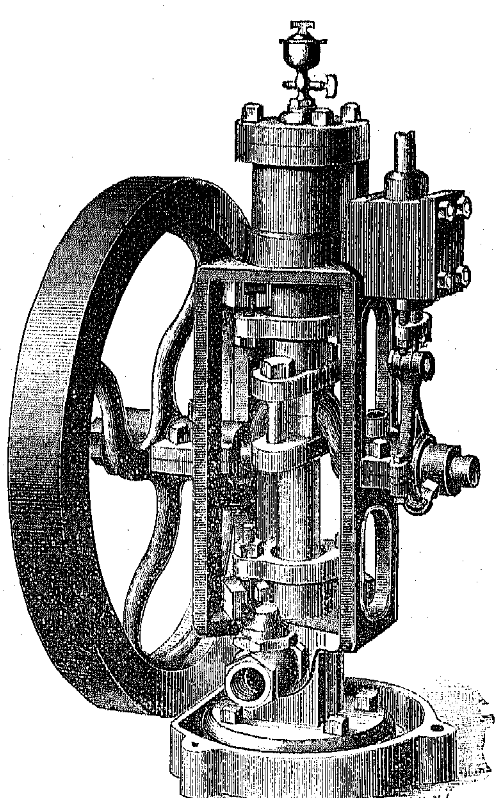

Fig. 28.

fly-wheel shaft, this is no obstacle. This arrangement permits wear to be taken up very easily, either by the jam-nuts upon the bolts (Fig. 26) which unite the yoke, or by tightening down the wedge-shaped faces of the slide-block (Fig. 24). The faces of the slide-block are babbitted, as also are the bearings of the two halves upon the crank-pin.

Several of these forms of pump are also made to work vertically for deep wells or similar purposes. The only difference made is in the length of the connections between the steam- and the water-cylinders. There are several, however, which are always made as vertical pumps, especially in the small sizes designed for boiler-feeders. These are illustrated by Figs. 27, 28, 29, and 30. The arrangement of the mechanisms is clearly shown in the cuts. Some

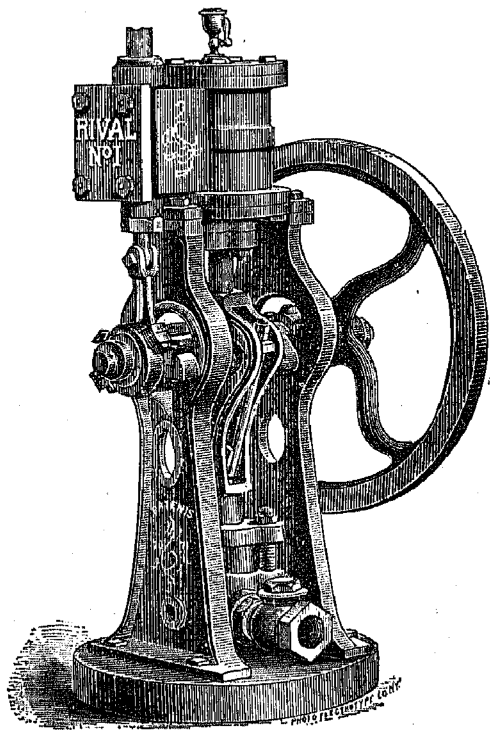

Fig. 29.

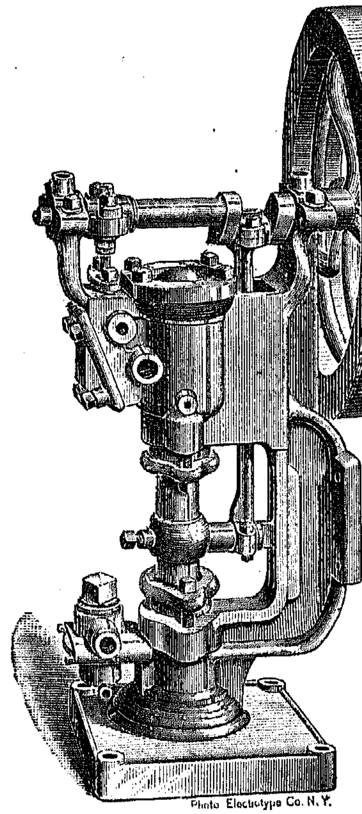

Fig. 30.

use the cross-head and connecting-rod, some the open yoke and connecting-rod, and others the bolted or solid parallel yoke with slide-box enveloping the pin of the crank.

In all these forms of pump where the piston is not continuous, the two ends will be secured to the yoke or cross-head in the best practice by keys. The ends of the rods and the sockets for them will be turned and bored tapering, and a key passing through both holds all securely. In a few cases, the rods are screwed into their sockets and are held from turning by jam-nuts. The method by keys is to be preferred, although not always the cheaper.

The fly-wheel pump as a type seems to be preferred at the West. It is also very largely used on shipboard and on river vessels. It has the advantage that it can be run as an engine by putting a belt on the fly-wheel, and can be very easily worked as a hand-pump in an emergency. It is, however, to the reliability claimed for it by those accustomed to its use, that its popularity is largely due.

2.—DIRECT-ACTING PUMPS.

The term "direct-acting" is applied to those pumps where the two pistons are on the same rod and there is no rotary motion in the mechanism. The crank-shaft, fly-wheel, connecting-rod, and crank are all dispensed with, and the valve which distributes steam to the ends of the cylinder is moved by steam into the proper position, instead of being actuated positively from a shaft. In the design of pumps of this class two problems must be solved. It is necessary first to provide for the control of the length of the piston stroke. As there is no crank to limit its travel, there is danger at high speeds lest the piston strike the cylinder-heads, and at low speeds lest only a partial stroke be made. The former is, of course, the danger most to be dreaded, and it is avoided in two ways. The steam passages may be so arranged that the exhaust-port shall be closed before the stroke is entirely completed (Fig. 45), and thus the piston shall be arrested by a cushion of steam inclosed in the cylinder. The other way is to give lead to the distributing-valve, so that boiler-steam reaches the piston before it has reached the cylinder-cover. In either case more clearance is judicious than is necessary in the other type.

The other problem to be solved is the moving of the steam-valve where there is no momentum of a fly-wheel to carry it past its central position when it covers both ports. It would seem as though the pump must stop after every stroke. The general solution of this problem is found in the employment of a second small steam-cylinder and piston whose function is to move the valve for the large cylinder. It is in effect a second engine, to which the admission of steam shall be controlled or effected by the motion of the main piston. This small piston will be called the auxiliary or valve-piston, and the valve admitting steam to this small cylinder will be called the auxiliary valve. A complete typical cycle would therefore consist first of the admission of steam to the auxiliary piston, the opening of the main steam-port by the main valve moved by this auxiliary piston, the stroke of the main piston, the movement of the auxiliary valve by the main piston, the motion of the auxiliary piston in the opposite way, and so the cycle would repeat itself for the return stroke.

The advantages of this form of pump are: First, that it can be run at very low speeds. Secondly, having no dead centers, there is no danger of the pump "stalling". For the same reason the pump must always start when steam is turned on, no matter how inaccessible or distant it may be. Thirdly, the essential parts are protected from injury by being to a greater or less extent internal. Some pumps show no mechanism at all on the outside, and in any case the pump is very compact and self-contained. Fourthly, many of the disadvantages of the fly-wheel pump are avoided, such as the varying velocity of the forcing column, and the sometimes inconvenient inertia of the fly-wheel.

On the other hand this type of pump has some disadvantages. The shock of the water-valves when the pump reverses promptly at speed, often prevents smooth working. This form sometimes makes only partial strokes. Expansion is impossible, except to a very limited degree. Not infrequently in some types the valve fails to throw over on the first stroke, and the pump will not start. This is usually due either to some defective expansion by heat, or else the small passages have been stopped up by a gummy lubricant or by scale or some similar cause. And finally, an appearance of complication due to the compactness and the number of small parts in the valve-gear, makes repair sometimes difficult from imperfect comprehension and poor facilities.

The differences in the various styles of direct-acting pump are mostly found in the valve arrangement. While all must use the auxiliary valve and piston, yet the different ways of utilizing them give rise to several varieties. The auxiliary piston is nearly always double-headed. In form it is not unlike a piston-valve. The larger sizes have spring packing-rings; the smaller ones are solid. The slide-valve which it is to move, either fits between grooves in the smaller central part of it, or else has a vertical lug which fits into a cavity left in the open middle part. Usually the steam is at all times upon the central part and acts equally upon the two heads. The piston is moved either by admitting live steam to one outer head while the other is in communication with the exhaust, or else by opening one outer head to the exhaust with previous equilibrium of pressures. In either case the piston moves in the direction of least resistance and carries the main valve with it.

This disturbance of the equilibrium of the auxiliary piston may be effected by a plain slide-valve, or the functions of this valve may be performed by some other part of the mechanism, and the slide-valve may disappear. In any case the admission of steam to the auxiliary cylinder must be controlled from the motion of the main piston. This may be effected directly from the piston inside the cylinder, or from an arm attached to the piston-rod outside. In the first type what are known as "short-connected" pumps can be used. The steam- and water-cylinders need be only far enough apart to permit the packing of the stuffing-boxes. This has the disadvantage of causing a part of the piston-rod to enter both hot and cold cylinders. Where the other system of an arm on the rod is used, the cylinders must be distant an amount equal to the stroke, in addition to the length of the clamp of the arm. These are called "long-connected" pumps.

There are several forms of direct-acting pumps where the essential parts are all present, with but little modification of the typical forms and of the underlying principle. Such a one is shown in Fig. 31. The main piston-rod carries a vertical arm which strikes tappets upon a rod which enters the valve-chest. These tappets are so placed as to be moved just before the piston completes its stroke. This tappet-rod has an arm inside the valve-chest, projecting from it at right angles and rectangular in cross-section. This arm rests between two ridges upon the back of a small slide-valve, whose motion must therefore be the same as that of the tappet-rod. The seat of this valve is in the spandrel between the main cylinder and the cylinder for the auxiliary piston. Its three ports communicate respectively with the two ends of the auxiliary piston-cylinder and with the exhaust of the pump, but there is also a passage to the ends of the auxiliary cylinder for exhaust only. This has only one-half the area of the similar steam-passage and enters the bore of the auxiliary cylinder nearer the middle. When the tappet-rod moves this auxiliary valve to one side, steam from the boiler is admitted through one port to the end of the auxiliary cylinder. The space at the other end is by the same motion opened to the exhaust through the hollow in the face of the slide-valve, and the piston obeys the excess of pressure and moves in the direction of its axis. This motion compels the motion of the slide-valve controlling the admission of steam to the main cylinder, because the main valve fits into this auxiliary piston at the reduced section of the middle, so that they must move together. Steam from the boiler, therefore, meets the main piston at or just before the completion of its stroke, and the cycle is repeated. The chest-piston is cushioned from going too far by its own exhaust steam, since in its motion toward the head of its cylinder it closes over its own exhaust-opening and shuts in a part of the steam which drove it on the preceding stroke. In this form of pump, therefore, the two engines with their two slide-valves are clearly present. One engine has for its sole function the moving of the slide-valve for the other and larger one, while the large engine moves the slide-valve for the smaller. To guard against the possible accident at high speeds that the auxiliary piston should not move the slide-valve soon enough to insure steam-lead on the main piston, the

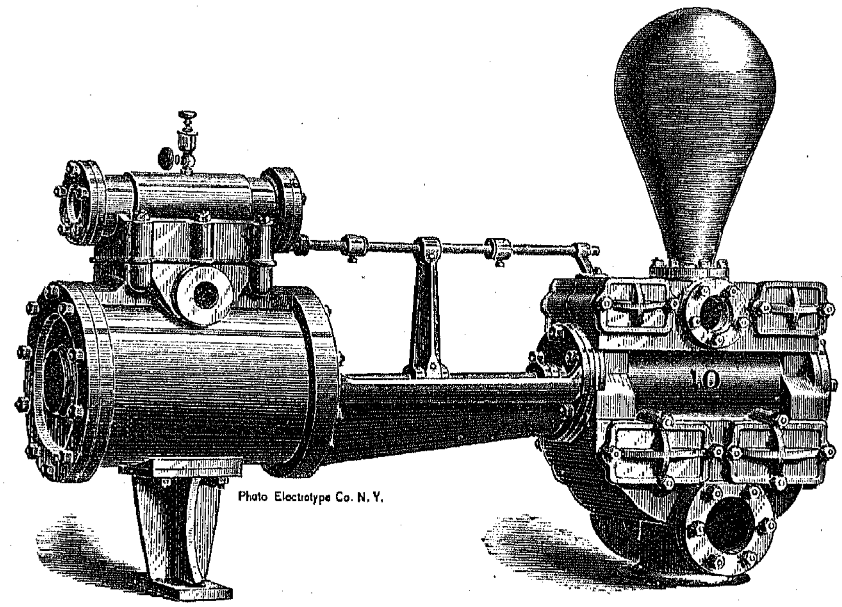

Fig. 31.

internal arm on the tappet-rod which moves the auxiliary valve rests between projecting ridges or lugs on the back of the main valve. These lugs are just so far apart that ordinarily they will not be touched by the arm as the main valve moves away from before it. Should the main valve fail to move, however, in time, this tappet-arm is moved forward against the lug by the advance of the main piston and will compel the motion of the main valve.

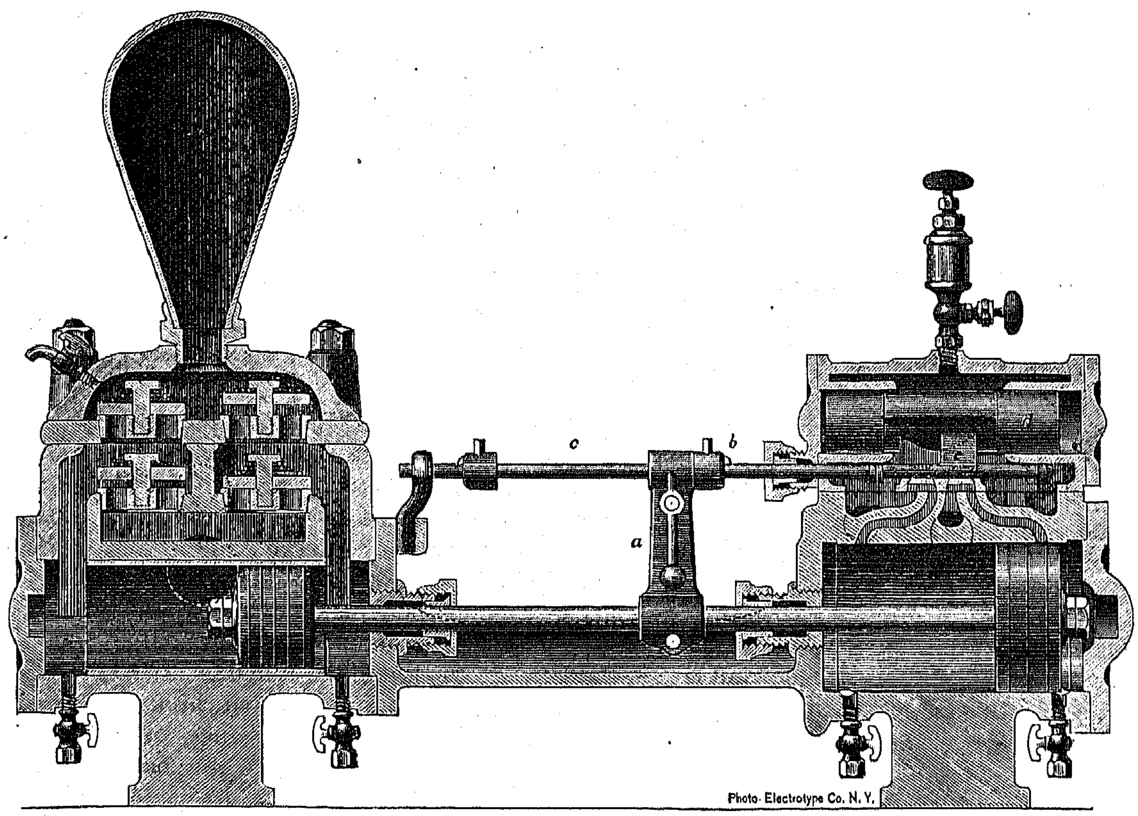

Fig. 32.

Steam-lead will thus be given before the main piston has struck the cylinder covers, even though the auxiliary piston had failed to act.

A similar type is illustrated by the pump shown in Fig. 32. The auxiliary valve is moved in the same way, by an arm on the main piston-rod which strikes tappets or chocks on the valve-stem. The valve is a flat slide-valve surrounding the main valve and sliding upon the same faced surface. There are two ports upon each side of the auxiliary valve and covered by it, communicating with the spaces at the end of the auxiliary cylinder. One is for steam to each end on one side, and those on the other are for exhaust. At the proper time when one steam-port is uncovered by the valve, the exhaust-hollow is in communication with the exhaust-passage from the other end of the auxiliary piston, and the main valve is thrown over. The exhaust-passages are shorter than the steam-passages, and hence the auxiliary piston cushions itself after it has covered the opening of the exhaust-passage. There is a similar precaution in this pump to insure steam-lead on the main valve and to avoid overstrokes. A lug upon the valve-rod projects into a cavity upon the auxiliary piston. The length of this cavity is such that the piston and main valve will be moved bodily by the motion of the chocks on the tappet-rod, if steam has not carried them previously forward. The cylinder of the auxiliary piston in this pump is carefully jacketed by steam from the boiler, in order to avoid any difficulties from unequal expansion in first starting up. Where this precaution is not taken, there is danger lest the piston stick in the bore, when they are of different temperatures, and have been fitted to each other at the same temperature.

In pumps of this class, where the auxiliary valve is moved by the main piston, and steam is admitted to the ends of the auxiliary piston, it will be seen that the ordinary slide-valve or D-valve will not answer for the main valve. In the ordinary valve, the steam is admitted and cut off by the extreme edges, and the valve moves just

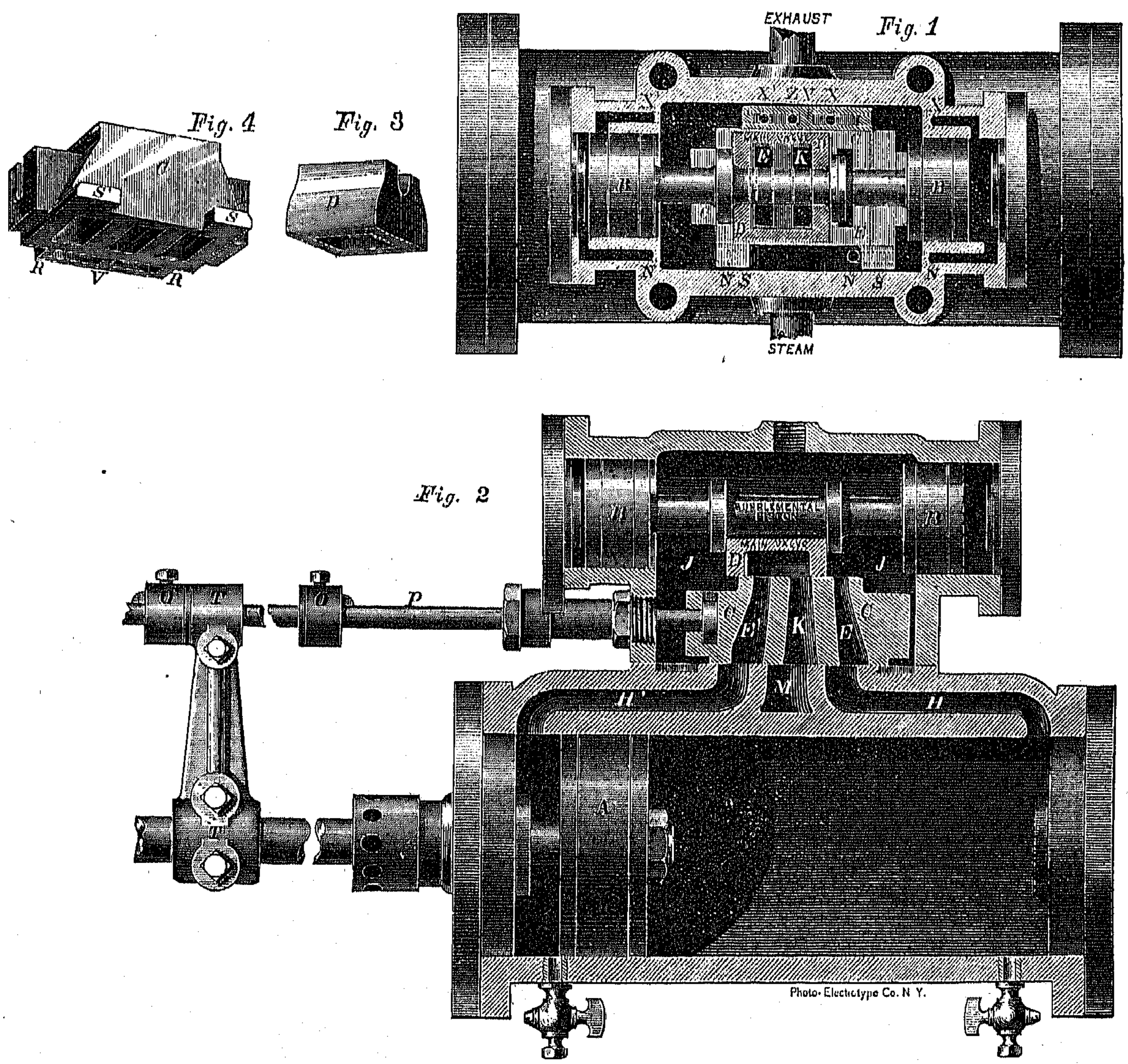

Fig. 33.

previous to admitting steam in the direction in which the piston is to be driven. When the auxiliary valve is of the D-form, and its steam-passages do not cross each other, it will be seen that the main valve will move in the direction just opposite to the future motion of the piston. Hence, especially in pumps which have the safety motion for the main valve, a form of valve must be used which shall be the reverse of the D-form, for either the auxiliary or the main valve. It must cut off and admit by its inner edges. This form of valve is shown in many of the sections, and is called from its shape the B-valve. Steam enters the port through one hollow in its face, while the exhaust is taking place through the other hollow. The partition separates the live steam from the exhaust. Hence it is rendered possible for a piston, moving in one direction, to actuate a valve which shall admit steam properly to drive the piston in the opposite direction.

In the pump shown in Fig. 33 the auxiliary valve lies between the main valve and its seat. This movable seat is moved when chocks upon a rod are struck by a tappet-arm clamped to the main piston-rod. This seat has through ports, matching the ports in the lower face, and upon one side are projecting lugs which are faced to a joint with the lower seat. These alternately open and close connections to the spaces at the heads of the auxiliary cylinder. Similar projections on the other side carry exhaust-hollows for properly opening these spaces to the exhaust of the pump through a second pair of passages in the walls of the casting. It will be at once seen that the main valve of the D-form will be thrown by steam when the movable seat and auxiliary valve admits steam to one end of the auxiliary piston and connects the other end to the exhaust. The motion of the auxiliary piston is cushioned as before by its own exhaust, inasmuch as it covers over the exhaust-outlet before it has completed its travel. The exhaust-passages are shorter than those carrying live steam.

The main piston is cushioned by steam-lead. The safety device in this pump to avoid overstrokes is attained by the movable seat. There is no lap on the main valve, and in case of rapid strokes the movable seat will move sufficiently to admit steam directly without causing the auxiliary piston to move the main valve at all.

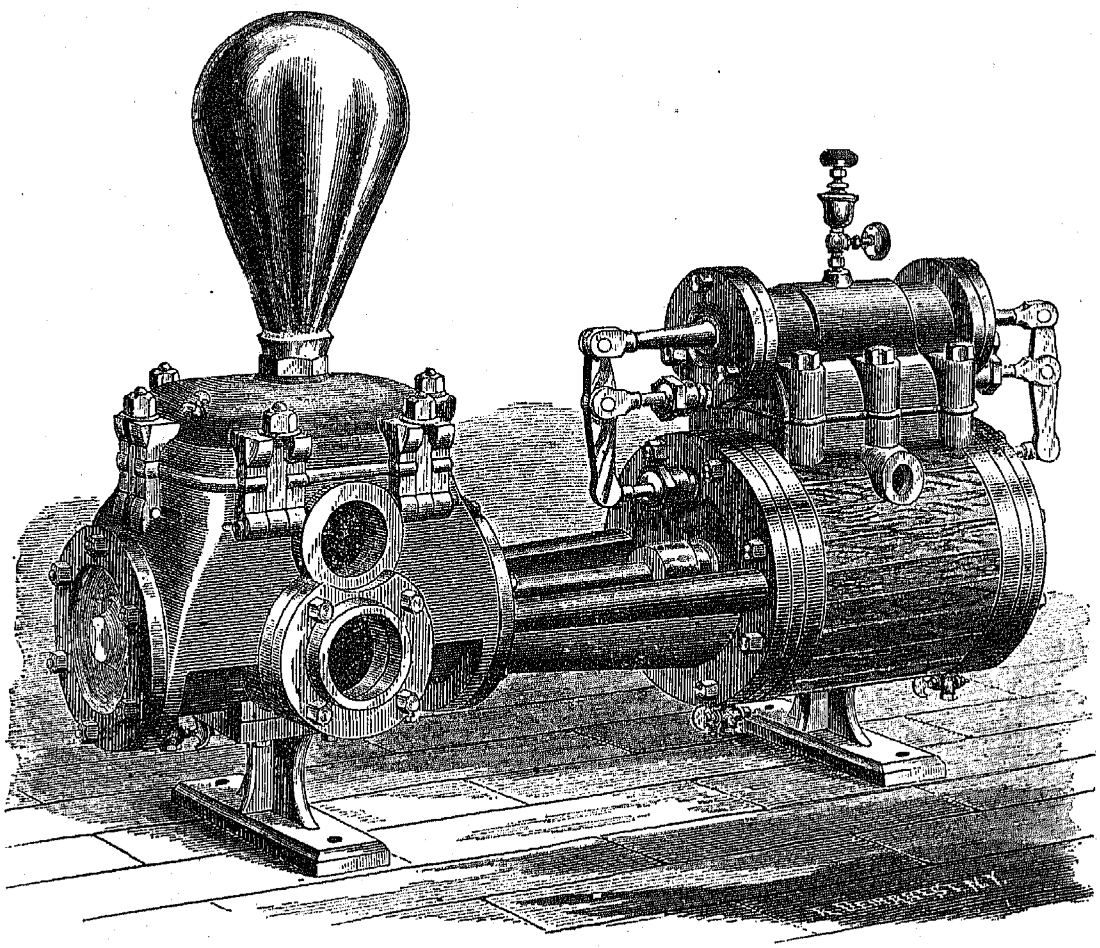

Fig. 34.

Where desirable to have a short connected pump of this design, the auxiliary valve is operated by the piston. Two short rods enter the cylinder-heads just above the center through stuffing-boxes (Fig. 34). These are struck by the piston just before completing its stroke in each direction. The motion of these rods is conveyed into the valve-chest by levers of the second order, whose fulcrum is a stud in the center of each end of the auxiliary cylinder. The seat is connected to the levers by links at about their middle point. The objections to this arrangement are the wear of the vibrating joints, and the necessity for extra stuffing-boxes. A plan tried at one time of having the seat moved by a rod struck alternately by steam- and water-pistons had to be abandoned because the rod would sometimes be moved by differences of fluid pressure upon its two ends.

A pump made in Pittsburgh, Pennsylvania, avoids the vibrating joints by using a larger rod to the seat, and making the connections to the rods entering the cylinder by rigid corners. When the piston strikes the short rod the whole frame moves bodily, shifting the auxiliary valve.

The pump shown in Fig. 35 moves the auxiliary valve by a pendant finger inside the valve-chest. The rocker-arm is moved by the horizontal rod, which receives its motion from the main piston through the two heads of the

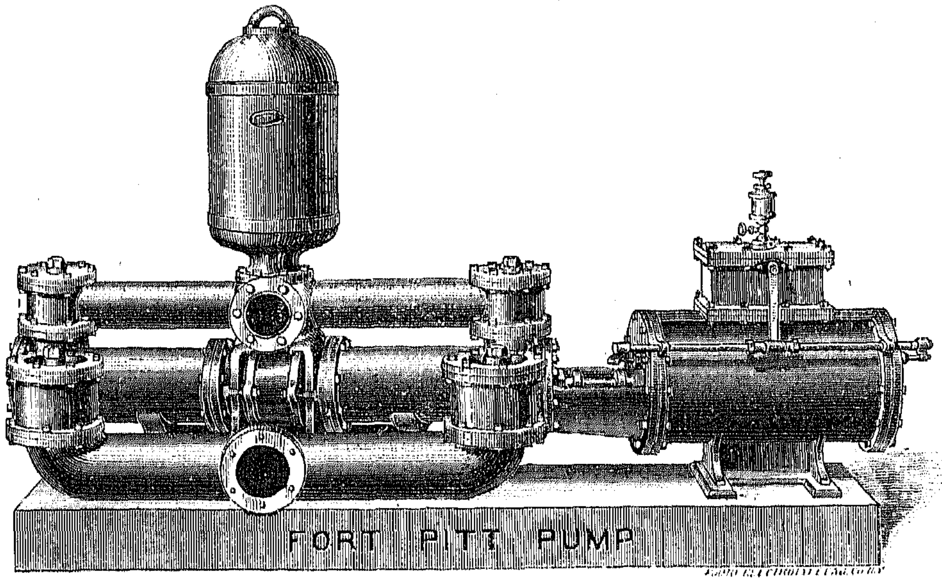

Fig. 35.

cylinder. The connection to the rocker-arm is made by a rounded contact-joint, so that here again the wear of a vibrating link is avoided.

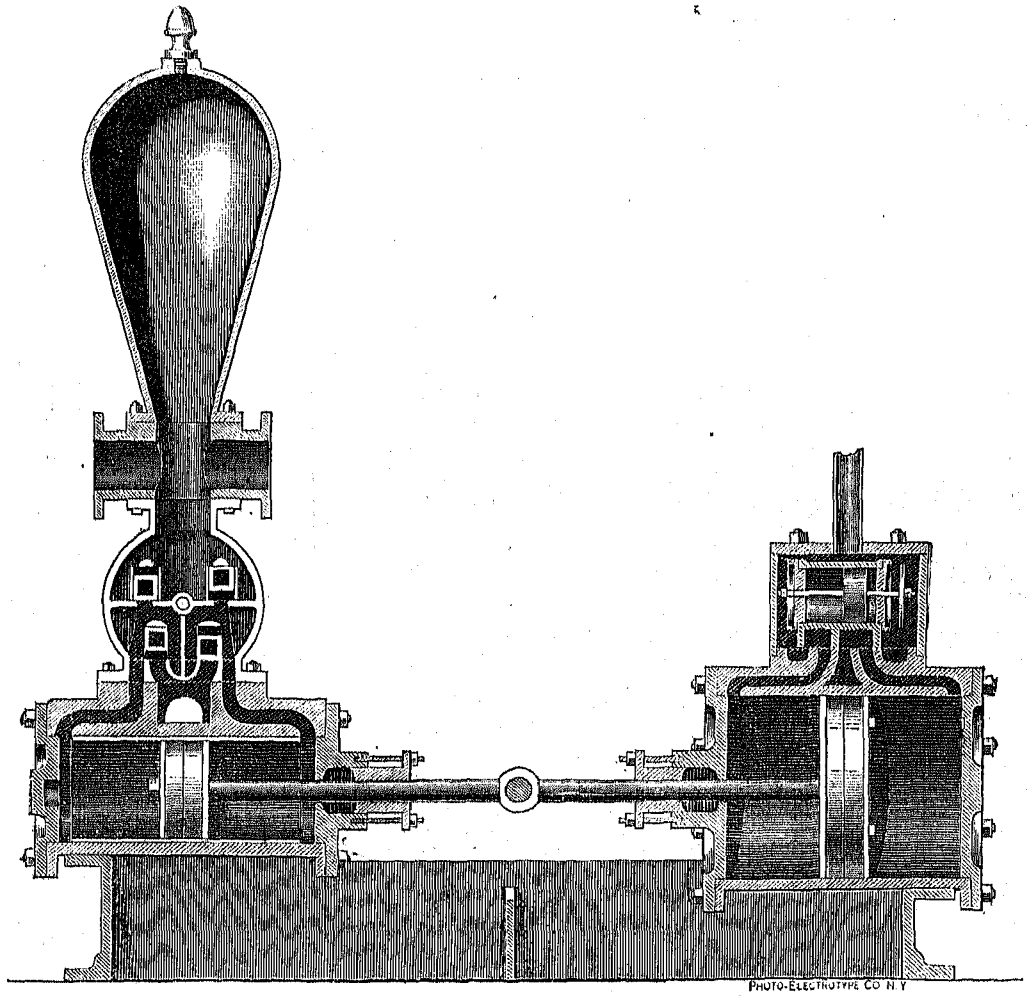

Fig. 36.

There are several inconveniences which are inseparable from the lack of positive connection between the main piston and the auxiliary valve. Such are the shock when the arm strikes tappets, and the danger of partial strokes. To avoid these is the object of several designs in which the arm clamped to the main piston-rod projects laterally from it. A link carries the motion of this arm to a rocker-arm hanging vertically from a short shaft which enters the valve-chest through a stuffing-box. Inside the chest is a finger upon this shaft which slides the auxiliary valve when a slight rotation is given to the shaft from its connections outside.

A pump of this type is shown in Fig. 36. The flat auxiliary slide-valve is moved by the finger between the lugs upon its back. It is of the B-form and admits steam to the alternate sides of a piston which is stationary

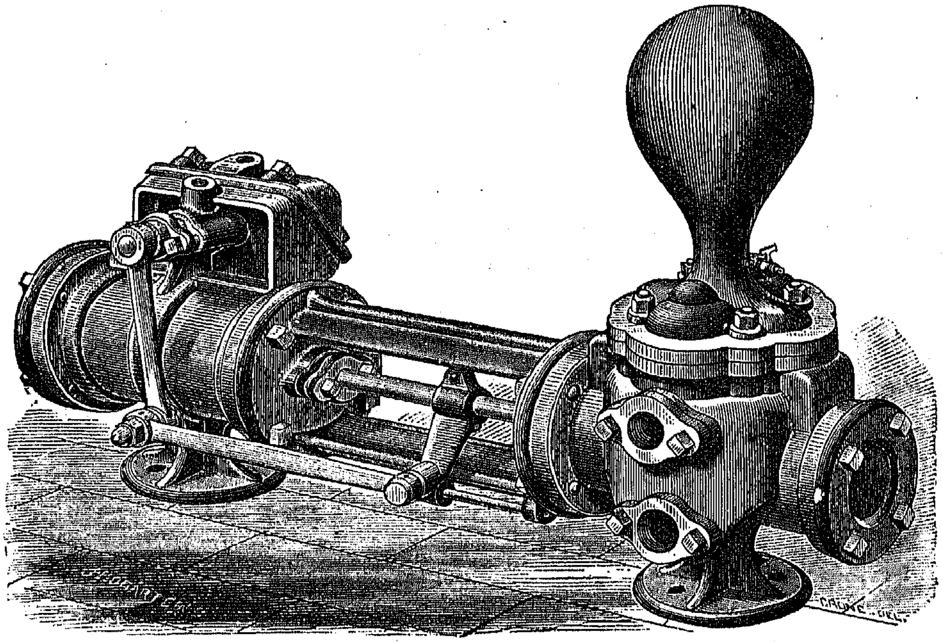

Fig. 37.

in a movable cylinder, of which the main valve is a part. The cylinder obeying the unbalanced pressure upon one of its heads, slides upon the seat and admits steam to the main cylinder. To cushion the motion of this valve-

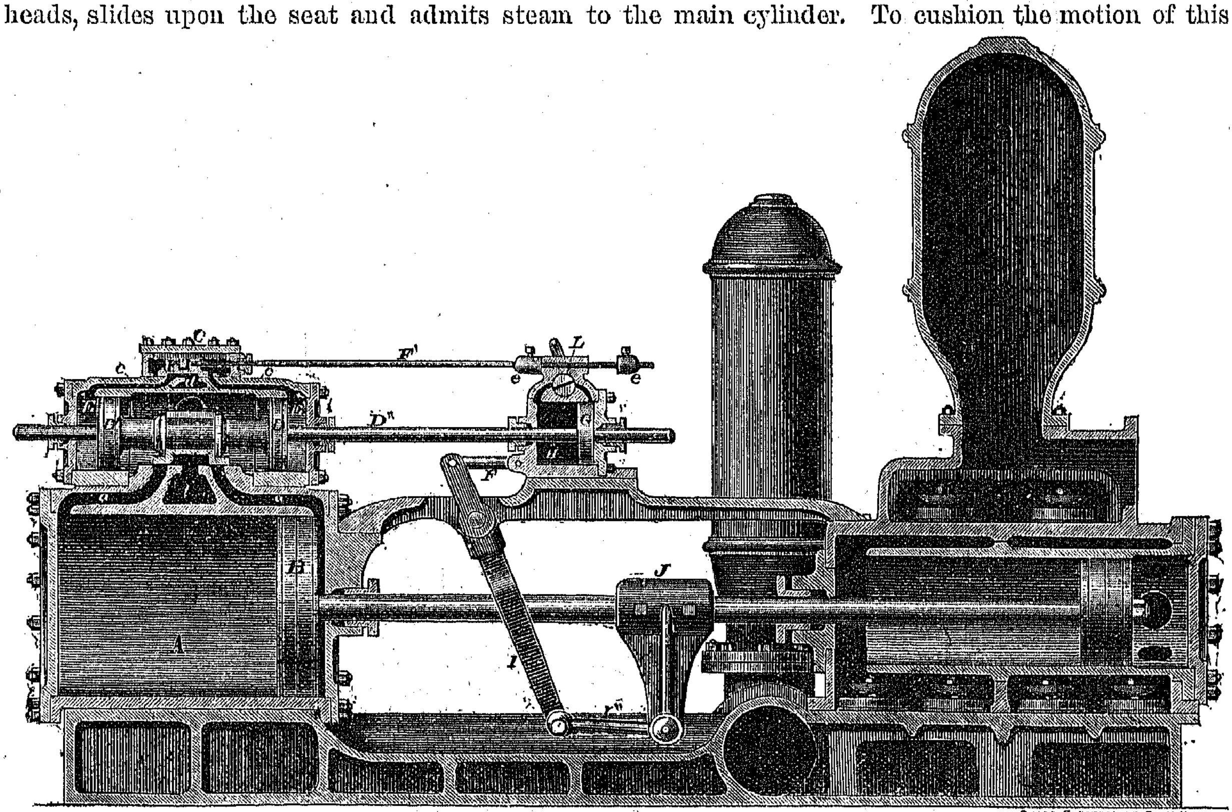

Fig. 38.

cylinder, the outer faces of its heads are bored out to fit two other stationary pistons upon the same rod as the internal one. These hollow faces compress the steam shut in when the cylinder caps over the pistons and thus arrest its motion. The main piston must have steam-lead.

Fig. 37 illustrates a pump using the more ordinary arrangement for operating the main valve, and admitting and exhausting gradually from the piston. A notable feature of this design is the form of valve-chest. A very large opening is permitted by the use of the inclined joint for fitting and repair. The same builders have applied the principle of the Cornish cataract to their larger pumps, to compel a uniform speed of delivery. The arrangement is shown in Fig. 38. On top of the auxiliary cylinder is a small slide-valve, F, admitting steam to the auxiliary piston D. This valve is moved by collars *e* on its rod which are struck by a tappet-arm. The tappet-arm is on the top of a small cylinder, H, which slides upon guides as it is compelled by its connection to the main piston-rod through links to a swinging lever, I, from a clamped arm, J. The piston G which moves in this sliding cylinder is connected by a rod, D″, with the auxiliary piston and main slide-valve. It is this sliding cylinder which constitutes the cataract. It is filled with oil, and the two ends are connected together by an external passage, controllable by a valve, L. By this valve the time required for the oil to pass from one end of the cylinder to the other may be made greater or less. It will be at once seen that when the auxiliary pistons receive steam from the slide-valve, their rapid motion is impeded by the resistance to the displacement of the oil in the cataract, and the main piston therefore receives its steam slowly, and the water-valves may therefore seat themselves quietly. During the stroke

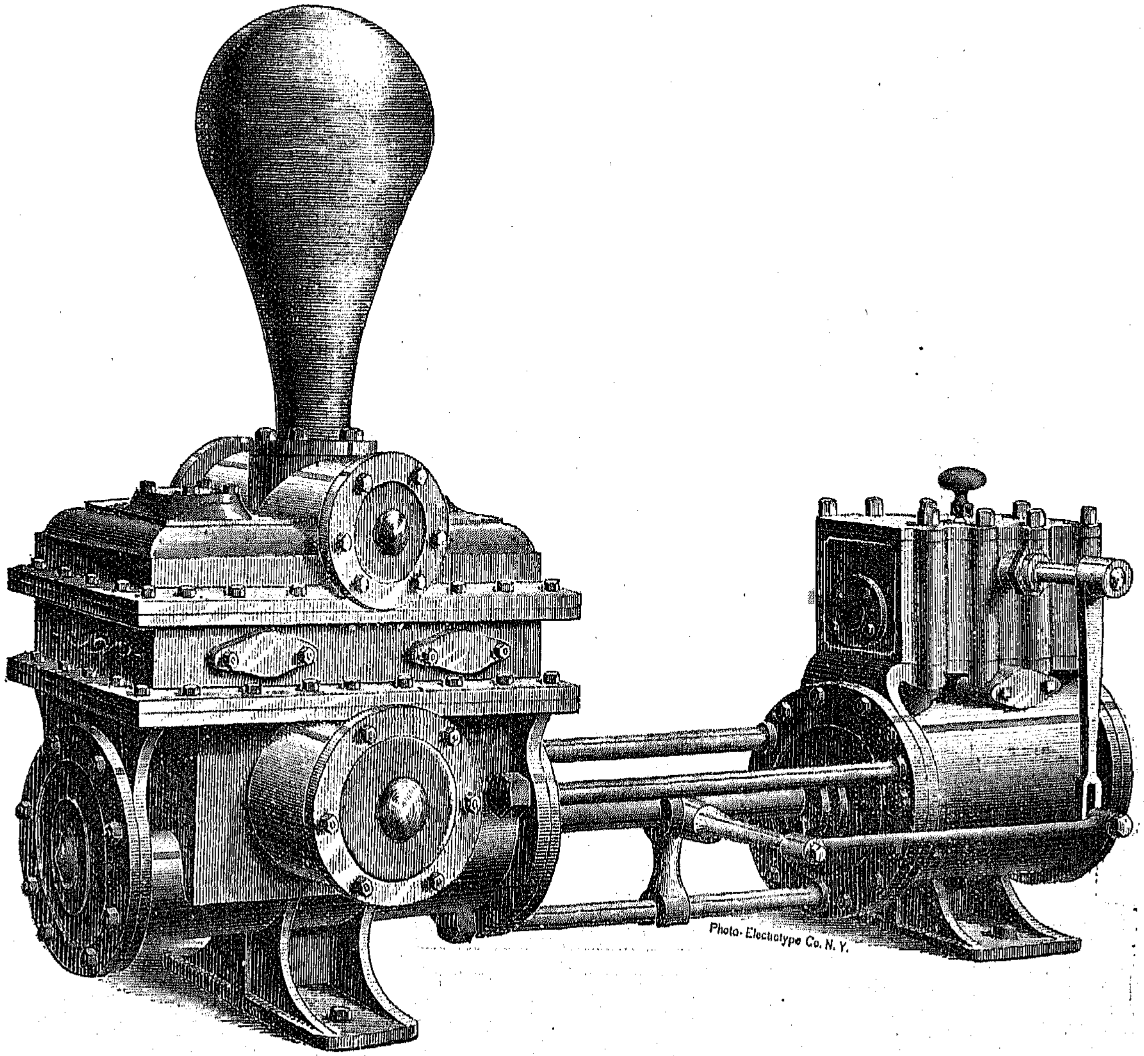

Fig. 39.

of the main piston the main valve is held open by the pressure of steam upon the head of the auxiliary piston. This pressure is opposed by the resistance of the oil to displacement in the cataract-cylinder as the latter is moved by the stroke of the main rod. Should the main piston start too fast, the oil-resistance will overcome the steam-pressure, and the valve will be partly closed. Should it move too slowly, the oil will pass freely through the valve, and the diminished resistance will permit the steam-pressure to give further opening to the main valve.

The cataract-cylinder is of just such a length as to bring its piston against the heads at the proper time to close the exhaust-port from the main cylinder, and to arrest thus the main piston by compression of its exhaust. At the same moment the auxiliary piston receives steam from the small slide-valve. The main valve has a small lap, to permit a small expansion, and to cause an interval between the closure of the port to one end of the cylinder, and the opening of that to the other. By this means also the shock on the water-valves is relieved.

The pump shown in Fig. 39 is also a positively connected pump, permitting a small degree of expansion.

A second great division of this class of steam-pumps will include those in which the hitherto flat surfaces of auxiliary and main valve become the surfaces of cylinders, and the valves either rotate or slide upon their seats, or both.

A typical pump of this class is the pump whose details are shown in Figs. 40 and 41. The tappet-arm causes

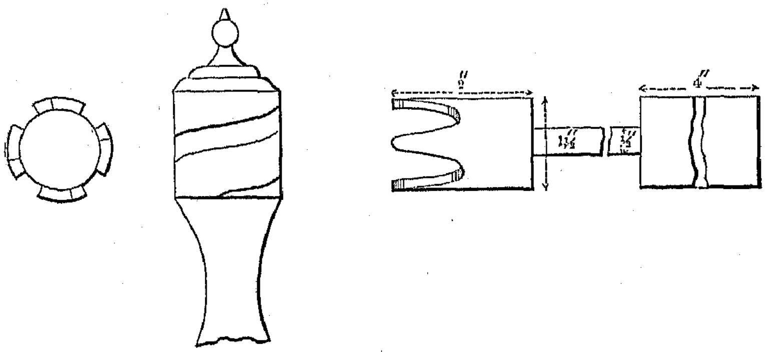

Fig. 40.

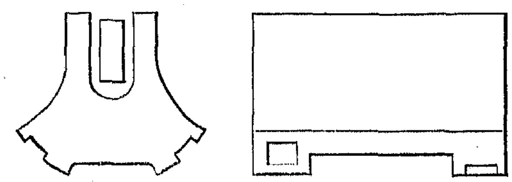

Fig. 41.

a slight rotation of the stem of the auxiliary valve, as the inclined surfaces strike the sides of the forked chocks. A very slight endwise motion will probably be also received. This rotation brings certain cavities in the cylindrical face of the valve into communication with small ports and passages in the wall of the casing, through which steam passes to the heads of the auxiliary cylinder and throws the main valve. The auxiliary piston is cushioned by its own compressed exhaust, and the main piston receives steam-lead. The principal departure from the preceding principles is found in the combining into one valve of the auxiliary and main valves. The rotation of the valve admits steam to the auxiliary cylinder; the axial motion of the same valve admits steam to the main cylinder. The valve is of the Corliss type (Fig. 41), a slide-valve moving on a cylindrical seat, the exhaust-hollow and steam edges being formed in the cylindrical surface of the valve. Similar in principle is the pump shown in Figs. 42, 43, and 44. The valve is of similar form and action, but is moved by the positive link-connection shown. The pendent

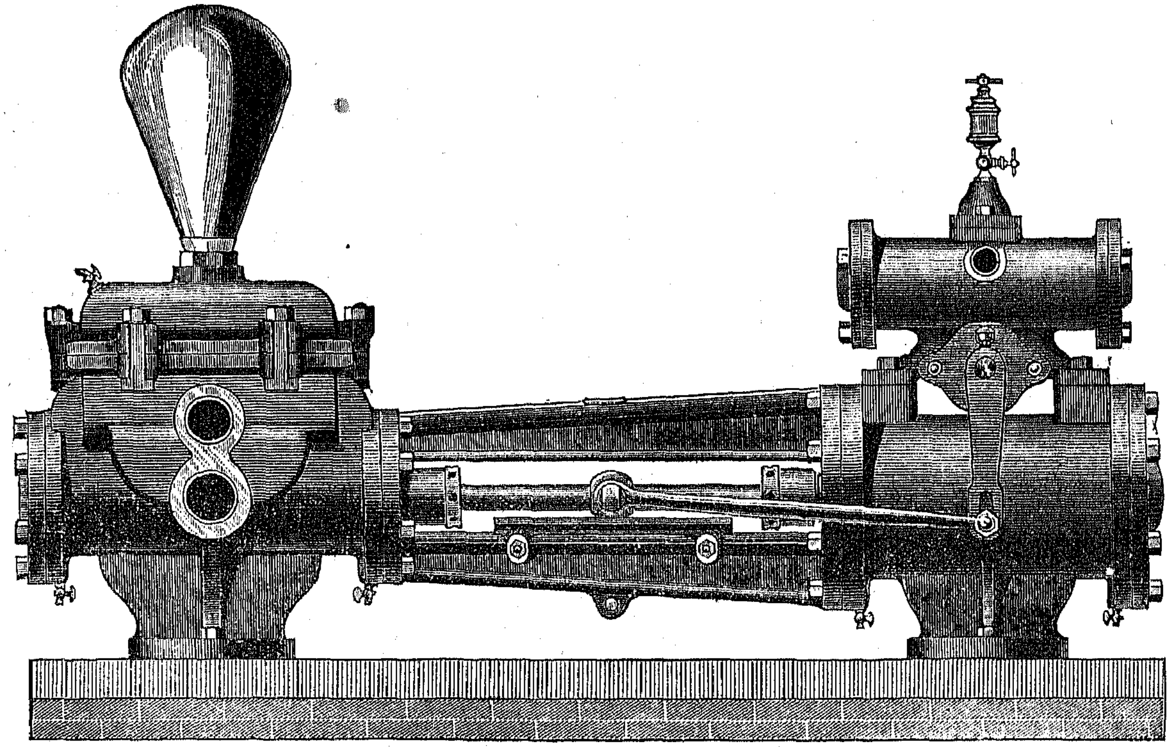

Fig. 42.

arm rotates a cam in the exhaust-area (Fig. 44), which consists of a cylinder with a diagonal groove milled out in its convex surface. Into this groove projects a steel pin from the bottom of the valve. This pin will give a slight rotation and trifling end-motion to the valve as the arm oscillates. The rest of the distribution is the same as in the preceding form. The safety-device to insure the throw of the valve is obtained by the length of the slot in the cam. It is short enough to throw the piston, if steam has failed to do so. In the pump shown in Fig. 45 the auxiliary piston is made to serve as an auxiliary valve. The main piston carries a roller upon a short stud clamped on its side. This roller strikes a curved rocker, concave downward, and centered at its middle point, so that each end of the rocker will be alternately raised and lowered by each stroke of the piston. The oscillation of this rocker is carried

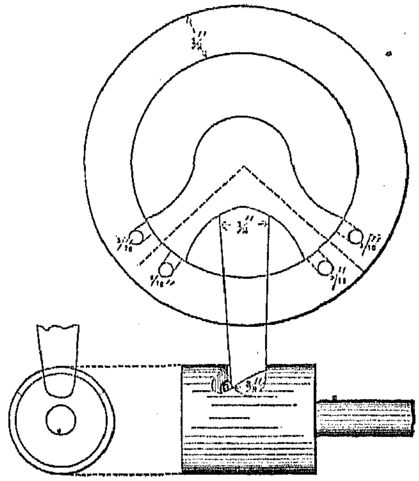

Fig. 43.

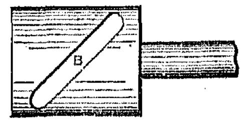

Fig. 44.

to the tappet-rod by a short link fitted with an adjusting sleeve with right and left screws. This tappet-rod is secured to the auxiliary piston, which thus is caused to rotate through a slight angle, determinable by the length of the link. This rotation of the auxiliary piston causes small hollows in its solid part to come opposite to openings in the casing, through which steam enters into the spaces at the heads, causing the piston to reciprocate and to move the main valve. The motion of the auxiliary piston is arrested by the compression of its exhaust after the outlet is covered. The main valve is of the B-form. The steam passages do not reach from the seat to the extreme end of the cylinder, but enter the bore at such a distance from the heads that the main piston covers them before the stroke is completed, and incloses sufficient steam to serve as an efficient cushion and prevent the piston from striking the heads. A separate passage, controllable by a hand-valve, opens to the valve-passages from the ends of

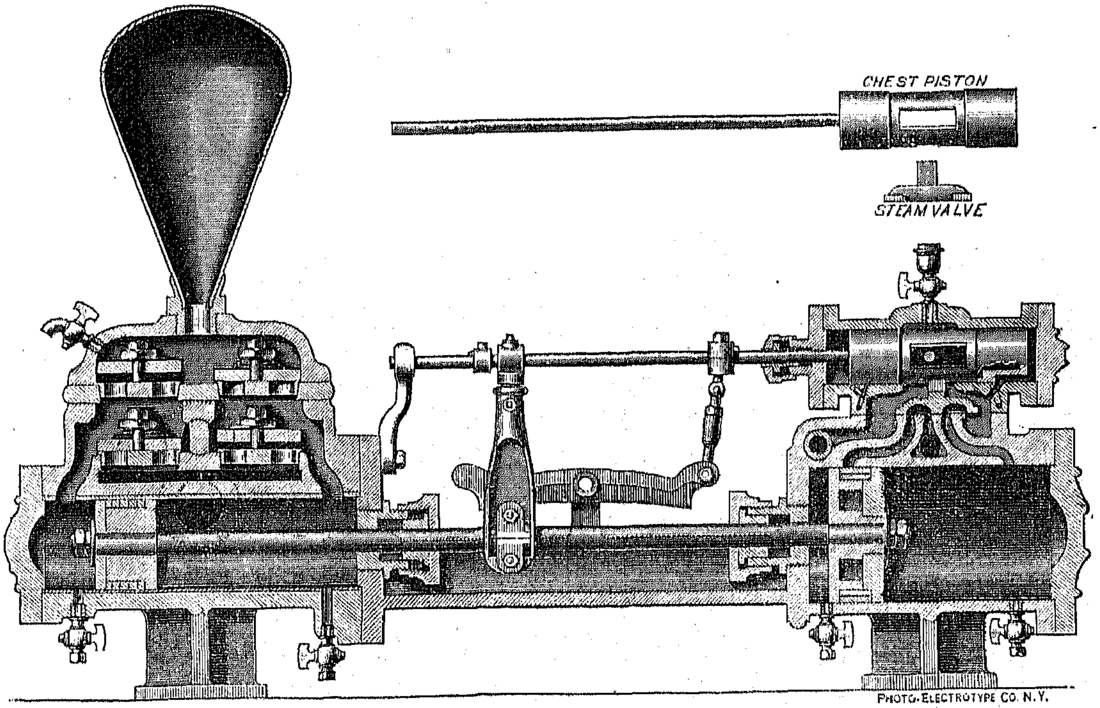

Fig. 45.

the cylinder-bore. By this means the amount of this compression can be reduced when running at slow speeds, or increased to a maximum by closure of the valves when running fast. This addition is very valuable in starting vertical pumps on the Cornish system, or where the resistance may be different on the up and down strokes.

As the main piston covers its own main steam-port at the beginning of each stroke, there has to be an auxiliary steam-port from the main valve-seat communicating with the extreme end of the cylinder. This small port is opened when the auxiliary piston throws the valve and the piston starts slowly on the return stroke. This is favorable of course to the water-valves. Where the pump is worked with a condenser, there can be no compression of the exhaust to arrest the main piston. In this case steam-lead is given by lengthening the link from the rocker, and the piston is arrested by the live steam. The safety-device in this pump, to insure the motion of the auxiliary piston, consists of a vertical arm clamped to the main rod, which strikes tappets upon the valve-rod, and compels its motion if the steam has not already effected it.

To this general class belong also the pumps made under the Loretz patents, shown in Fig. 46. The auxiliary

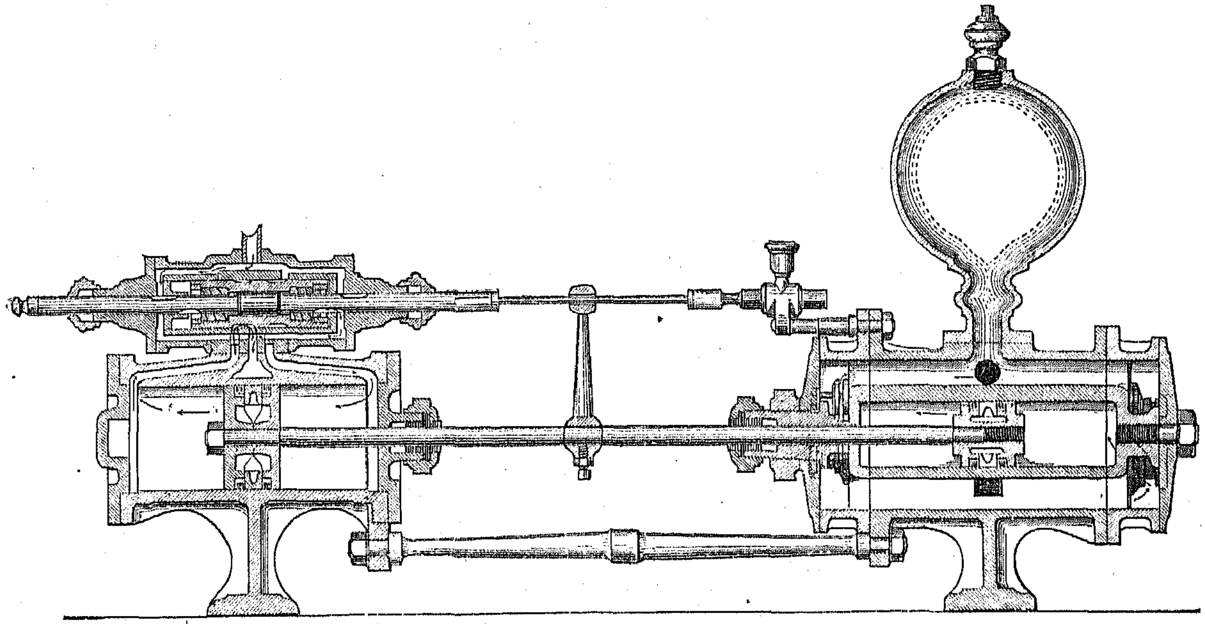

Fig. 46.

piston fits in a jacketed cylinder, and has grooves made in its central part so spaced as to give to it the profile of a **B**-valve when seen in longitudinal section. Steam entering these grooves can pass to the main steam-passages and

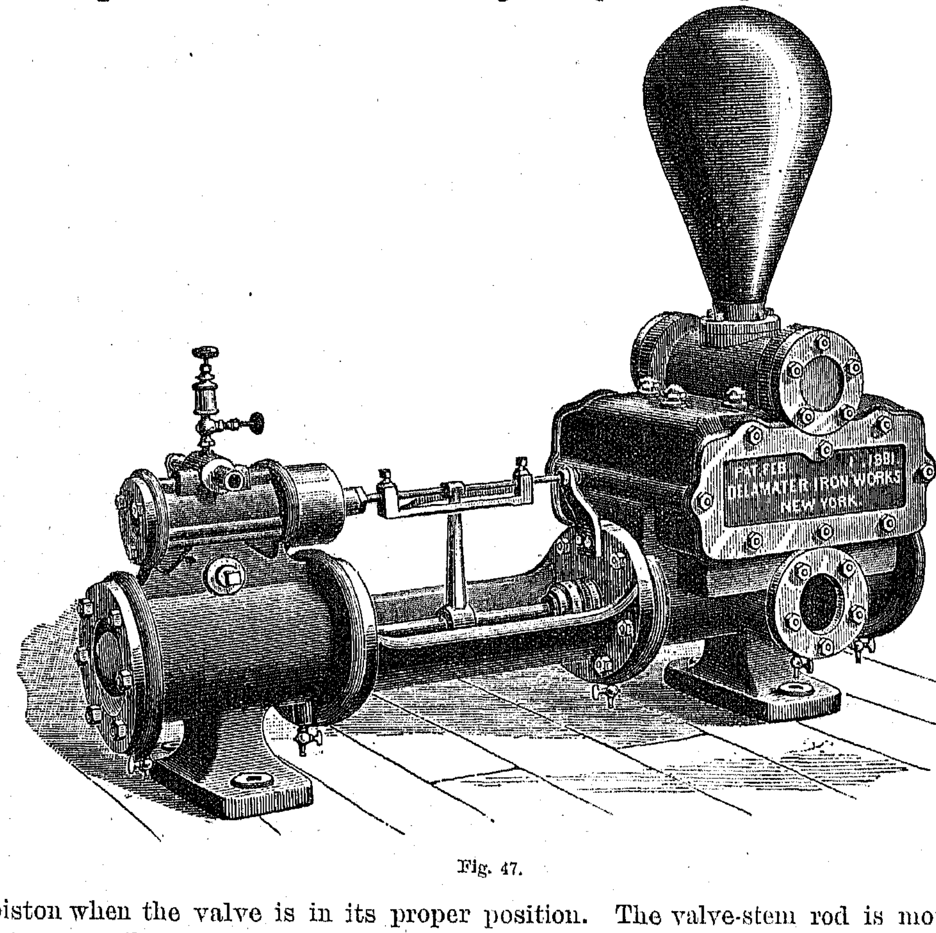

Fig. 47.

move the main piston when the valve is in its proper position. The valve-stem rod is moved by collars when struck by a tappet-arm on the main piston-rod, and the valve-stem is the auxiliary valve. The stem is of larger diameter than the rod, and has short splines milled out of its surface at proper places, so that steam can pass from the jacket through a drilled passage and the spline, and reach the head of the auxiliary piston, which is also the main valve. At the same time a similar spline and drilled passage below at the other end of the auxiliary cylinder

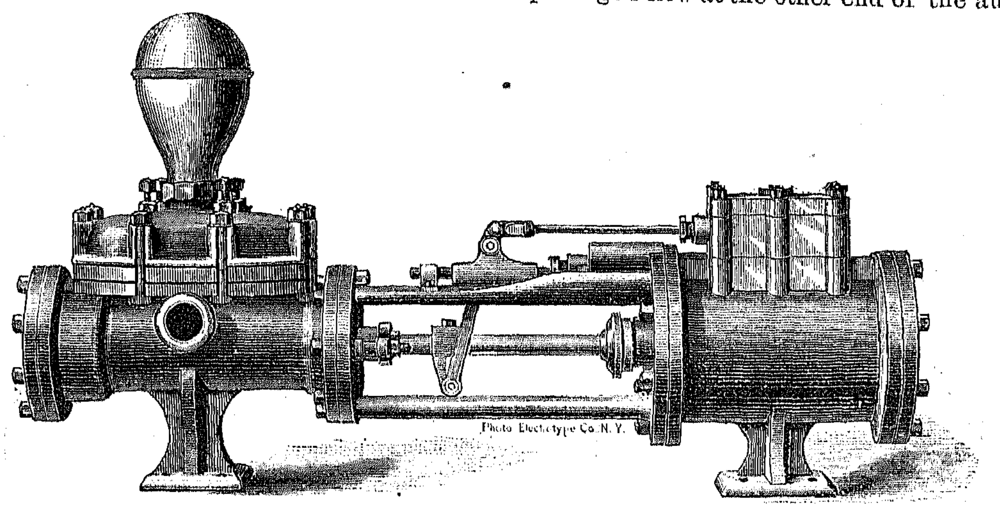

Fig. 48.

opens the space at that end to the exhaust. The piston-valve obeys the excess of pressure, and is thus moved over. The momentum of the valve is arrested by plated steel springs, and the main piston is cushioned by steam-lead. The boss in the middle of the valve-stem will serve to move the valve positively, if steam fails to throw it. To prevent displacement of the splines relative to the planes of their ports, the farther end of the valve-rod is squared and passes through a guide.

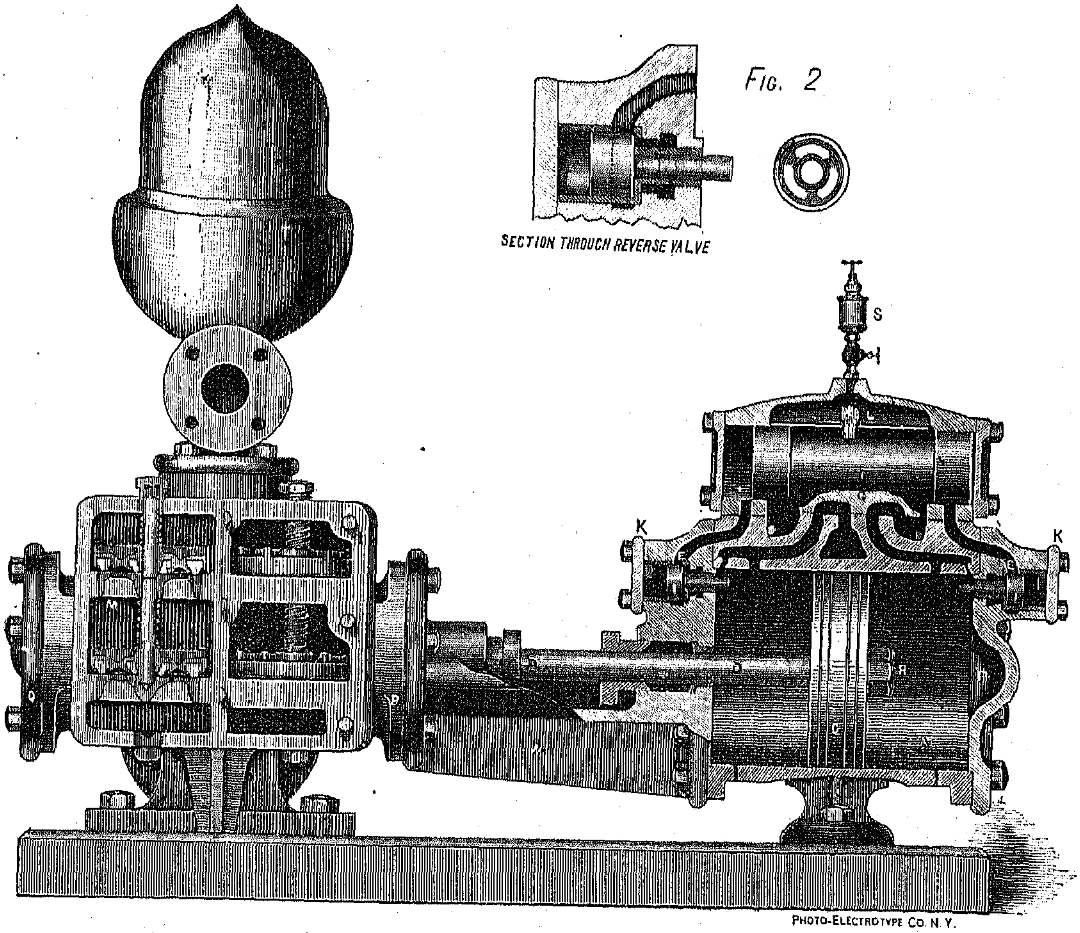

Fig. 49.

The pump shown in Fig. 47 uses the auxiliary piston as the main valve. A vertical arm on the main rod carries two rollers at the sides of its head. These rollers act upon the inclined faces of the brass cradle upon the valve-rod and give a small rotation to the valve. This rotation admits steam to the combined piston and valve, and proper distribution ensues. There is a departure here from previous forms, in that the auxiliary valve is upon the same axial line as the main valve. This is also shown in the Gaskill pump (Fig. 48), although here all the parts are present. The auxiliary piston is in front of the main valve and its chest.

The third class of valve-gear for direct-acting pumps embraces those in which the main piston is brought in to play a part in actuating its own valve-gear. Such a pump is the one shown in Fig. 49. The steam-piston, at the end of its stroke, strikes the end of the stem of a poppet-valve. The opening of this valve connects the space at the head of the auxiliary piston at that end with the exhaust. The other head has the steam pressure upon it, and the auxiliary piston obeys the excess of pressure, and throws over the main valve. The poppet-valve closes when released by the main piston, by the pressure of steam upon its back, equilibriating the pressures upon the auxiliary piston till the end of the stroke in the opposite direction. Minute openings in the heads of the auxiliary piston

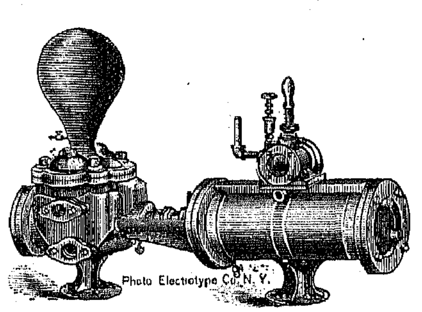

Fig. 50.

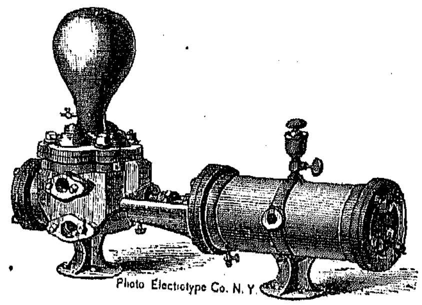

Fig. 51.

permit live steam to leak into the spaces beyond its heads, and the position in the bore of the small ports to the exhaust cause the cushioning of its motion by compression. The main piston is also cushioned by compression of its exhaust. Small ports to the extreme end of the counter-bore admit sufficient steam to start the pump slowly till the larger ports are uncovered.

This arrangement permits very "short-connected" pumps to be used. The same builders design also a pump with a long stroke. The advantage sought by the length of stroke is a large capacity with diminished number of reciprocations. There is a loss when the direction in which the fluid is moving is changed very often.

A pump called the "rock-shaft" pump has the auxiliary valve moved by a finger resting between ridges on its back. The motion of the finger is transverse to the axis of the main cylinder. This finger is attached to a rock-shaft, parallel to the axis of the cylinder, and at one side. A curved arm attached to it projects slightly into the

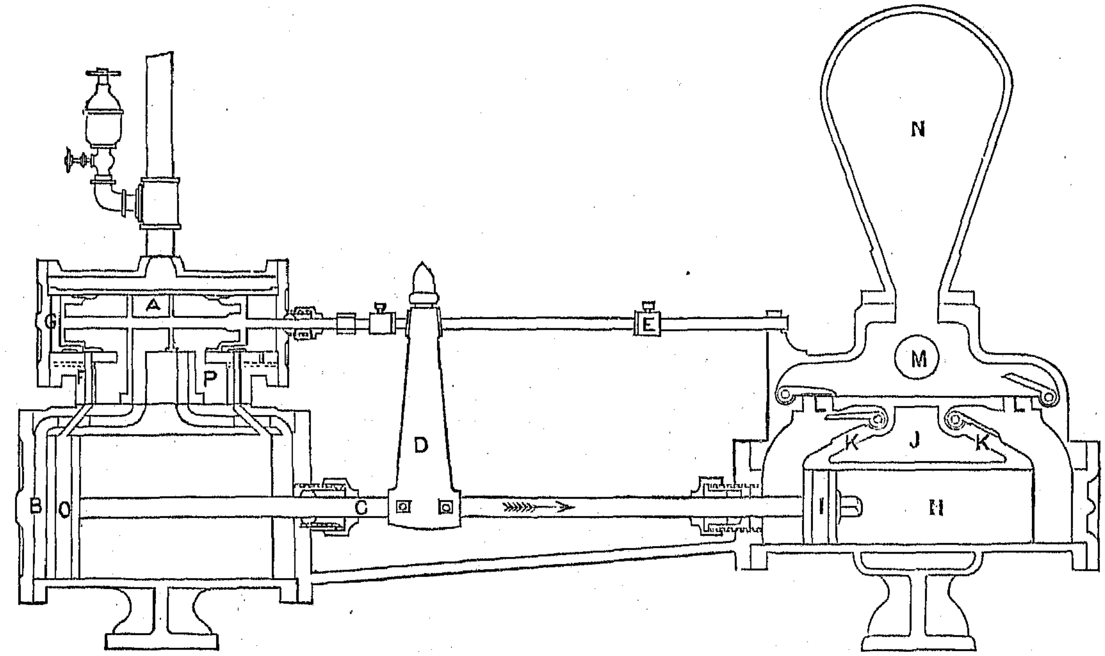

Fig. 52.

bore of the main cylinder at each end, and is so placed that the main piston will strike an incline upon the arm and lift it just before the end of each stroke. The auxiliary valve-openings permit steam to throw the valve at the proper points. The same builders also make what is known as their "differential motion" and their "middle segment" pumps. They are short-connected pumps and, like the first form illustrated, have no fragile external parts (Figs. 50 and 51).

In the pump shown in Fig. 52 the main piston acts somewhat as the auxiliary valve. Live steam enters a jacket around the casing of the cylindrical piston-valve, and passes thence into the space between the heads. From these the steam may enter the main ports when they are uncovered. A tappet-arm on the main piston-rod moves this valve so that a groove in it comes opposite a hole drilled into the main cylinder in the top of its bore. This groove fills with the steam which is still driving the main piston, and which can now pass through a small horizontal passage through the auxiliary piston-head to the space beyond it. The space at the other end of the auxiliary cylinder is by the same motion of the valve put in communication with the exhaust, and the piston, obeying the excess of pressure, moves over and opens the ports for the return stroke. The auxiliary piston and main valve is cushioned by its own exhaust, since the main piston covers the small passage at the other end before its throw is completed. The main piston is cushioned by steam-lead.

To one or the other of these several types, the so-called direct-acting pumps in use at this date will be found to belong. As a type, the direct-acting pump is preferred and mostly used at the east. It has been introduced and successfully applied in mining practice, and a very large number is in use for boiler-feeders and for tank-service. The several valve-motions are also used in designs of pumps for special services, such as air-pumps, elevator-pumps, fire-pumps, etc. The modifications made upon the typical design for such cases are in relative proportions only, and not at all in fundamental principles. These remain unchanged in all the varieties of form.

3.—DUPLEX PUMPS.

The principle underlying the duplex pumps is an extension of the fundamental principle of the direct-acting pumps. The piston-rod of a pump of the latter class opens a valve admitting steam to a second piston, which again causes the admission of steam to the first piston. In the duplex pump the second piston becomes as large as the first and is made to drive a water-piston. The auxiliary engine becomes a second pump, and will be placed at the side of the other. Hence there will be two equal steam-cylinders side by side and two water-cylinders, the piston-rods of each being continuous. Upon each rod is clamped a stud which moves an arm hanging from a rock-shaft (Fig. 53).

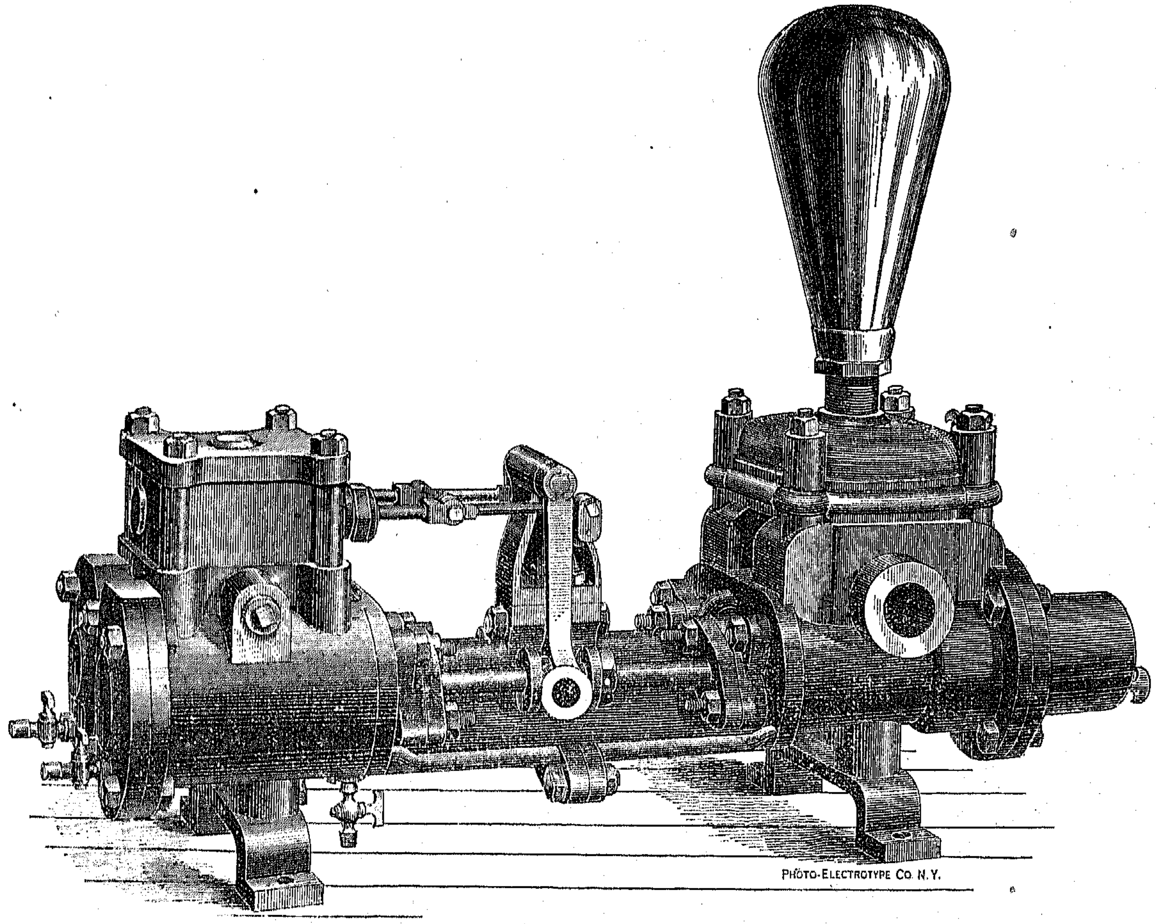

Fig. 53.

The vibrating motion of this arm as driven by the piston-rod of each pump is transmitted to move the slide-valve of the other pump, through a short arm and jointed valve-rod. By this means it becomes possible to arrest the motion of each piston by the compression of its exhaust, which causes a short interval of rest for the water-piston, during which the water-valves may seat themselves without jar. The method of effecting this exhaust-compression is shown in Fig. 54. There are two passages to each end of the cylinder. Both act as exhaust-ports, but the slide-valve is so proportioned that only the outer one admits live steam. The outer port is first closed by the valve on the exhaust-stroke, and then the inner one is closed by the piston itself. Compression of the included steam

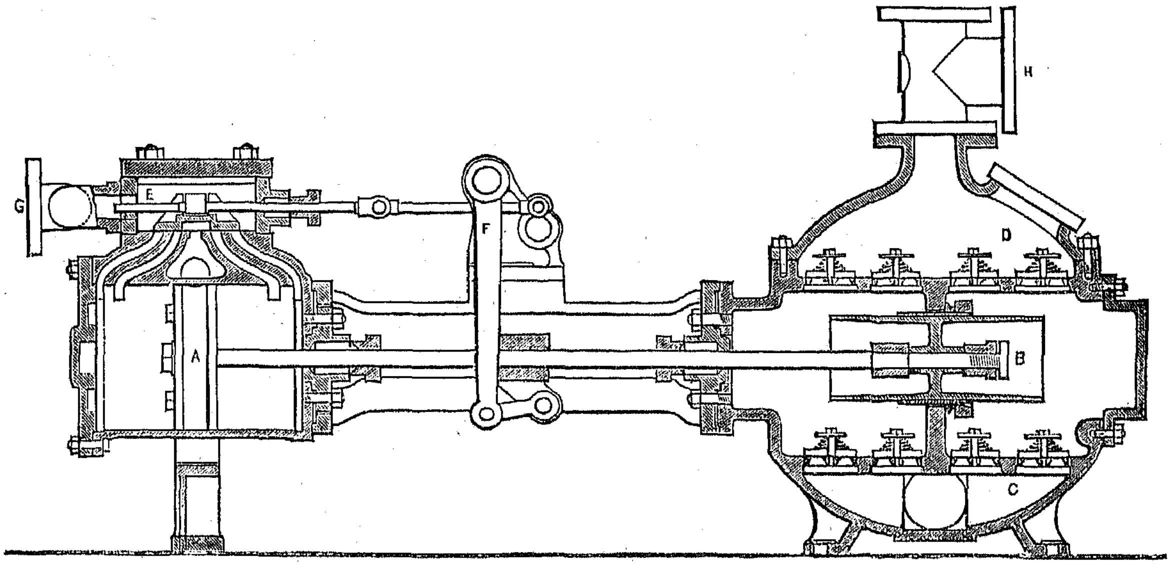

Fig. 54.

must result, arresting the piston. This is the same principle which is applied to cushion the motion of so many auxiliary pistons in the direct-acting pumps. In the larger designs a special bunter-valve is often put upon the cylinder-heads, kept to its seat by boiler-pressure upon its back. Should the piston come too near the head, it strikes the spindle of this valve and insures an independent steam-lead. This, of course, will only occur in case of accident, the valve remaining shut in regular working.

By this duplex system, also, there can be no danger of stalling at even the lowest speeds. When one piston stops it must have moved the admission-valve of the other, and thus must have set the other piston moving. The pumps must, therefore, start as soon as steam is turned on.

This system, moreover, has the advantages which inhere in the positive connection between the piston and its auxiliary valve. The slide-valves, which are of the B-form, move quietly and without shock.

The arrangement of the valves and plungers compels a steady flow in the delivery-pipe, thus diminishing or avoiding entirely the shocks produced in any other system from intermittent pulsations.

The duplex design is due, as a system, to the late Mr. Henry R. Worthington, of New York. Other makers at this date, however, are putting pumps of this type upon the market. They have met their special application in working under heavy loads, as in water-works, mines, oil-pipe lines, and for hydraulic machinery, for which their steady motion peculiarly fits them.

4.—CAM PUMPS.

The fourth general class of pumps includes what are known as cam-pumps. They are of different classes.

The pump shown in Fig. 55 has its valve thrown by steam by means of an auxiliary piston. This piston is moved when a small slide-valve at the side of the auxiliary cylinder opens a connection between the space at the head of the piston and the exhaust-passages. The auxiliary piston responds at once to the unbalanced pressure and moves the main valve. The valve-rod for the auxiliary valve is attached to the end of a rocking lever, pivoted upon a lug in the middle of the cradle between the two cylinders. The lower end of this rocking lever is extended in a T-form, so as to include the profiles of a grooved cam, upon whose acting surfaces bears a horizontal roller. The axis of this roller is a stud clamped to the main piston-rod. It will be at once seen that the profile of this grooved cam can be so shaped at the two ends as to move the auxiliary valve just before the end of each stroke, and thus to reverse the pump. But the intermediate part of the profile has a special function in this design. After a greater or less length of time in many pumps, the auxiliary piston wears loose in its bore, and boiler-steam is continually leaking through the auxiliary ports into the exhaust. To prevent this loss in this type of pump, as soon as the piston has reversed its motion and the roller leaves the steep part of the cam, it strikes the straight lower profile, and thus brings back the auxiliary valve to its central position. This closes all the auxiliary ports, and keeps them closed until the stroke is completed. Then the curves of the cam open the exhaust-connection as before to the other end.

In addition to accomplishing the desired object of preventing leakage, by this system of actuation of the auxiliary valve, is avoided the shock of impact against collars which is to be observed at high speeds in so many designs.

The cam-pump shown in Fig. 56, uses a plain slide-valve and avoids the complication of the auxiliary cylinder and attachments. The valve-rod is connected by a short link to a short arm upon a rock-shaft. This shaft rotates in bearings upon both sides of the cradle. To the shaft in its central portion is secured a long arm which extends

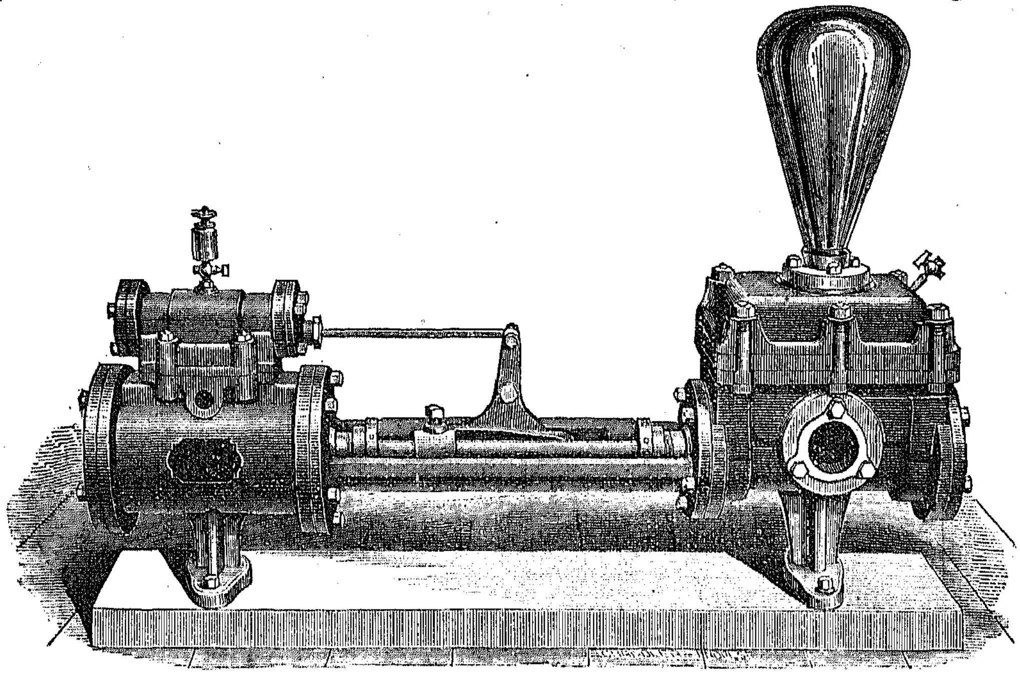

Fig. 55.

out horizontally to be acted upon by the cam. The cam-casting is secured to the piston-rod at its middle point, the acting profiles being the edges of grooves shaped upon its side. These grooves act upon the long arm of the rock-shaft, through a horizontal friction-roller upon a stud at the end. The grooves of this cam are so constructed as to cause the admission of steam to be greatest at the middle of the stroke, while but a small port-opening is permitted

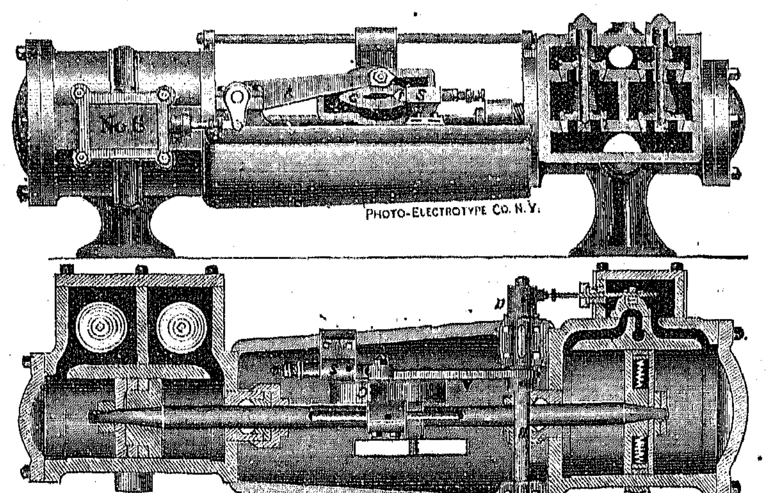

Fig. 56.

at its beginning and end. In order to prevent stalling at the ends of the stroke, a well-known and efficient device is used. The end of the long arm of the rock-shaft is made wedge-pointed horizontally. As the curve of the cam raises or lowers the end of the arm, it brings this wedge-point against the incline of a similar horizontal wedge-point upon a short spindle. This spindle moves in guides upon one side of the cradle. The end of the arm acting upward or downward upon the inclined face of the movable wedge, tends to force it back in order that the arm may pass by. The motion of the spindle is resisted by a spiral steel spring. It is practically impossible for these two wedges to hold each other caught upon their sharp edges, which is the relation corresponding to the central position of the slide-valve. The spring upon the spindle is strong enough (with the leverage which it has) to throw the rocker-arm in the direction in which it is free to move, and thus opens a small port-passage. This small opening will start the pump slowly, bringing the cam to act on the valve and control it for complete distribution. The stiffness of the throw-over spring is controllable by jam-nuts.

In large pumps for heavy duty the spring for the driving-wedge is given by boiler-steam acting upon a piston upon the spindle. By this means the heavier the pressure upon the back of the valve, the stronger is the spring to overcome the resistance.

5.—SPRING-PUMPS.

To this class belong those pumps in which the throw of the valve is completed by the action of a spring which has been strained by the motion previously made. Such an one is the pump shown in Figs. 57 and 58. The steam-valve is of the piston-pattern, exhausting at the ends. It is therefore balanced and should move easily upon its seat. There are two chocks upon the valve-rod which are moved by a tappet-arm, and will carry the valve into

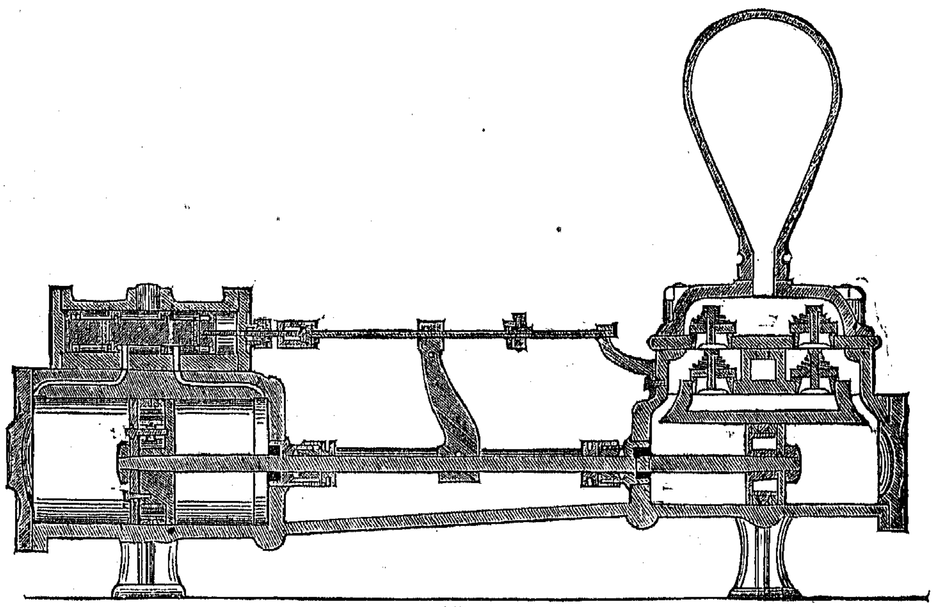

Fig. 57.

its central position. It is prevented from remaining over both ports by the arrangement of two short links and a pair of elastic steel arms. The latter are secured by one end to the sides of the valve-chest, parallel to the rod, and the free ends are jointed to the links, which in turn are jointed to a collar upon the rod. The length of the links is such that, when they are at right angles to the rod the steel arms will be bent back, and therefore under strain. It will be seen that in any other position than at *exact* right angles, the strain of the springs will tend to

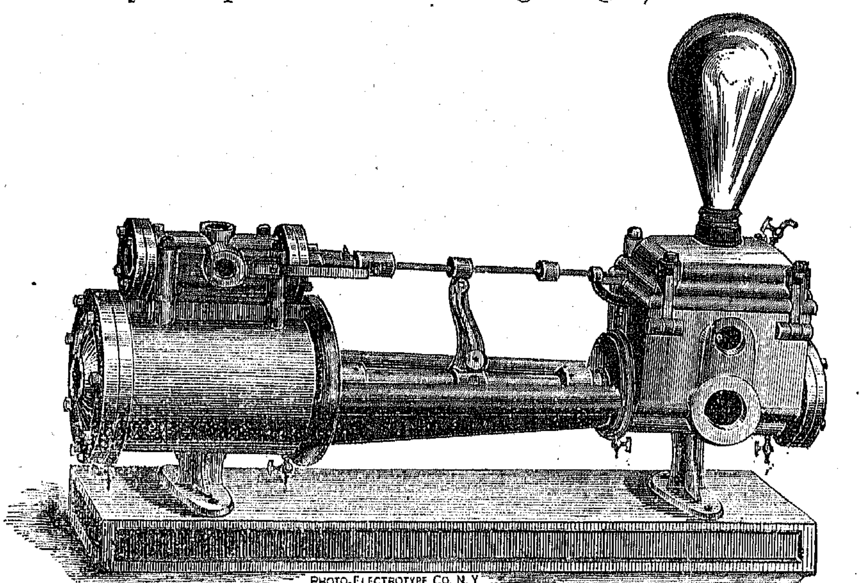

Fig. 58.

move the valve-rod lengthwise, since by no other motion can the springs be released. Since it is very improbable that the main piston will stop with the strain upon the links at exact right angles with the valve-rod, the springs will complete the throw of the valve and the pump will reverse.

This type of gear is historically an early one. It will not be found very widely upon the market at this time.

In concluding the discussion upon the reciprocating pumps, it is to be observed that they are essentially positive in their displacing action upon fluids. They will therefore find their application for forcing under high heads or great resistances, even with a considerable lift. It is best, however, that the fluid to be displaced should flow easily, and that it should not contain a very large proportion of solids. For such material a different form may be preferable.

CLASS B.—ROTARY PUMPS.

The various types of rotary pumps may be examined under three classes:

I. Rotary piston-pumps.
II. Centrifugal pumps.
III. Propeller pumps.

The essential parts of a rotary pump are comparatively few. In a casing of cylindrical shape, or made up of parts of cylindrical surfaces, will revolve one or more pistons. These will be driven from an external shaft which enters the casing through stuffing-boxes in the heads. There must also be an abutment to separate the sucking and forcing sides of the pump. This will, of course, be movable, and will either be driven by gearing outside, or its motion will be compelled by the internal structure of the machine. Any rotary engine may be turned into a rotary pump by the simplest inversion. There are certain forms in use at this date, especially for pumping purposes, to which attention will be drawn.

The centrifugal pumps, however, depend upon a different principle. Their function is simply to produce a motion in the fluid, which shall cause certain natural forces to come into play, whose action shall produce the desired displacement. Hence there will be no displacing pistons nor any abutment.

The propeller pumps simply apply the principle of the screw to the raising of a fluid, in which as a nut the screw shall be made to revolve. In all these cases it will be seen that no valves are necessary, except possibly a foot-valve at the bottom of the suction-pipe, and only in a few types will any air-chamber be called for.

1.—ROTARY PUMPS.

The rotary pump most generally in use is the Holly pump, illustrated in Figs. 59 and 102. There are two

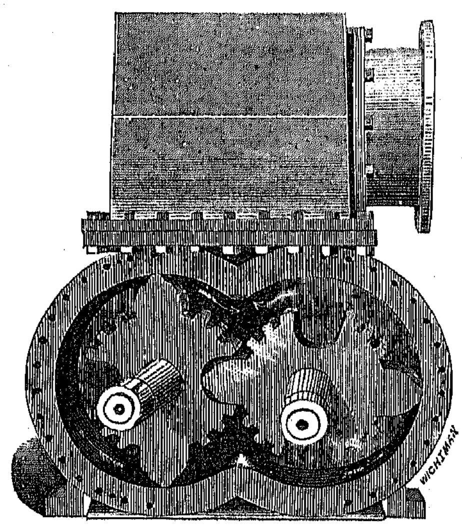

Fig. 59.

revolving shafts geared together externally, which carry the two revolving pistons in the chamber. Each of these serves as abutment for the other from its shape, and the joints are made water-tight by packing strips in the ends

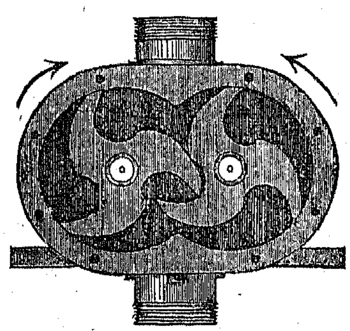

Fig. 60.

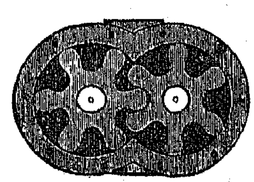

Fig. 61.

of the arms of the spider. These strips have an offset to keep them from being forced out when not in contact with the casing, and are kept to their work by flat springs. When the pistons are made to revolve in the direction of the arrows, it will be at once seen that rarefaction of the air in the suction-pipe must ensue, and atmospheric pressure will ultimately cause the water to enter the spaces between the pistons. This water will be displaced by the arm following and forced into the space above, from which the only outlet is through the discharge-pipe. The flow will be continuous, or with but slight pulsations, and of course no valves are required.

Another type using two pistons is shown by the pump illustrated in Fig. 60. Here the action of the parts is the same, the arms of the spider being more curved. The profiles of the pistons as in the former case are so shaped as to be complementary each of the other, so as to be always in contact along the center line.

Similar in action is the pump made by the same firm illustrated by Fig. 61. The curves of the pistons are epicycloidal, and fit completely the spaces opposite as they pass successively the center line. This type avoids the necessity of gearing outside.

The pump of Fig. 62 shows a similar type of construction. The curves of each piston clear the prominent

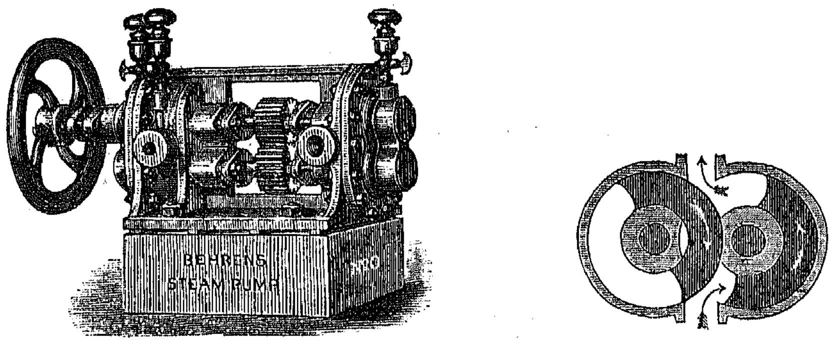

Fig. 62.

profiles of the other.

There are several designs in which the abutment is distinctly present, instead of being concealed in the second piston. Such an one is shown by Fig. 63 of the Torrent pump. The large lower piston fits without clearance into

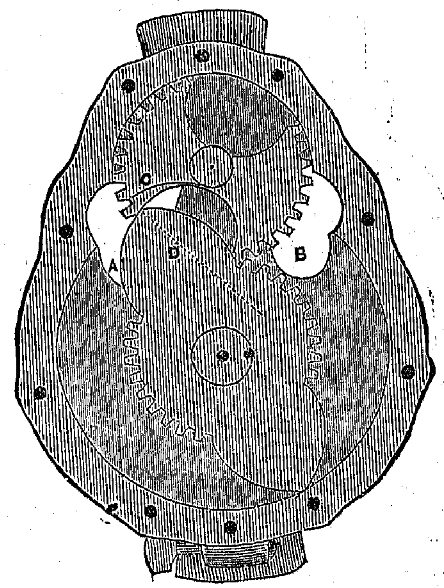

Fig. 63.

the hollows of the abutment above, or else the division is effected by the contact of the toothed surfaces along their line of centers. A departure from previous types is made by having the inlet and the outlet orifices upon the side of the casing and not at the bottom and the top. By this means is avoided the necessity of having a leak into the suction for the fluid which would be forced from the abutment space by the long tooth of the piston. The piston and the abutment must be geared together externally.

In the Foster pump, illustrated in Fig. 64, there are four radial pistons revolving in contact with the casing, and the solid center which drives them serves as an abutment. The center is eccentric to the casing so that it remains in contact with it at one line, and the pistons slide in and out as compelled by their tangency to the casing. They retreat inside the abutment as they pass the point of its tangency with the casing.

Still another type is shown by the pump of Fig. 65. The displacement is here effected between the casing and the eccentric revolving ring. The latter is driven by a belt-wheel outside and no gearing is required. The

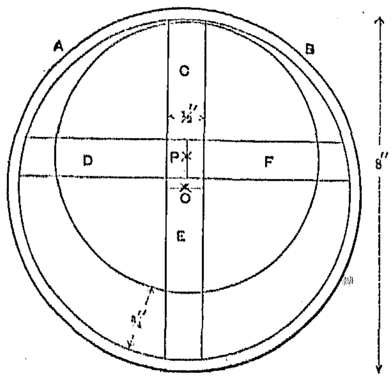

Fig. 64 *a*.

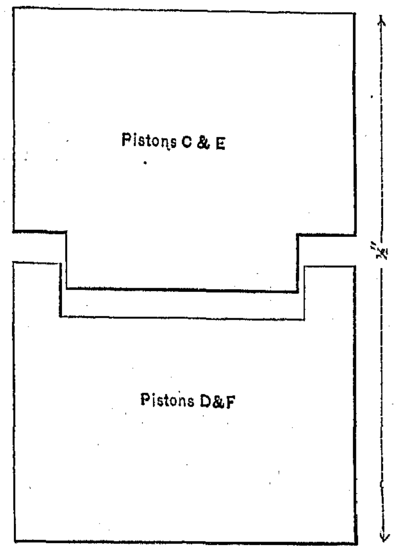

Fig. 64 *b*.

abutment is here made by a slide-valve, the eccentric ring sliding through the middle of the valve and thus moving it upon its seat. The delivery outlet is upon one side of this valve and the suction inlet I is upon the other. In

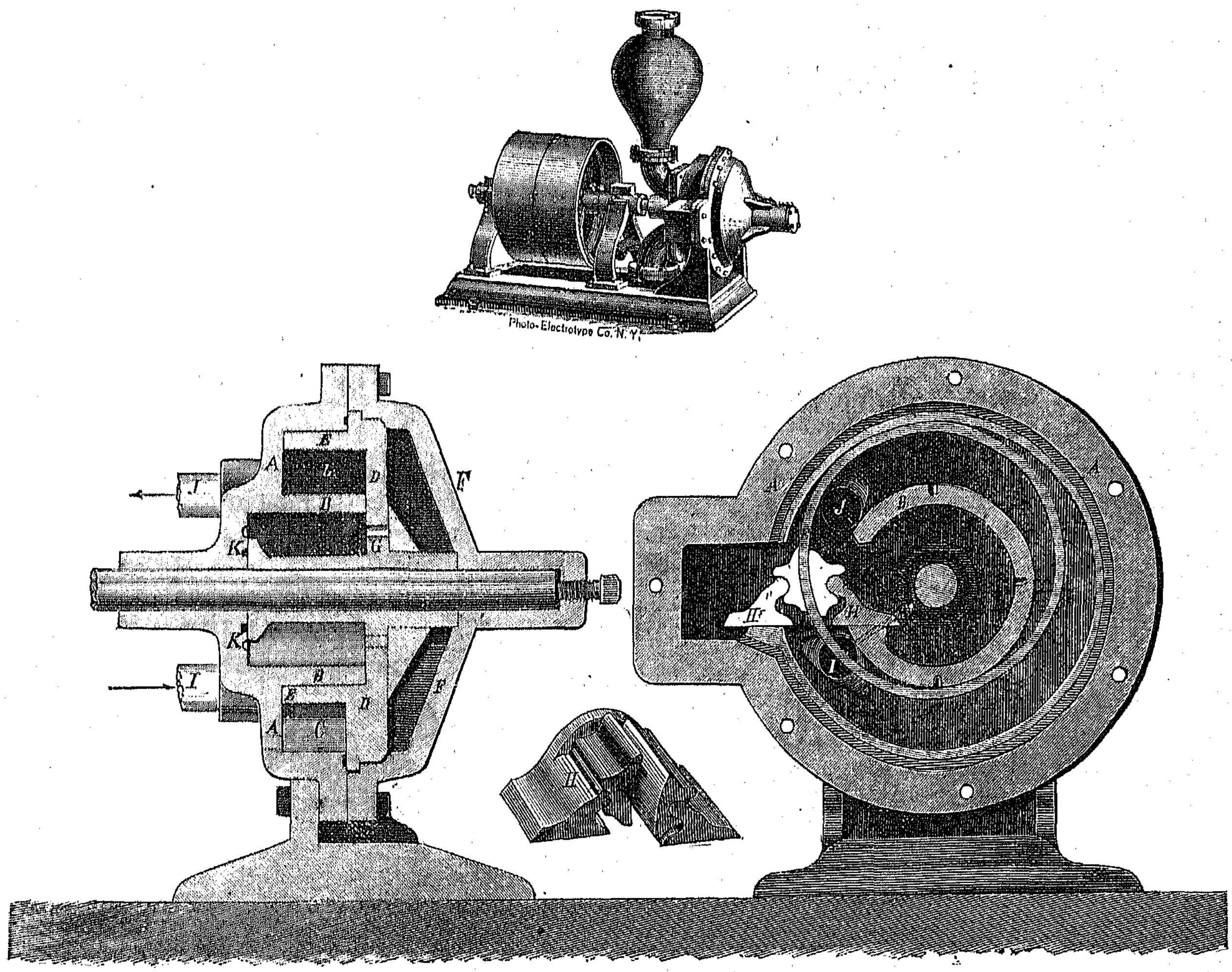

Fig. 65.

newer forms the abutment-slide is at the top of the casing, so that the pump can be driven in either direction, either outlet serving as delivery-vent.

In the pump shown in Fig. 66 still a different type is presented. The chamber is divided into three parts, in each of which is revolved a spur-gear of five teeth. These gears are revolved by the pin-plate, which has seventeen pins upon it, which engage in the gears and positively displace the contents of the spaces between the teeth into the

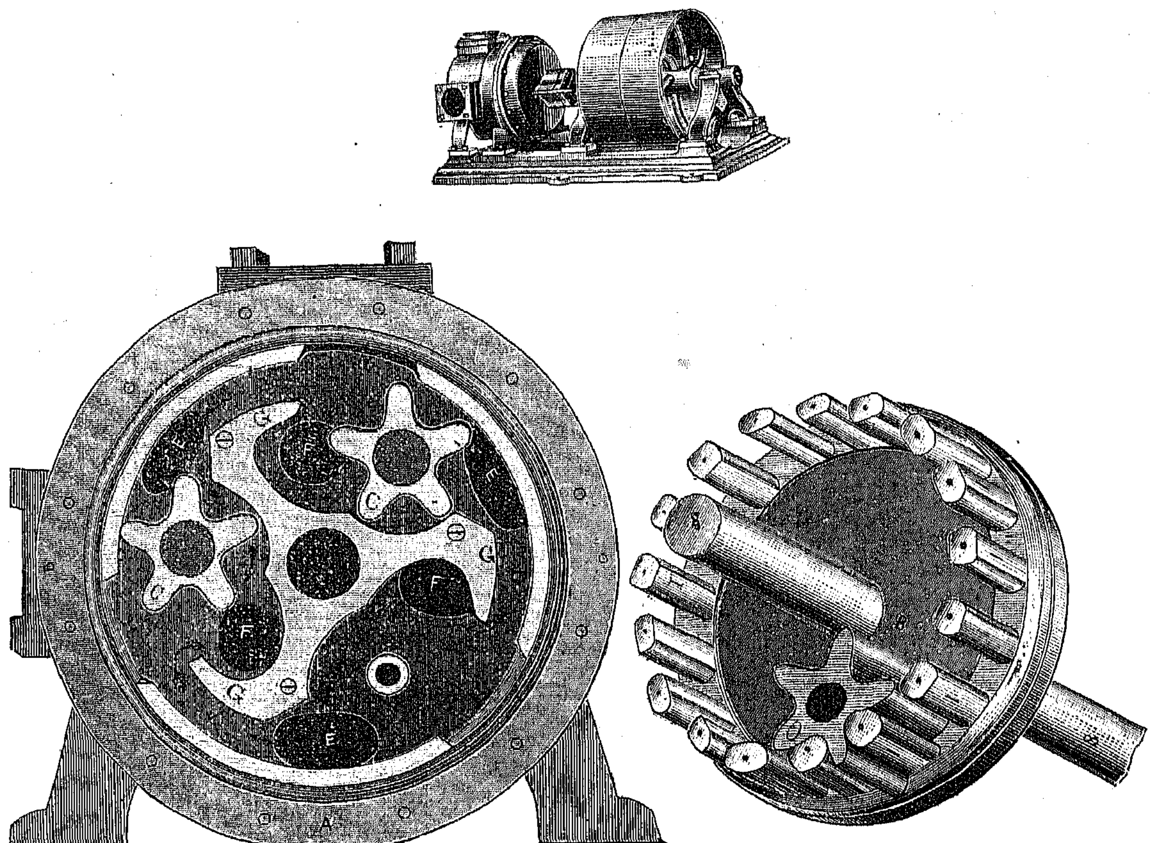

Fig. 66.

delivery-pipe. The arrows show the course of the fluid. The number of teeth in the pin-plate is made seventeen in order that it might be a prime number to five, and prevent pulsations in the flow. The pin-plate is driven by a belt-wheel, and is balanced against the end pressure of the forcing-column by a film of fluid. The gears fit upon hollow studs which are filled with tallow. In the event of heating, some of this tallow will melt and lubricate the rubbing surfaces.

2.—CENTRIFUGAL PUMPS.

In the centrifugal pump there is but one moving part. A wheel with a number of arms revolves rapidly within a casing. These arms are so shaped as to put the fluid into motion along the radii of the wheel, and cause it to have a centrifugal tendency when it leaves the arm. The casing receives a scroll-shape so as to favor this

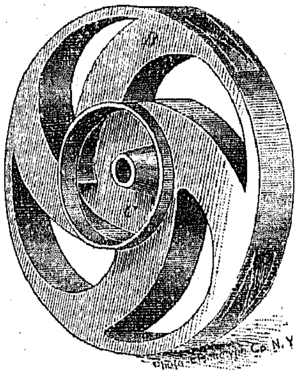

Fig. 67.

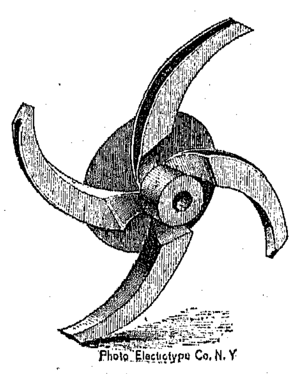

Fig. 68.

centrifugal tendency. The space at the center of the wheel being thus left void, the pressure of the atmosphere forces fluid to fill it through the suction-pipe and the process repeats itself. The fluid in the rising column is continually displaced by the effort of the fluid within the casing.

The general type of wheel used in pumps of this class is shown in the four figures, 67, 68, 69, and 70. The arms are essentially spirals to allow for the two motions of every particle of water within the wheel. It moves in the direction of the radius and also revolves with the wheel. The hollow arm (Fig. 67) is best for water and most

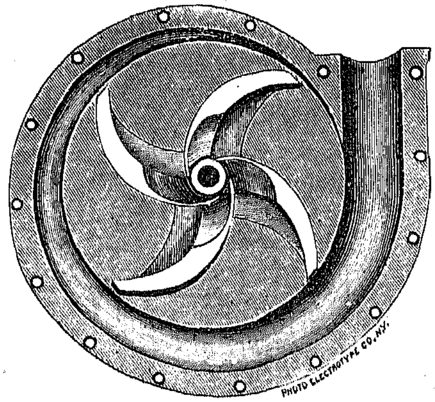

Fig. 69.

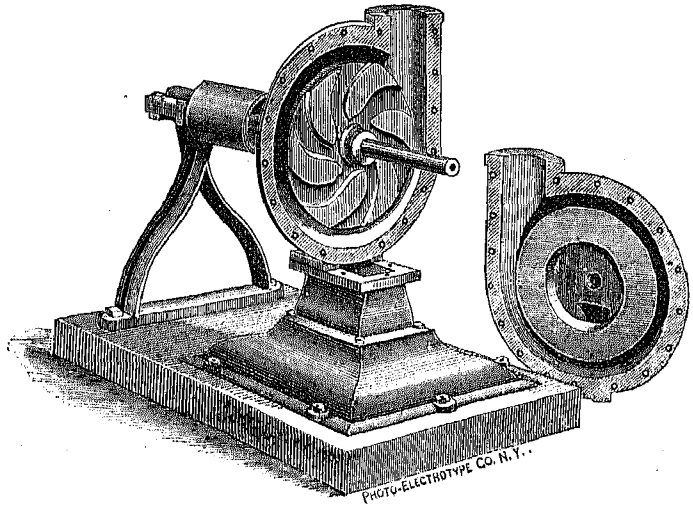

Fig. 70.

other fluids, the solid arm (Fig. 68) being used for viscous fluids or for services where there are ropy matters to be

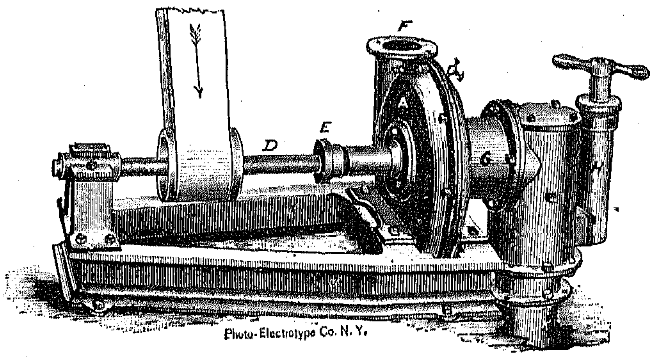

Fig. 71.

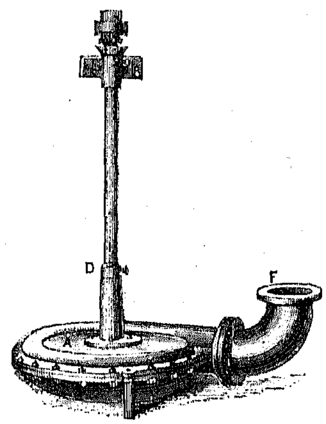

Fig. 72.

displaced. The third form (Fig. 69) has sharp edges to disintegrate such material and render more easy its passage through the wheel.

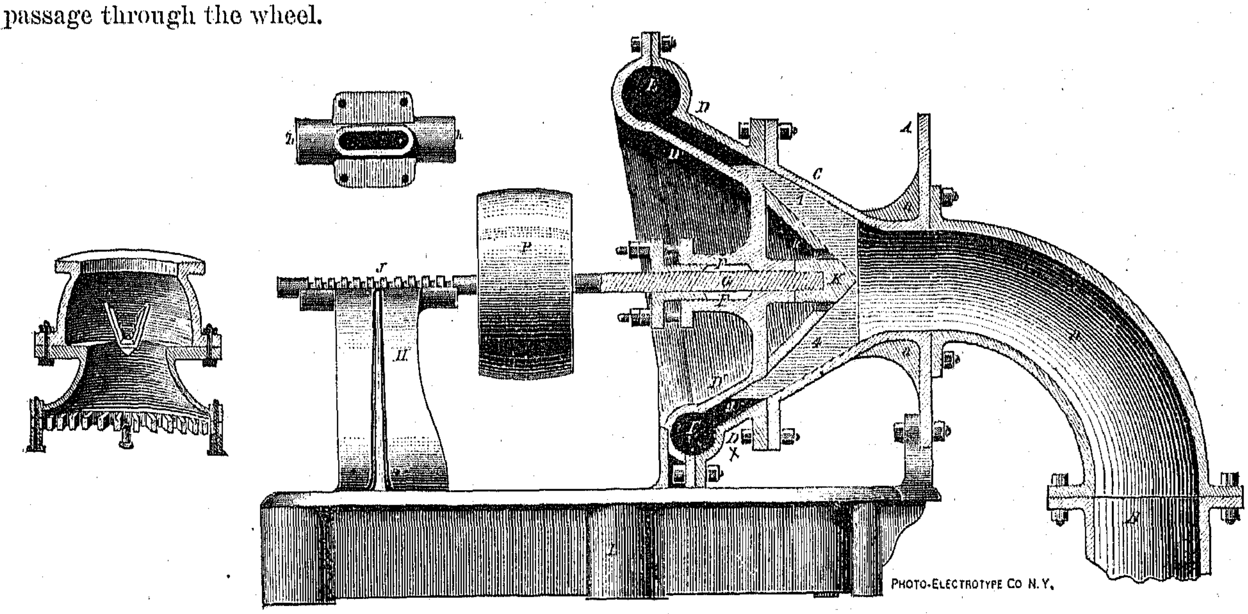

Fig. 73.

These pumps may be used upon a horizontal or a vertical shaft (Figs. 71 and 72). The latter arrangement has certain advantages, since the pump can be put at the bottom of the area to be drained. These pumps, when used to lift for any distance, require to be primed by filling the suction-pipe before starting. To this end a hand-pump is put at the elbow of the suction-pipe to exhaust the air and fill the pump (Fig. 71).

The centrifugal pump shown in Fig. 73 has a wheel with straight blades, which radiate from the surface of the frustum of a cone. The fluid enters at the smaller base to leave the wheel at the larger base with a centrifugal tendency. The chamber into which it enters is of the scroll form, being gradually enlarged till the full discharge-area is obtained. The wheel revolves upon a horizontal shaft, so that there is but little loss from friction of fluid in turning corners. The driving shaft is carried by bearings and stuffing-box out through the side of the casing, and the strain on the driving-pulley is partly carried by the casing. But a small portion of the flexing effort is borne by the shaft in one form. A coupling is secured on the shaft, and this coupling is bolted to the end of the hub of the pulley. The pulley turns upon a hollow sleeve bolted upon the casing through the center of which passes the shaft. There is no thrust upon the wheel, except that due to the atmospheric pressure against the vacuum, and even this can be overcome by small passages connecting the two sides of the cone. Fig. 73 shows a design with a thrust-bearing.

3.—PROPELLER PUMPS.

In the propeller pumps the blades are portions of a screw. As they are made to revolve, the water is continually forced up the inclines of their faces, and is thus continuously displaced.

In the type shown by the pump of Fig. 74, the axis of the screw is horizontal, and it is driven by a belt. The

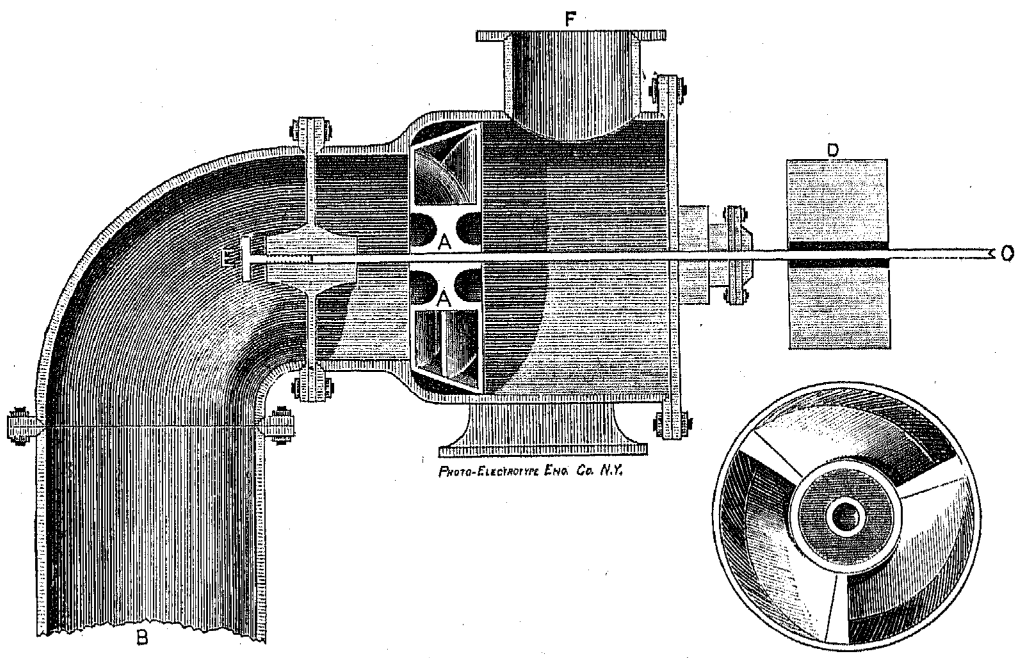

Fig. 74.

thrust of the water-column is borne by a step-screw in the diaphragm at the elbow. In the Shaw pump, illustrated in Figs. 75 and 76, the axis is vertical, and there is a series of helical blades at intervals all the way down the lifting-pipe. The shaft is steadied by bearings at suitable intervals, perhaps five feet apart. There are also fixed blades upon the walls of the rising-pipe, which should diminish the rotative tendency of the ascending column. The upper end of the pump terminates in an elbow, through which protrudes the shaft to receive a belt-wheel. To resist the thrust of the lift and to carry the weight of the shaft and its attachments in the larger sizes, is the object of an especial apparatus. There is attached to the revolving shaft a horizontal disk, which turns with it (Fig. 76). Between this disk and a stationary one just below it, water is forced in at a pressure just sufficient to lift the upper disk from the lower, so that it revolves upon a thin film of water. This makes its motion practically frictionless at this point. The escape of this water laterally is prevented by an annular piston with ring packing, but if the water-pressure lift the disk too high, the excess escapes over the top and returns to the forcing-pump barrel. The whole is protected by a dome-casting.

The propeller pumps will not lift by aspiration. They must, therefore, be put down close to the surface of the fluid, and work entirely by the lifting action of the blades.

The centrifugal and the propeller pumps are especially adapted for moving large quantities of fluid under small heads of lifting or forcing. The rotary pumps will deliver under greater pressures, but can move only smaller volumes. The absence of valves and the forms of the passages adapt them all for moving fluids in which solid matter may be present. They will, therefore, be employed for draining and wrecking purposes. When it is

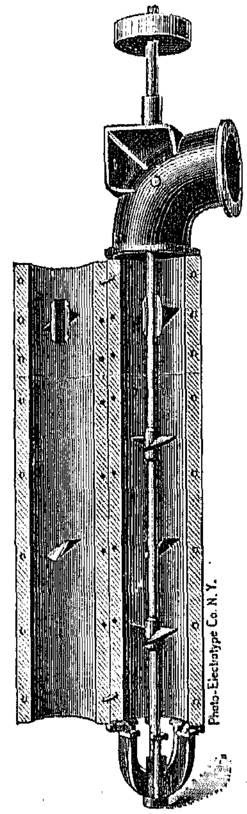

Fig. 75.

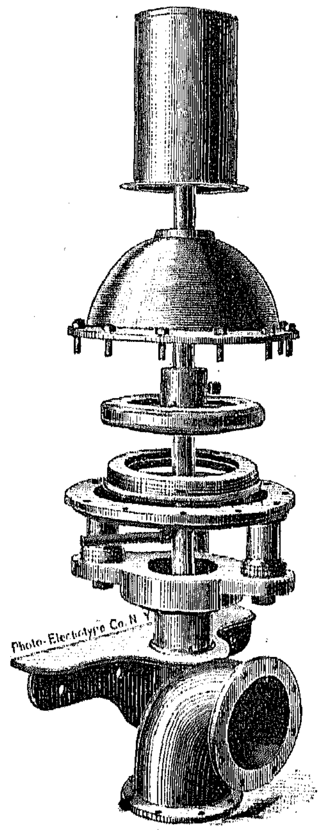

Fig. 76.

attempted, however, to work these pumps under great resistances, a loss from "slip" becomes apparent, especially in some forms, and after they have become worn.

Class C.—DIRECT-CONTACT PUMPS.

To this last general class belong those pumps in which the action of the steam upon the water is direct. There is no reciprocating nor rotary mechanism, and in many of them there are no movable parts at all. From this simplicity result an avoidance of lubrication, and of wear, and also great compactness and ease of repair and renewal of any parts liable to deterioration. The pumps of this class belong to two general groups. The first group includes those in which the lifting action is caused by the condensation of steam in a chamber, while the forcing action is caused by the alternate direct-pressure of steam upon the surface of the water in that chamber. This is somewhat the principle of the very earliest forms of pumping-engines.

Pumps of this class are called pulsometers or aquometers, because of their alternating and pulsating action. A type of one of these is shown by Figs. 77 and 78. There are two pear-shaped chambers, uniting at their converging necks into one steam-inlet pipe, and connected at the bottom by valves to a common suction-pipe from the fluid to be displaced. A similar valve opens to the discharge from the bottom of the chamber, both valves being usually rubber disks, prevented from rising too high by curved guards of brass. There must be a vacuum-chamber on the suction-pipe to relieve the shocks of arrested inlet. It has a small air-check valve, with its stem downward, and similar air-valves are screwed into the neck of each chamber. At the neck-casting is a ball-valve, which oscillates between the mouths of the two chambers, closing them to the access of steam alternately. When in action, steam enters one of the chambers and forces out the contained water until the level of the water falls below the delivery-valve, when steam escapes into the discharge-pipe. This escape causes a partial condensation of the steam in the chamber, and the ball-valve at the neck, obeying a buoyant effort of the water in the other chamber, rolls over to close the orifice of the emptied chamber. Upon the closure of the steam-inlet, the resulting vacuum is at once filled with water forced by atmospheric pressure through the foot-valve, and the cycle would repeat itself for each chamber. The inlets are so proportioned that the chambers shall fill with water more rapidly than they will discharge it. One chamber will be full when the other has discharged about two-thirds of its contents. To start the pump, the steam is admitted to the chambers for an instant and is permitted to condense. Water, of course, fills both chambers through the suction-pipe, the air-valves remaining closed. When both chambers are full, the steam is again let on, the air-valves are opened a little and the regular working will ensue. The air-valves are

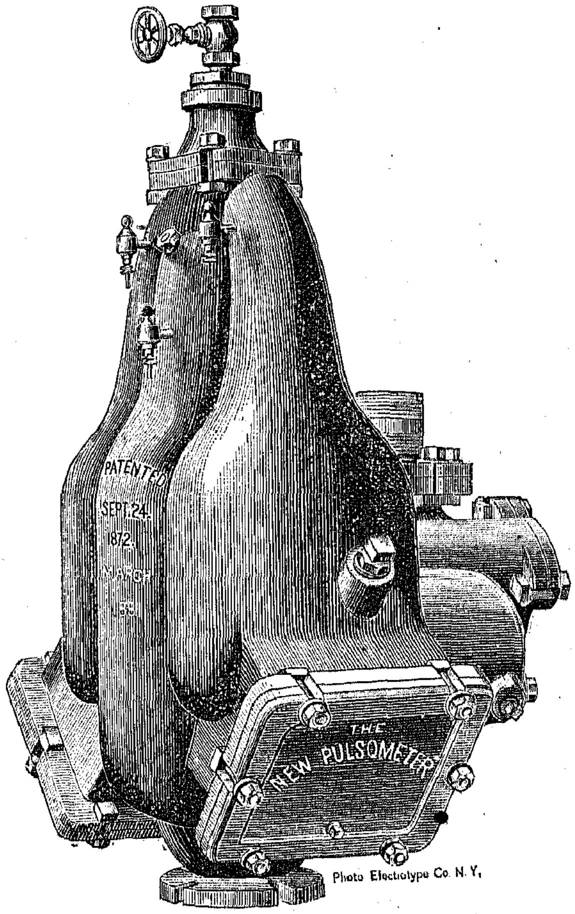

Fig. 77.

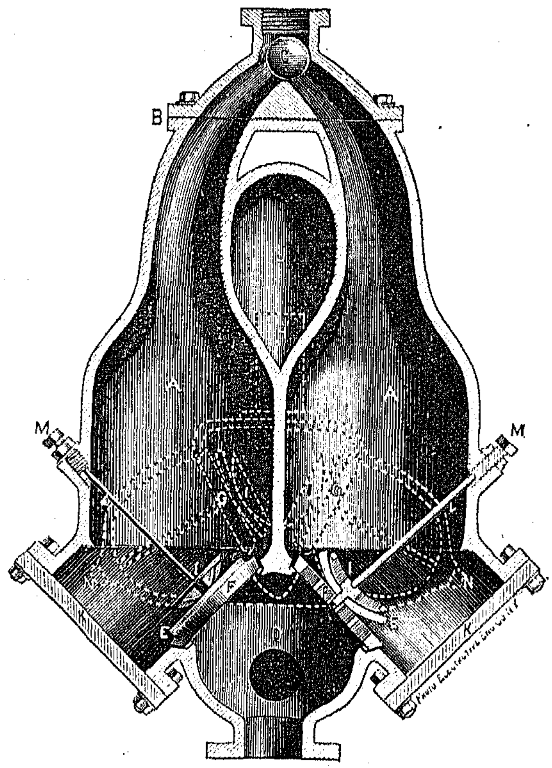

Fig. 78.

controlled by milled neads, to secure the desired amount of opening. Bonnets permit access to the valves, both on the suction and the discharge.

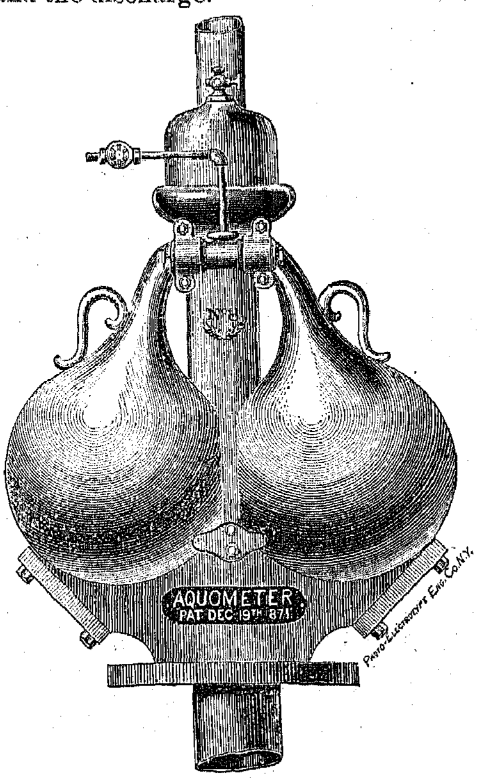

Fig. 79.

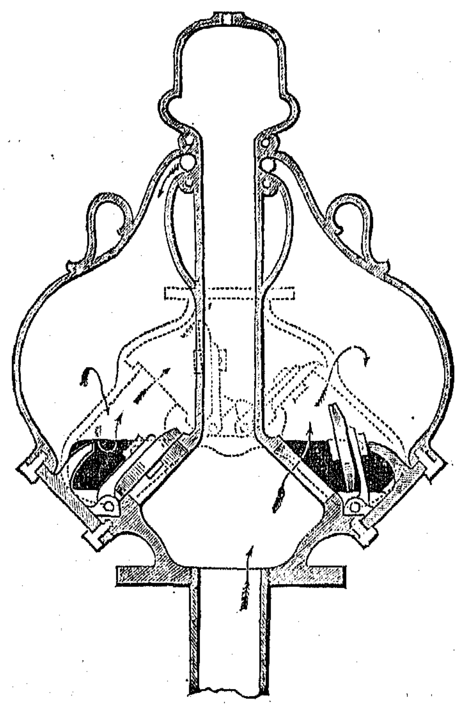

Fig. 80.

Similar in principle is the aquometer, Figs. 79 and 80.

To the second group of pumps of the direct-contact class belong those which depend upon the principle of induced currents. A jet of steam escaping at a high velocity through a small nozzle in the axis of a larger pipe, will act as a species of piston in that pipe, and will aspirate and rarefy the air behind the jet. The current of steam induces the current of air to follow it. Upon this principle depend the steam-jet blowers and exhausters, the vacuum-brake apparatus, and many other devices. For use in pumps, however, the principle is especially applicable, because, beside the simple lifting by the induction of the current and the consequent upward motion of the water in the suction-pipe, a forcing action is possible. When the water lifted up by the pressure of the atmosphere meets the jet of steam, the latter is at once condensed. The living force, however, which was present in the steam still remains in the condensed water, and is competent to force the lifted water forward with a velocity proportional to the original steam-pressure. Hence in pumps of this class there need be no valves even, nor any moving parts, and the delivery will be continuous.

Two devices of this class are shown in Figs. 81 and 82. The steam jet enters from below, the water is sucked

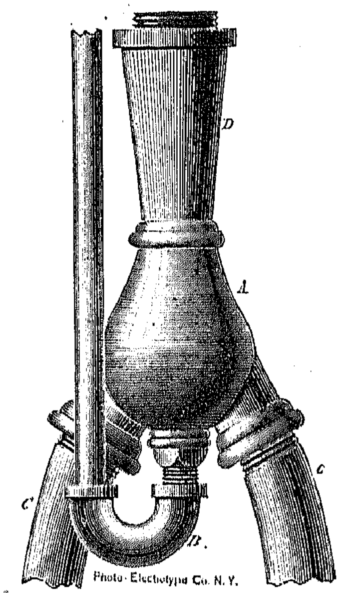

Fig. 81.

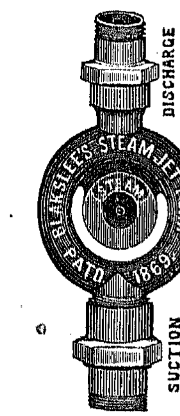

Fig. 82.

up through the two orifices below, and they pass together outward, through the outlet upward.

In the pump illustrated by Fig. 83 are typified the various forms of ejector. A jet of steam induces first a

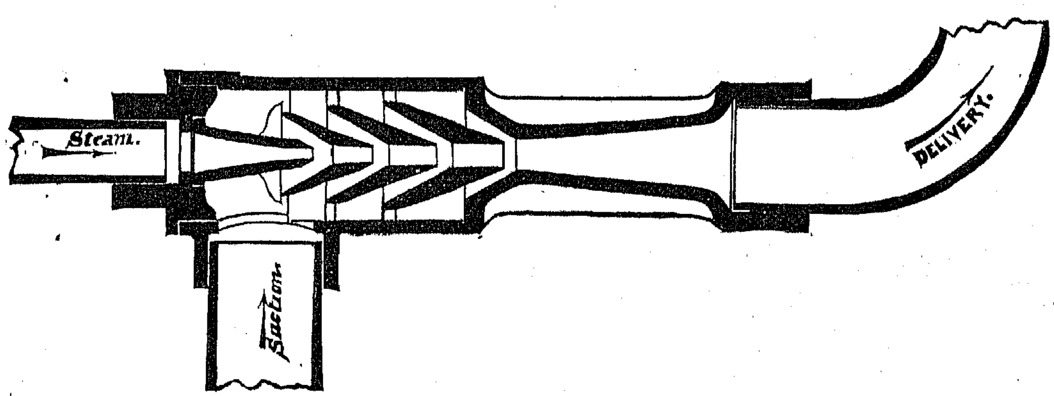

Fig. 83.

current of air, and finally of water. But by the use of several nozzles of an annular construction, the first jet of water is made to induce others, and by this means the living force of a small jet of steam is more thoroughly utilized. Pumps of this class are especially adapted for drainage purposes, where the heating of the discharge-water is no detriment, and gritty solids might damage a pump with moving parts. They are also adapted for an emergency-pump, as they require no foundation nor setting. They need only to be connected at the three outlets by flexible hose, and there is no exhaust to be disposed of.

The class of injectors or inspirators differ in no material respect in their application of the preceding principles. They are designed mostly for boiler-feeding purposes, where they must deliver under a heavy pressure. Hence the delivery-end is reduced in area, and not enlarged as in the type of ejectors. The differences in the various forms are rather in the arrangements looking toward ease of management.

PART II.

PUMPING-ENGINES.

PART II.

PUMPING-ENGINES.

As heretofore stated, the distinction between the steam-pump and the pumping-engine is solely due to their difference in size. A large pump becomes a pumping-engine. But as the result of the large amount of water to be displaced, certain details become important, which could be overlooked in the case of the smaller pump.

It becomes necessary, in the first place, to reduce the consumption of fuel to a minimum. Hence the steam must be worked expansively. For a similar reason the engine should be fitted with a condenser and attachments, or even made compound. To secure the greatest economy under varying conditions of speed and load, the expansion must be made variable, and is often in the best practice made automatic.

In the second place, great care must be taken to avoid shocks from the water. The weight and mass of the water increase the inertia to be overcome at every stroke, and any sudden stoppage compels the absorption of living force at some point. If this absorption has to be rapid, a shock will result whose repetition will ultimately loosen joints and wear out the machinery. Hence the valves in the water-chamber must be specially arranged with a view to this, and air-chambers on both suction and delivery sides must be freely introduced. The speed of such pumps, beside, cannot be made very high, for the same reason, and the motion of the water in the forcing column must be uniform.

In the third place, the large volume to be displaced at each stroke makes it necessary that all single-acting plunger-pumps should be vertical. The transverse-flexing strain due to the weight of the plunger at the ends of its stroke would bring excessive wear upon the gland which guides it. Moreover, in pumps of this class, the weight of the plunger is depended upon in part to force the water against the head due to the column. Piston-pumps may be horizontal, inasmuch as the weight of the piston is borne at all times by the bottom of the cylinder, and there may be sufficient bearing-surface to prevent excessive pressure upon each unit of area. The plunger-pump may be horizontal in the double-acting designs where the gland is in the middle of the two water-chambers, or in pumps of short stroke.

1.—NON-ROTATIVE PUMPS.

Pumping-engines may be grouped under two classes, the rotative and the non-rotative, according as they attain the expansive working of the steam by means of a fly-wheel or not. To the non-rotative class belong the vertical Cornish pumping-engines, the horizontal Worthington engines, and the other engines of the direct-acting type. To the rotative class belong the Holly and Leavitt engines, and all the horizontal engines which use the living force of the fly-wheel.

The Cornish pumping-engine is essentially a vertical one. The weight of the plunger is made sufficient to displace the water against the head, and the work of the steam is only that necessary to lift the weight of plunger and rods. The original Cornish engine was a beam-engine, the plug or master-rod passing down the pumping-shaft from the outer end of the beam. For water-works purposes there are but few beam-engines, the side lever being used in one or two cases. The direct-acting or Bull-Cornish engine is the type which has been preferred. In this type the steam-cylinder is supported upon transverse beams directly over the plunger and pump-barrel, which are immersed in the well. The mass of the rod is so calculated that steam admitted below the piston and cut off at an early point shall be just adequate rapidly to lift the plunger and fill the barrel, without endangering the upper cylinder-head. When the piston is at the top of its stroke, the equilibrium-valve is opened, which establishes a connection between the top and the bottom of the cylinder, so that the piston and plunger may sink gradually and displace the expanded steam into the volume above the piston and the water in the barrel into the forcing main. When the lower end of the stroke is reached, the equilibrium-valve is closed, the admission-valve is opened below the piston, and the valve to the condenser is opened above it, so that the cycle may repeat itself. It is possible by means of the "cataract" to cause any desired interval between the strokes. The rod opening the admission-valve may be the prolongation of a piston-rod from a small cylinder. If this small piston be lifted on the descending stroke of the pump, the cylinder may fill with water by aspiration through a check-valve. The small piston, which is weighted, can therefore descend only as the escape of the aspirated water will permit, and the speed of this escape can be controlled by the greater or less opening of a small cock in the bottom of the cylinder. Hence for variable or intermittent service, it is possible to have a very small number of strokes per minute.

In this system it is the mass of the plunger-rod and piston which intervenes between the variable force of the expanding steam and the constant resistance of the water-column. But as the motion is not continuous, there must be special devices of buffers to prevent overstroke. The boiler-pressure must also be kept uniform, or else careful regulation of the throttle-valve is made necessary. Then inasmuch as it is the resistance of the water-column which retards the rapid fall of the plunger, any failure of the foot-valve either to open or to close will permit the great weight of the reciprocating parts to come down with high velocity, perhaps knocking out the bottoms of both cylinders and demanding extensive repairs. The danger of the latter accident has been diminished on the Bull engine at Erie, Pennsylvania, by a device of the engineer in charge. The rod cannot move enough to open the equilibrium-valve unless the full resistance is upon the pump-barrel. A small cylinder connected by a pipe to the pump-barrel moves suitable catches which only release the valve-rod when the little cylinder is full of water, and this latter can only occur when the pump-barrel is full and the foot-valve is closed, and the motion of the plunger has begun to displace the water upward. The little cylinder empties of course upon the up-stroke of the plunger, and sets the catches anew. This, however, will not prevent accident to the pump in case of the bursting of the rising main nor in case of the failure of the eduction valve. The valves of the Cornish engine are usually opened by tappets upon rods which move with the plunger. They are held open by catches, which are in turn released by other tappets. Upon the front of the cylinder are two rock-shafts, one of which carries the levers for the admission and exhaust, and the other carries the gear for the equilibrium valve. Each shaft carries the catches for the other, to hold the valves open during the proper interval. The valves are closed by weights when released, which fall into dash-pots below.

The Cornish system has given what were considered at the time very economical results. The high expansion, varying velocity, and moderate driving of these engines have enabled them to show a high duty in some cases. But there are great drawbacks to the system. The flow is not uniform in the forcing main, the liability to accident is great, they are costly to build and to erect foundations for, and their duty has been exceeded by other types. The number erected for large pumping-works has been growing less and less every year.

The other class of the non-rotative pumping-engines includes those designs which are simply large direct-acting steam-pumps, with the slide-valve thrown by steam or else working upon the duplex system. They are made either non-condensing, condensing, or compound, according to the magnitude of the service for which they are employed, in order that a suitable relation may be maintained between the interest account and the coal account in any enterprise. Most of the leading builders of steam-pumps have several pumping-engines in service, but the duplex system devised by the late Mr. Henry R. Worthington is the most widely extended. This pump is met with in five forms. As an auxiliary or spare engine, and for small and intermittent service, a high-pressure, non-condensing engine, working without expansion, has been introduced. It works upon the duplex system, but cannot be depended upon for a duty higher than twenty million. The second form is also non-condensing, but works with a certain degree of expansion, and gives a duty of thirty or thirty-five million. The expansion in each complete pump takes place in two cylinders.

The third form includes the condensing but non-expanding engines, using but one steam-cylinder upon each rod. The fourth form includes the compound engines with receiver. There is a small high-pressure cylinder upon one rod, and a large condensing cylinder upon the other. The steam exhausts from the small cylinder into a receiver or tank of cast-iron or boiler-plate, having a capacity of eight or ten times that of the cylinder. From this receiver the larger cylinder takes its supply. By carefully proportioning the areas of the two cylinders to the work to be done, a uniform propelling energy is retained upon both. There is no expansion attempted in the small cylinder, the expansion being effected by the differences of area in the two cylinders. The fifth form includes the four-cylinder, expanding and condensing compound engines of the largest type. The steam-valves are balanced by being hung from a hinge-joint in the top of a dome upon the valve-chest, with ring-packing to avoid the difficulty of the motion in the direction of the versed sine. The condenser and air-pumps are in a well below the axis of the cylinders, moved by a bell-crank and link from a cross-head. The steam-valves are moved by a contact-joint permitting a little lost motion at the end of the valve-stem. This latter is continuous for each pair, the steam-passages being made longer for the smaller cylinder. The arrangement of the plunger is a special feature. It is hollow and air-tight and slides through an inelastic ring of some depth, fitted in the partition which divides the water-chamber. The valves are made of small diameter and are close to the barrel. Pumps of this class will give an average duty of sixty-five million.

Other makers have also put pumps of the duplex type upon the market within a recent date. The advantages of the direct-acting duplex system are its compactness, and, therefore, cheapness of foundation; the strains are distributed so that the engine is self-contained; the ease of their motion, the direct application of power, their freedom from shock, their certainty of action, and the reduction to a minimum of the momentum of the moving parts. This latter feature secures an immunity from accident in case of breakage, or failure of valves. The Corliss pumping-engine at Providence is also of this class, or is rather a sextuplex engine. Six steam-cylinders disposed on radii round a circle cause a central vertical crank-shaft slowly to revolve. There is no fly-wheel, the speed is controlled by the resistance of the water, and every stroke is of definite length. The water-cylinders are upon radii intermediate between the steam-cylinders, and are worked from the same crank.

2.—ROTATIVE PUMPS.

To the rotative class of pumping-engines belong those in which the living force of a rotating fly-wheel gives out to the pumps during the latter part of a stroke the work stored up before expansion began. Since this rotation of the fly-wheel is caused by a crank, the stroke of piston and plunger must be of definite length, and one element of danger in the Cornish system is thus avoided. But the momentum of the fly-wheel may cause special dangers of its own, inasmuch as the water-plunger may be made to crash resistlessly against an obstruction which would arrest the Cornish or direct-acting plunger, without accident. Moreover, the varying velocity of the plunger and column as driven by a uniformly revolving crank brings strains upon the mains when the velocity is accelerated during the first half of a stroke. The interval also for the closing of water-valves is quite short, causing them sometimes to slam against their seats instead of seating quietly.

In spite of these drawbacks, the crank and fly-wheel pumping-engine is in very general use. It appears in six forms. The first is the horizontal piston pumping-engine, and the second is the inclined engine. These are connected directly to the crank, and the steam- and water-cylinders are upon one line. The third form is the bell-crank engine, where the pumps are vertical in the well, and the steam-cylinders are horizontal. The fourth form is the beam engine, with cylinders vertical, and the beam overhead or below. To this class also belong the side-lever engines. The fifth form includes the few vertical engines directly connected, with two fly-wheels outside the frame. The sixth form includes the types of geared engines, where the pumps and steam-engines may be of different designs.

To the first type of the horizontal engines belong the several engines which are but large specimens of fly-wheel pumps. These have been erected by several designers of these specialties, and illustrations may be seen at Nashville, Tennessee, and at Covington, Kentucky. The larger engines of the horizontal type would be exemplified by that of Grand Rapids, Michigan. The engine is condensing, the steam being distributed to the cylinder by four poppet-valves. The air-pump is at the side of the bed-plate, being worked by a rock-shaft below, and an arm from the cross-head. The arm under the connecting-rod is of the U-shape, so universal in inclined ferry-boat engines. The steam- and water-pistons are keyed into a cross-head between the two cylinders. The water-valves in horizontal pumps are either disk-valves or else clack-valves, seating upon inclined gratings. The Corliss Pawtucket engine uses the Corliss valve upon both the high and low pressure cylinders.

A very prevalent type of the inclined engine is shown by the Holly engine. Four steam-cylinders are connected to one fly-wheel shaft, one pair being connected to one pin upon the wrist-plate. These pins are arranged quartering so as to give a regular flow of water, the two upon each side again being bolted to the bed-frame so as to be at 90° with each other. The steam connections are such that the engine can be run as a four-cylinder condensing engine or as a compound engine, expanding in any desired number of cylinders, and condensing in the last only. The piston-rods are keyed into a sleeve, so that any of the four pumps may be disconnected upon occasion. The steam is distributed by slide-valves, but the degree of cut-off is determined by a poppet-valve on the back of each cylinder, which is opened by a cam. The length of admission through this poppet-valve is determined by the position of the cam upon the shaft which revolves it. The cam is of the well-known form which is of different lengths of face at different parts of its length. The shorter the face under the valve-lever the shorter will be the period of admission, and the position of the cam on its axis is determined by the device called the regulator. This consists essentially of a weighted piston connected by small pipe with the forcing-main. The motion of this piston is carried to a pair of bevel-friction cones, which is caused to move endwise upon a spline, and effects contact with a third friction-cone on an axis at right angles to that of the other pair and between them. It will be seen at once that if these first cones be made to revolve, they will turn the third in one direction or the other according as it is engaged with number one or number two. It is a very simple problem to cause the positive or the negative motion of the third wheel, caused by rise or fall of the properly weighted piston, to produce a later or earlier cut-off of the admission of steam, and maintain a uniform pressure in the mains, by adjusting the position axially of the lifting-cams. There are, of course, objections to the expansion of the steam inside the valve-chest, but it is a very simple method of securing regularity.

Another inclined engine is the Shield engine of Cincinnati. The steam and exhaust valves are of the poppet-type, the former being worked by lifters moved by an especial cam upon the fly-wheel shaft, playing in a yoke at the end of the hook-rod. This secures an early and prompt cut-off. The pumps are vertical and below the fly-wheel shaft.

There are several types of the third form or bell-crank engine in use in Pennsylvania. A pair of cylinders is upon one rod which is connected by short connecting links to the upper end of a large right-angled isosceles triangle. To the other end of the hypothenuse are attached the pumps, down in the well. The triangle which makes the bell-crank is pivoted at the apex, and the fly-wheel is carried upon the horizontal bed-plate. This type has not been very largely duplicated.

The fourth form includes most of the largest and most successful engines of the day. The pumps are vertical, and the steam-cylinders, vertical or slightly inclined, are connected to the crank-shaft and to the pumps through a beam. In the greatest number the beam is overhead, supported either upon the open frame or upon a hollow pillar, which also serves for air-chamber. In the earlier engines (Chicago North Side, and New Bedford for example), the engine is a simple beam-condensing engine, resembling very much the type still in use for propelling river and coast steamboats on the Atlantic waters. The cylinder-valves are of the poppet-type, working in two chests connected by side pipes. The valves are lifted by toes from lifters on a rock-shaft or by rotating cams. The steam-rods usually have an adjustable cut-off gear of the Stevens or the Sickles type, by which the rods are let fall when a latch is released by the action of an adjustable wedge. The blow of the falling weight is cushioned by a dash-pot. The cut-off, when revolving cams are used, is effected by causing the cams to bear upon a block of varying profile, instead of lifting the toes directly. By moving this intermediate block the steam-valve may be kept open a longer or a shorter time. Often the steam-rod carries a bracket with a screw at the end, which may be caused to rest upon a similar bracket on the exhaust-rod. While the latter rod is up the steam-valve cannot be closed entirely. The water-pumps are either below the steam-cylinder, directly connected, or else are worked from the beam, one being placed upon each side of the beam-pedestal. In the later engines the cylinders are compounded, by which the duty of the engines has been increased, and the pressure upon the beam and crank made more uniform. At Chicago West-side station, the valves are of the Corliss type and arrangement, worked from a wrist-plate. The release is effected by throwing out of gear a jaw-clutch on the valve-stem. The engine is started by working the wrist-plate by a small steam-cylinder. In the Leavitt engines, at Lynn and at Lawrence, the two cylinders are inclined to the perpendicular, and take hold of the beam on opposite sides of its center. The valves are gridiron slides moved by cams which have graduated faces, and their position axially on the cam-shaft is determined automatically by a governor. The pump is of the bucket-plunger type. A beam-engine with the beam below the cylinder, is illustrated by the Scowden engines of Cincinnati. The pumps are below the cylinders, and the fly-wheel shaft is at the floor-level. The peculiarity of these engines lies in the connection of the two engines by a drag-link between two wrist-plates.

The fifth form includes those vertical engines where there is no beam. The pumps are below the cylinders, the fly-wheel being turned by pins upon the spokes through connecting-rods from a cross-head between the cylinders. There are two engines of this type also at Cincinnati. The valves are poppet-valves, worked from a rock-shaft by lifters and toes.

Under the sixth form may be included the various types of geared engines. Upon the fly-wheel shaft of the steam-engine is put a pinion which meshes into a large gear upon the shaft which is the crank-shaft of the pumps. By this means is secured the necessary slow motion of the pumps without compelling an equally slow motion of the steam-piston. Hence a smaller steam-cylinder can be used, and the internal condensation and re-evaporation may be less, inasmuch as the radiating surface is reduced, and the number of revolutions is increased. The steam-engine also can work more expansively, since its weakest time does not always come when the resistance is greatest, compelling in this latter case a heavy fly-wheel. There are several illustrations of these geared engines at various places. At Hartford there is an automatic cut-off condensing beam-engine, driving four plungers, and at Providence there is the Nagle engine, which is a vertical direct-acting engine with disengaging valve-gear, driving horizontal pumps. There would seem to be great advantages in this type of engine, but their reported duty has been exceeded by compound engines of the fourth form.

The present condition of the pumping-engine problem is a very hopeful one. The duties of previous experience have been far exceeded, and builders are able to furnish engines under a guarantee. In many cases it is simply a question of financial policy, whether a cheaper and less economical engine will not cost more than a compound beam-engine with its economy of fuel, but its greater first cost and outlay for foundations and buildings. This question can only be answered in any given case by a thorough investigation of all the conditions which enter into the problem.

PART III.

STEAM FIRE-ENGINES.

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The steam fire-engine is a pumping-engine which presents several peculiarities. It must be combined with a boiler and must be self-contained. It must be capable of being driven to its highest capacity without giving out. It must be as light as is consistent with the condition of strength, so as to be easily propelled to the scene of the emergency and must adjust itself to variations of level of road-bed and of position. The boiler must be a rapid steamer and capable of using very poor waters. The pump must be able to suck water from deep cisterns and force it through long lengths of hose to a considerable height. The running-gear must be such as to make the engine manageable upon the road and yet not too unstable when at work. The essential parts, therefore, of the steam fire-engine are the frame and running and propelling gear, the boiler, and the pump and attachments. There must be certain features common to all the designs, but there is a considerable variation in the details. Engines are made of different sizes and capacities, being known as engines of the first, second, third, or fourth

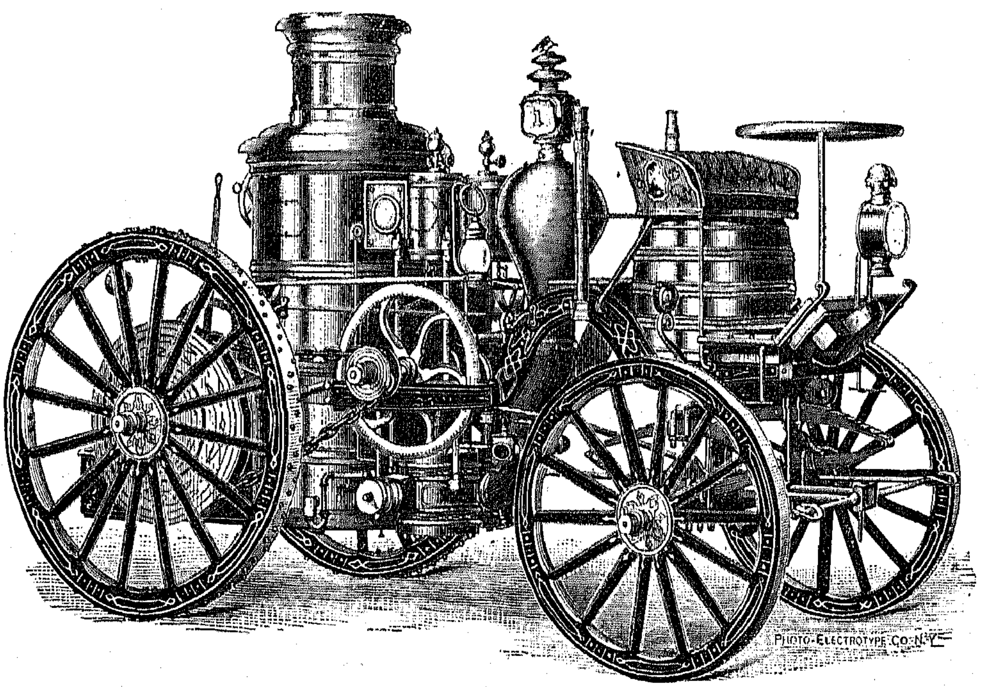


Fig. 84.—Amoskeag self-propeller.

class. There is unfortunately a lack of uniformity in the classification by different builders. The smaller sizes are often made to be drawn by hand, the larger ones being adapted for horse-traction, single or double, and there are a number of self-propellers in service, where horses are dispensed with.

The running gear consists of four wheels, made either entirely of iron or preferably of wood and iron combined. The front wheels under the driver's seat support the seat and the front end of the frame, either through two elliptical wagon-springs, through two locomotive springs, or else through a spiral spring in the center. In the former case the two springs, permit a sidewise inequality of the ground to be taken up in the flexible connection to the frame. In the second method it is judicious to make a horizontal pin-joint between the axle and the spring-case casting, so

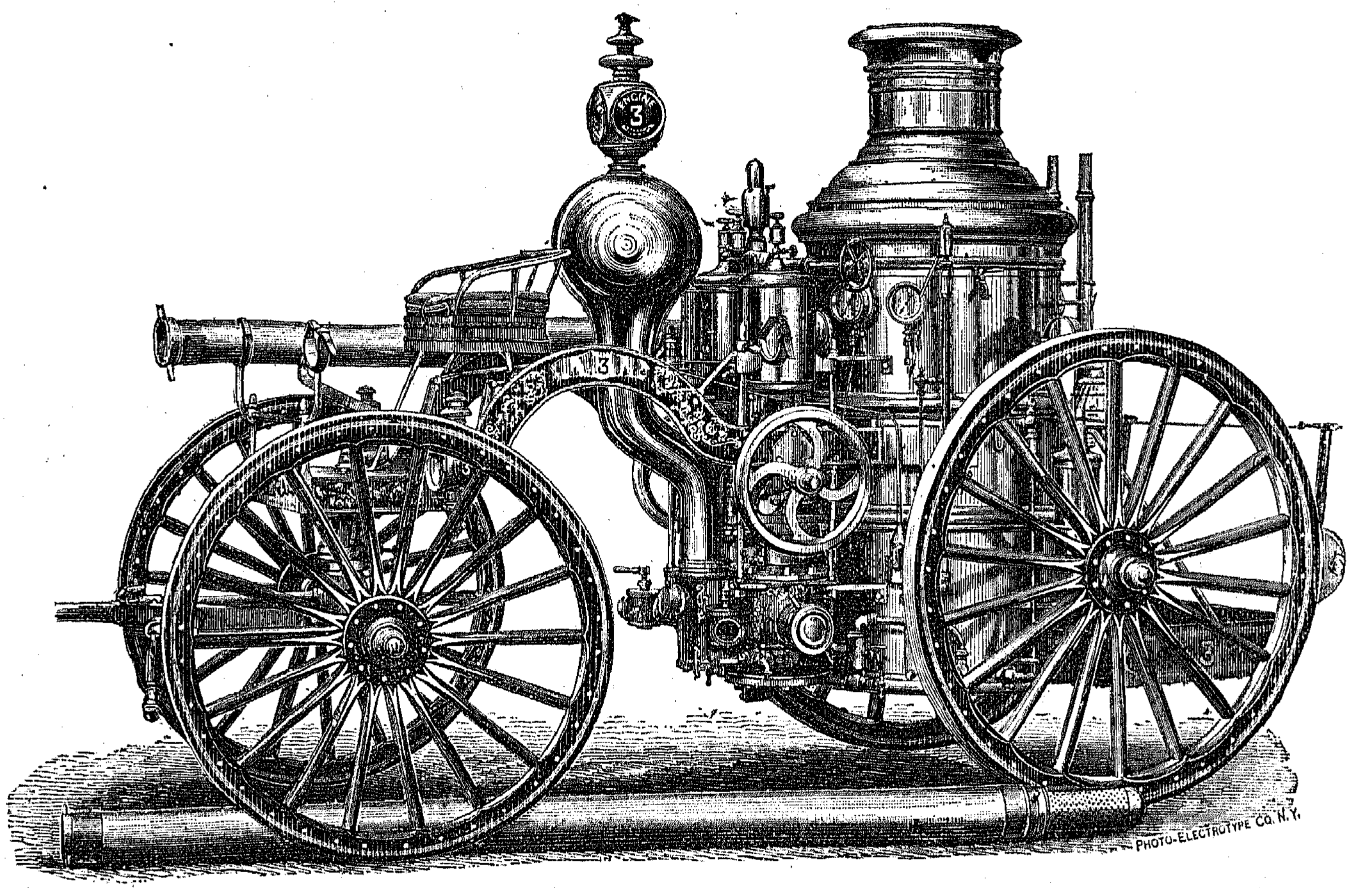


Fig. 85.—Gould engine.

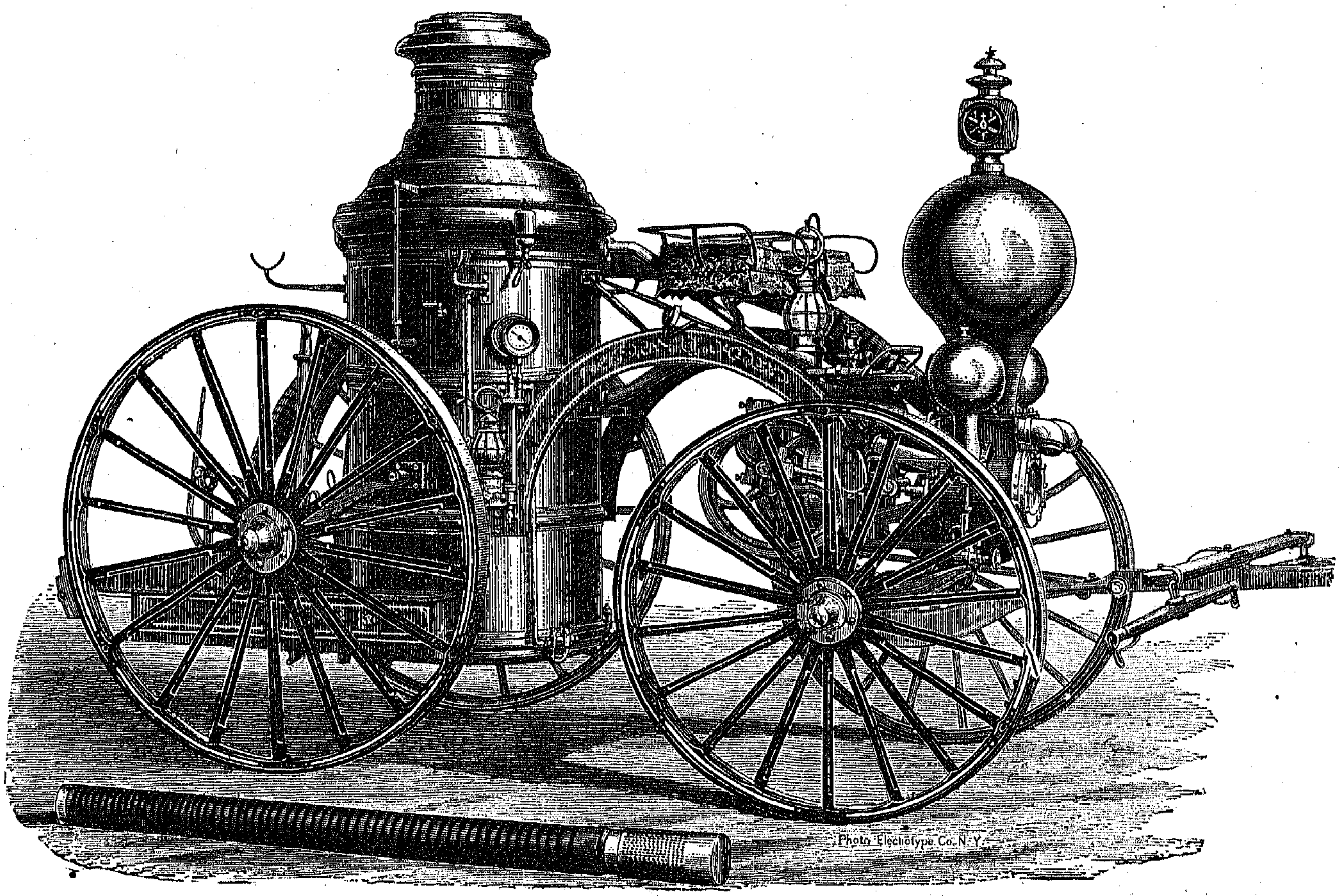


Fig. 86.—Button engine.

as to prevent the wrenching of the frame when one wheel falls in a hole. The same end is attained by hanging the front end from a locomotive spring across the engine by links from the axle.

The frame is made of forged iron about four inches deep, in many designs forming the foot-plate brackets of the driver's seat. The frame is made either "straight" behind the seat or else is curved into the "crane-neck" form. The advantage of the latter shape is that the fore-wheels can turn under and permit a short curve to be turned. In one of the forms of engine the frame bolts down to the pump sole-plate behind the fore-wheels, and is so shaped as to permit the wheels to clear. The angular crane-necks are made by welding up flat metal into the required profile. One form of round neck is made from the solid without welds. The rear end of the frame is often bolted directly to the shell of the boiler, and the rear axle, bent to encircle the latter, supports it by links

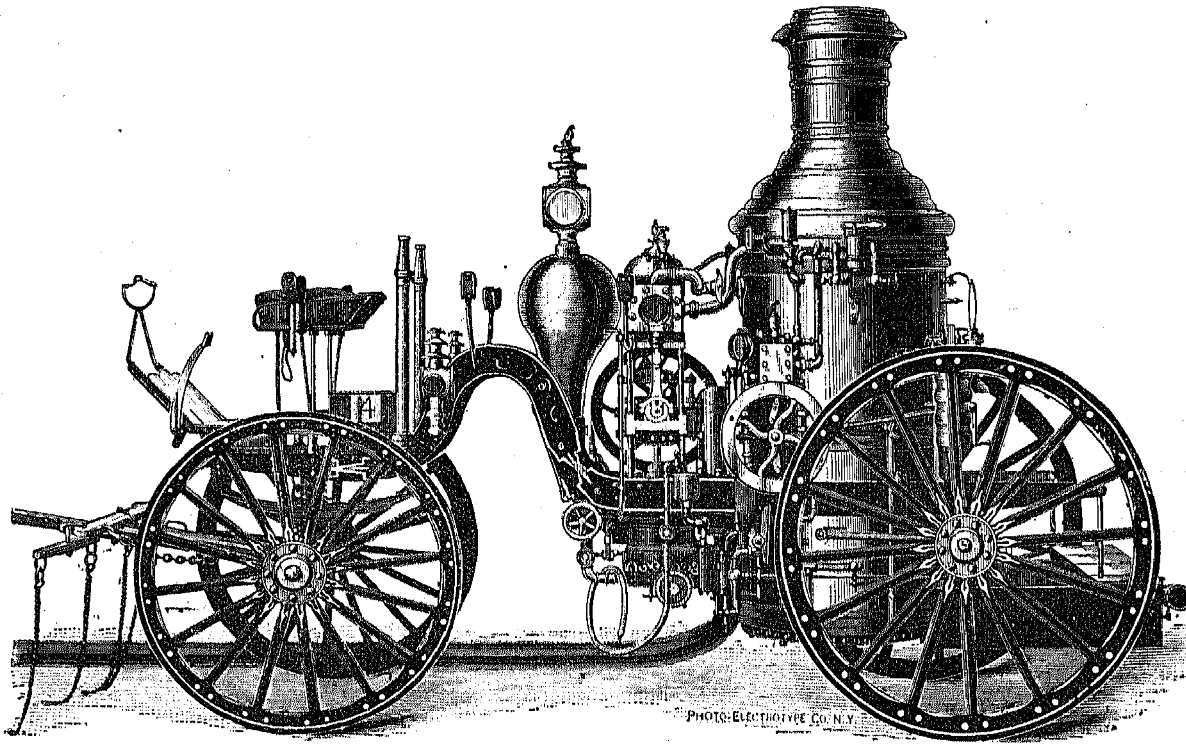


Fig. 87.—Ahrens engine.

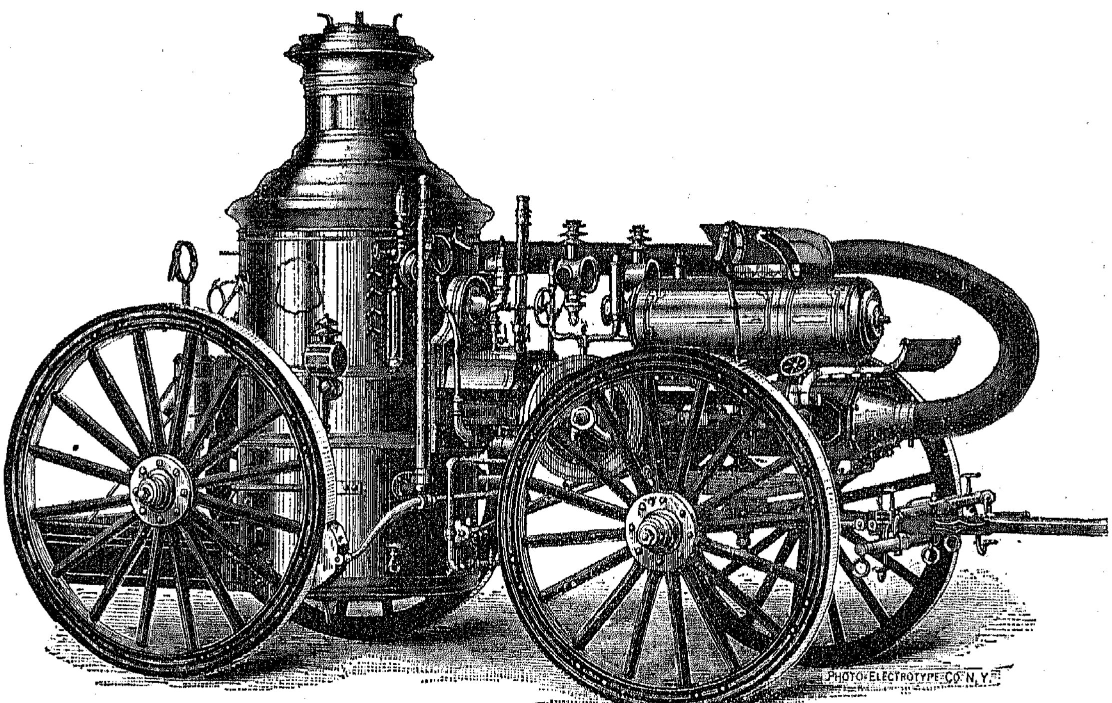


Fig. 88.—Clapp & Jones engine.

from a locomotive spring upon each side. Another arrangement is to curve the frame around the boiler and to hang the latter to the axle by stout spiral or rubber springs. In the case of self-propellers the rear axle has to be straight and continuous and passes across the frame behind the boiler. The propelling gear consists in an endless

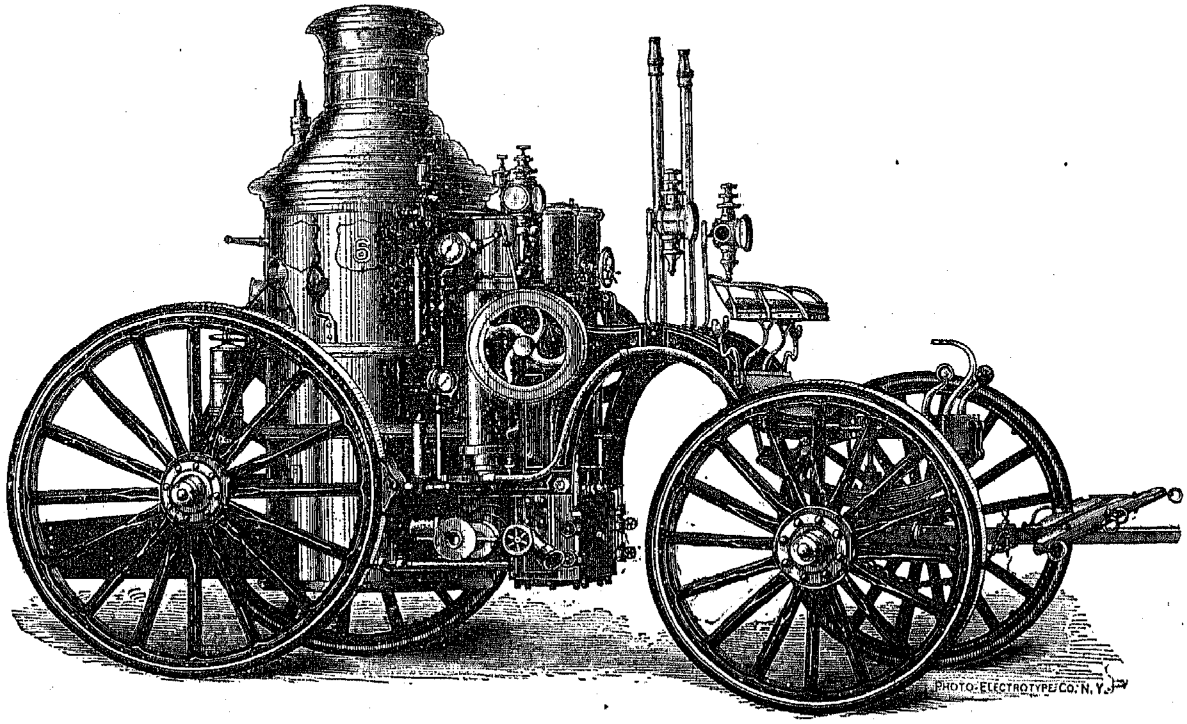


Fig. 89.—Clapp & Jones engine.

chain connecting the fly-wheel shaft of the pumps with the rear driving-axle. The chain passes over a grooved sprocket-wheel on the fly-wheel shaft which is secured to the latter by a removable spring key. The removal of this key permits the fly-wheel shaft to revolve for pumping without driving the propelling axle. The face of the large grooved pulley on the rear axle is similarly recessed for the chain, but is loose upon the axle as also is the traction-

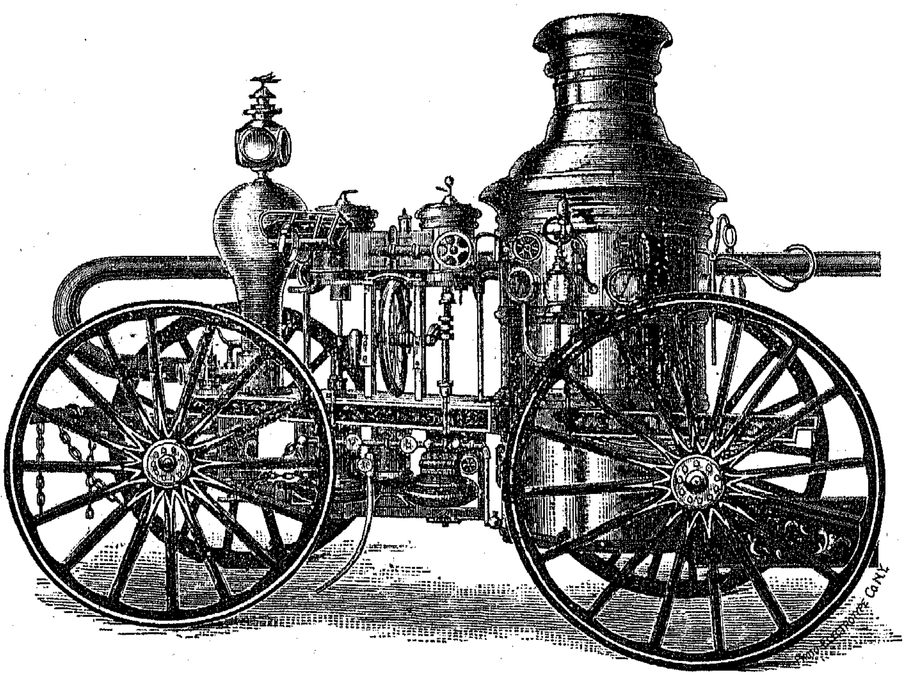


Fig. 90—Cole engine.

wheel upon the same side. The reason for making one wheel fast on the axle and the other loose, is to enable one wheel to move farther than the other in going around curves and in turning. The chain-pulley has a pair of bevel-wheels (whose axes coincide with a diameter of the pulley) upon the circumference of an inner concentric circle. These bevel-wheels engage into a bevel-wheel upon each side of the pulley. One is fast to the loose traction-

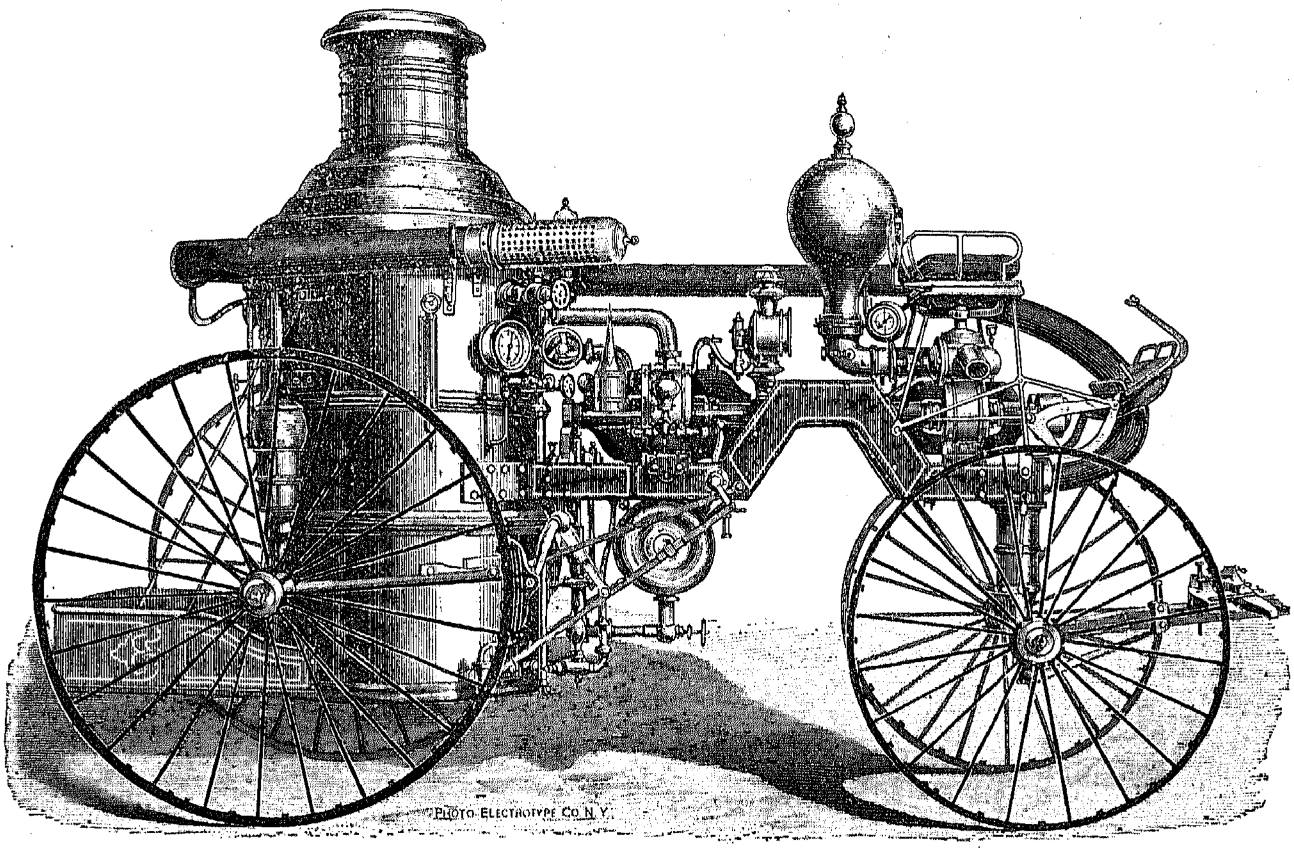


Fig. 91.—Silsby engine.

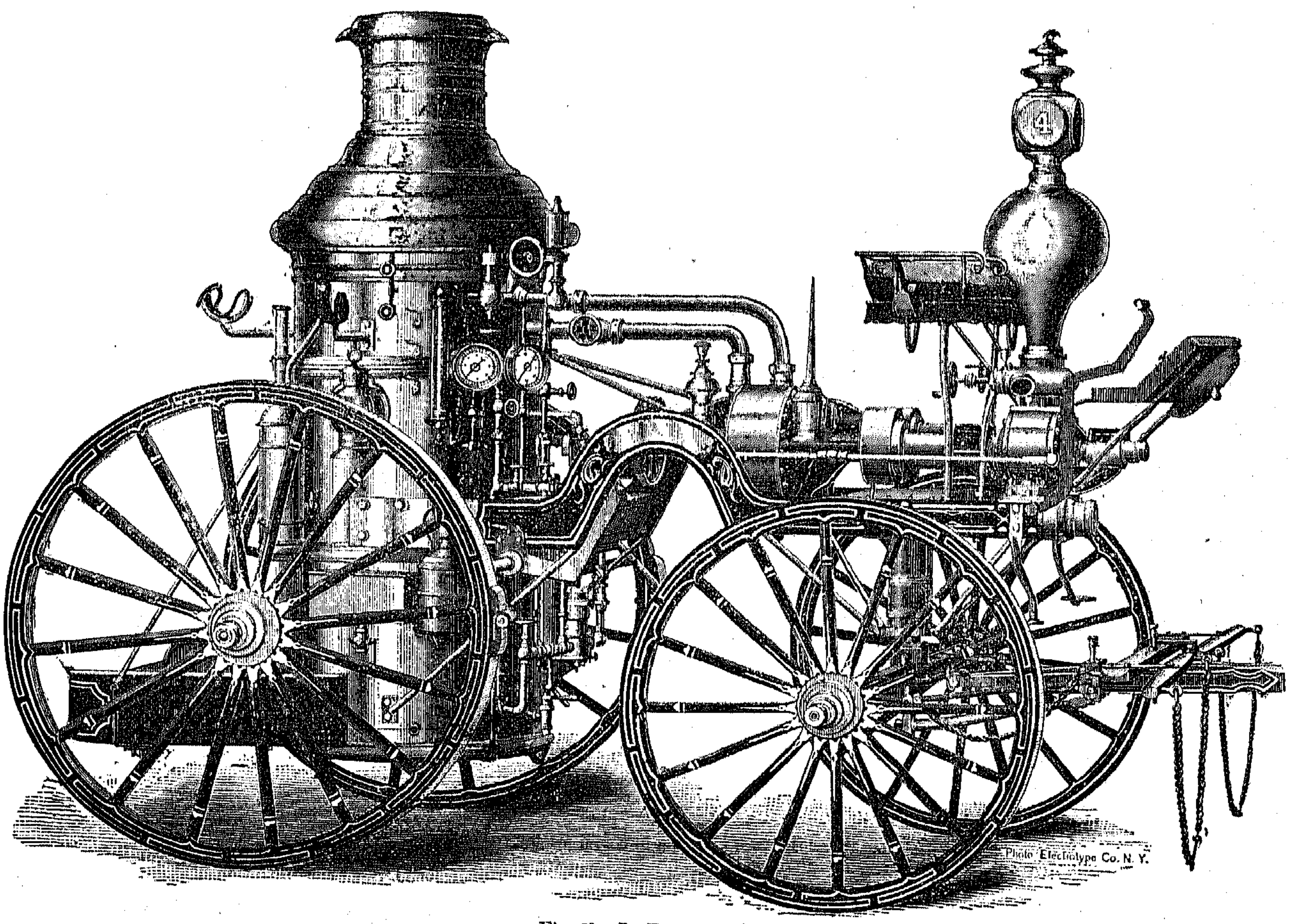


Fig. 92.—La France engine.

wheel on the outside, and the other is fast to the driving-axle on the inside and therefore to the other traction-wheel. If the resistance offered by the two wheels is the same they will turn together. If the resistance is unequal the gears on the pulley will roll upon the gear fast to the most resisting wheel and permit the slip of that wheel while the other is driven. To permit the brakes upon the rear wheels to bear equally on both, even if they

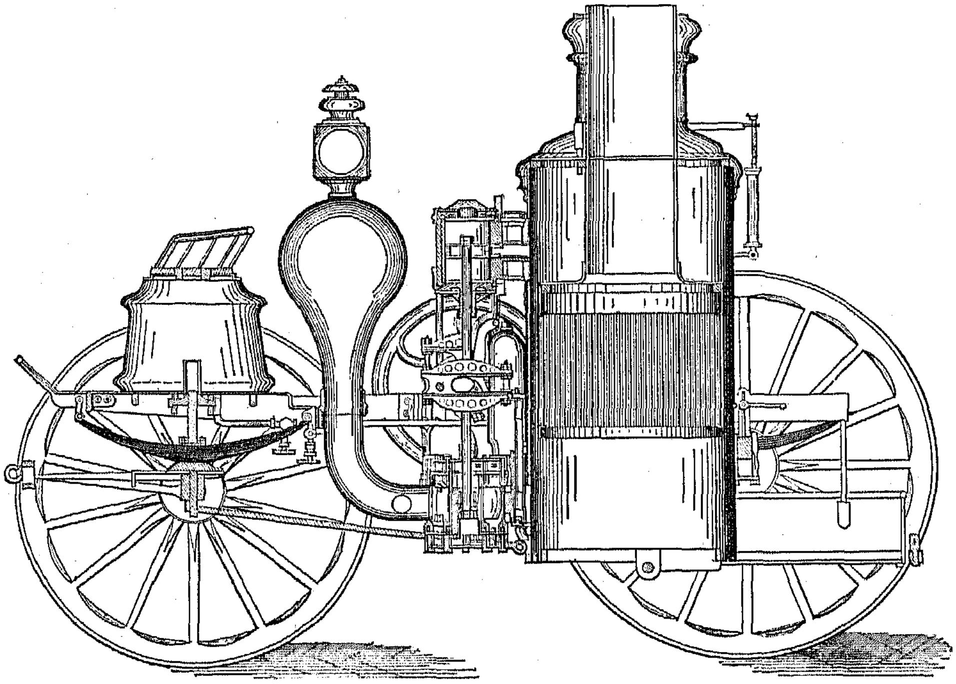


Fig. 93.—Section of Amoskeag engine.

are not traveling on level ground, an excellent practice is to put the shoes on separate beams, connecting them to the foot-lever by an equalizer. The steering gear upon self-propellers is by a hand-wheel in the front foot-plate,

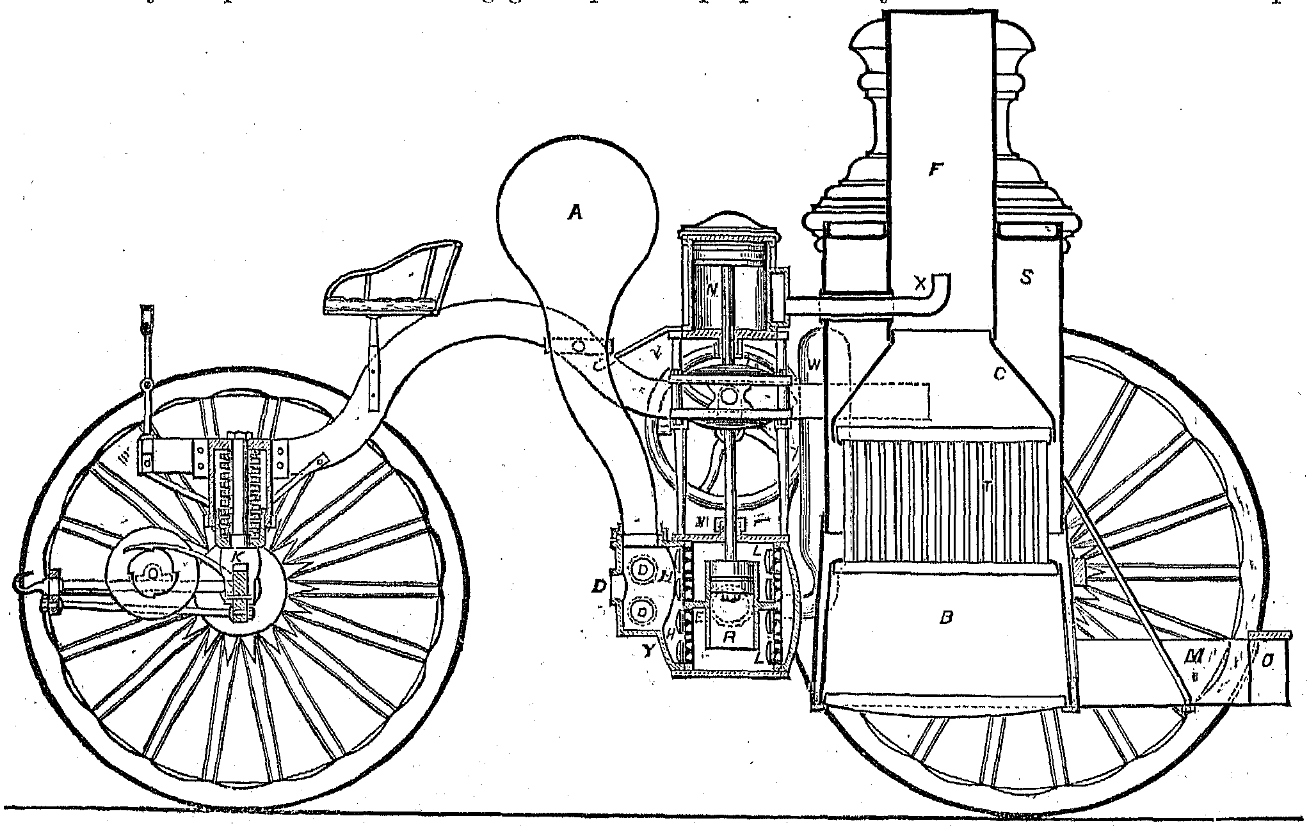


Fig. 94.—Section of Gould engine.

which turns a small pinion meshing into a sector forming part of the fifth-wheel gear. The engines are fitted with a link-motion for reversing the direction of the travel of the engine. This self-propelling gear is applied only to the larger engines with two pumps.

The fire-engine boiler must be specially designed for making steam rapidly. The boiler must be small so as to be easily carried, and yet there must be a large heating surface thoroughly utilized. The boiler is universally of the upright tubular type, the older practice approving fire-tubes of brass very close together, and all submerged. The submergence keeps a uniform tube temperature and lessens the dangers of leakage and accidents from unequal contraction and expansion. The chimney passes through the steam space, and acts as a drier and superheater. Newer practice prefers the water-tube in addition to the fire-tube. The Latta boiler of the Ahrens company, the Field-tubes of the Silsby company, and the La France boiler, are types of these designs. The rapid circulation

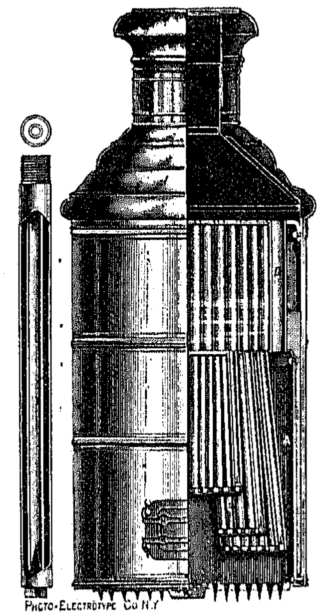


Fig. 95.—Silsby boiler, with Field-tubes.

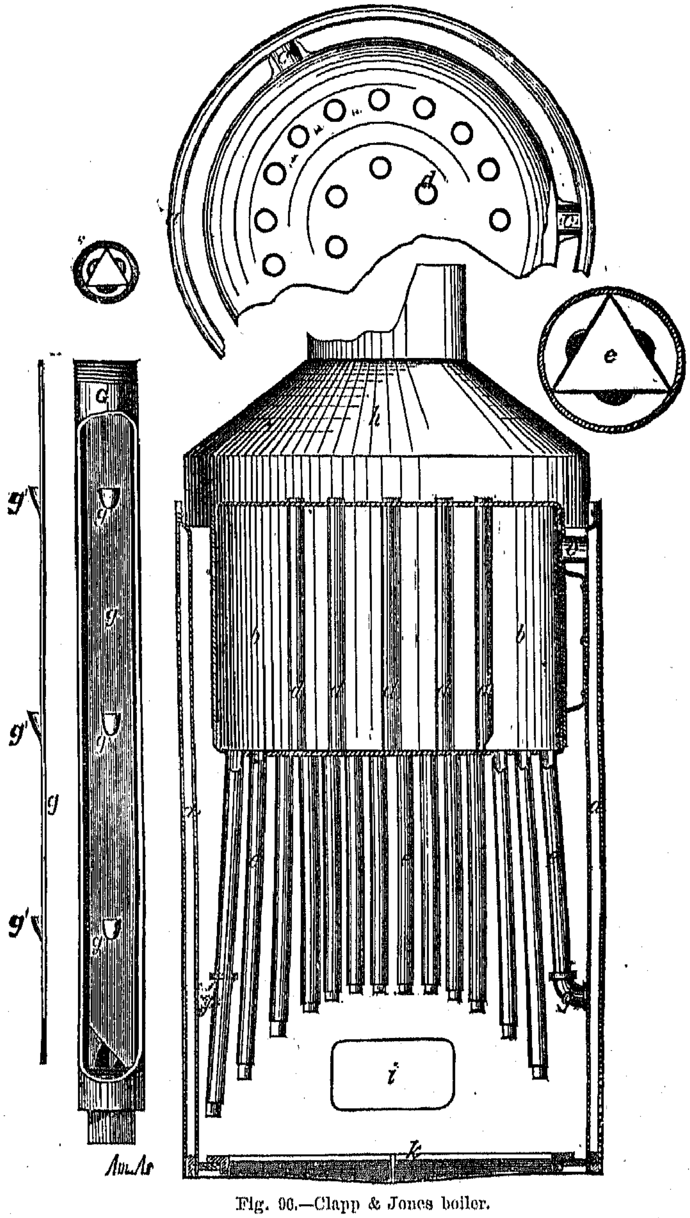


Fig. 96.—Clapp & Jones boiler.

in the water-tubes prevents the adherence of scale to them, and they cannot lose their efficiency by becoming covered with soot and ashes. In the La France boiler is a special trough or ring for catching the sediment carried into it by the currents of convection. Many of these water-tube boilers diminish the number of the fire-tubes, retaining only enough for the draft, and having them only partially submerged, as in the stationary upright boiler. The blast is furnished by the exhaust from the engine or else by special jet or blower in the stack. The exhaust-pipe terminates in a number of nozzles under the petticoat-pipe, which nozzles can be more or less closed by conical plugs. The position of these plugs can be controlled from without, and the velocity of the jets made variable. The boilers work usually under steam from eighty pounds up to about locomotive pressure, and are lagged. Wooden strips are covered with a sheathing of Russia sheet-iron, and the whole is banded by brass rings. The smoke-box trimmings are usually also of brass.

For pumping there are three general classes of engine. The first class contains the few where the valves are steam-thrown, as in the direct-acting pump. The second class includes the fly-wheel pumps, which can be again separated into the connecting-rod engines and the yoke-engines. The third class includes the rotary-engines and pumps. There are either one or two reciprocating pumps, according to the size of the engine, arranged side by side

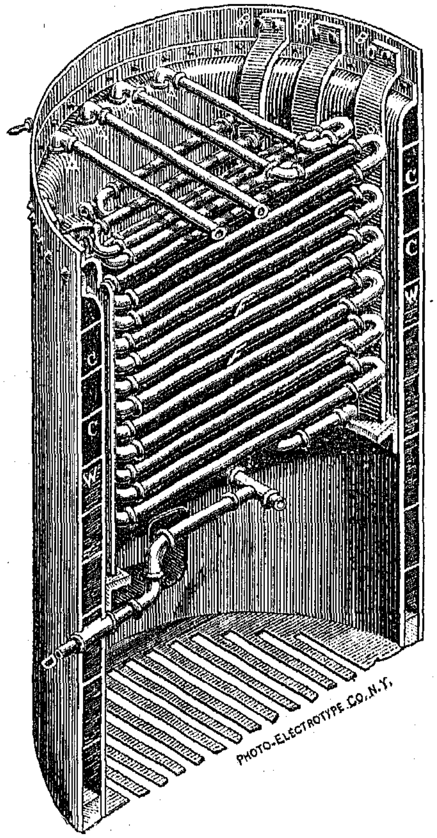


Fig. 97.—Latta boiler.

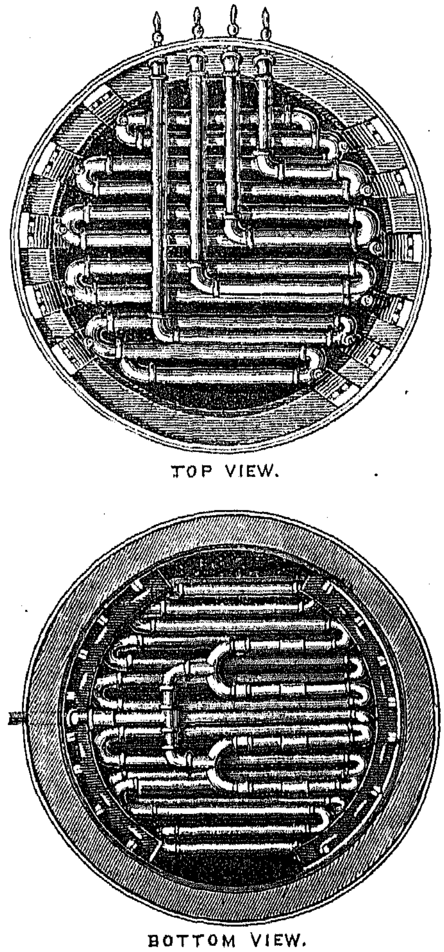


Fig. 98.—Latta boiler.

against the front of the boiler. One builder puts one in front of the other, to avoid the tendency to lurch when only one of the two is in the service. Using high pressures, the locomotive type of piston-packing is very

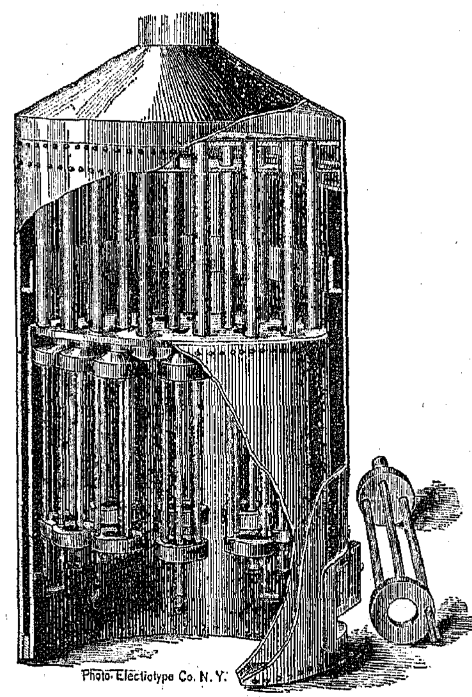
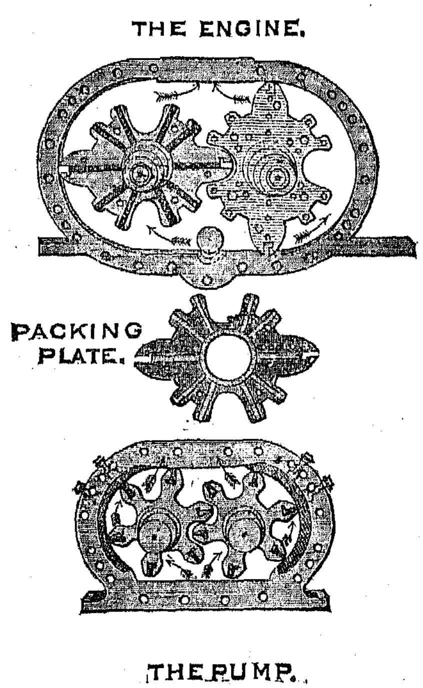


Fig. 99.—La France boiler.



Figs. 100 and 101.—La France engine and pump.

usual. There are not very many steam-thrown valve-gears in service. It is not popular because no cause can be allowed to result in a failure to start immediately, in such pumps as these. There is one form of connecting-rod engines where the cylinders are horizontal, but the vertical arrangement, driving the cranks of the fly-wheel shaft by a yoke and slide-block is much more usual. The same shaft is prolonged at one side to carry the chain-pulley in the self-propellers. The pump-barrels are below the steam-cylinders, and are usually piston-cylinders. The valves are commonly rubber disks, and in some designs are so arranged as to be all on one plate, which is easily removable. The bore of the pump is often made of brass and removable. Cup-leather packing is popular for the pistons.

There are two builders making rotary pumps and engines exclusively. The advantages of both rotary engine and pump are their freedom from valves, their high speed and capacity, and their compactness. There is also no reversing of the water-currents at a high speed. They are not popular for certain services, inasmuch as increasing

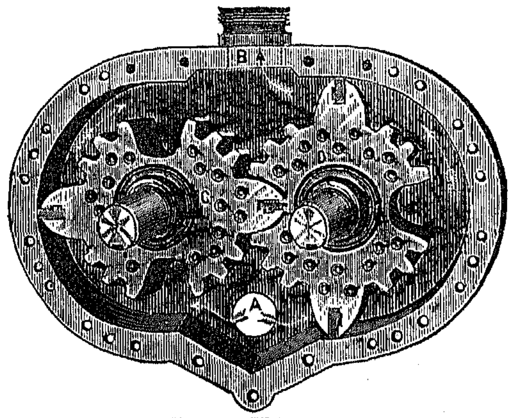


Fig. 102.—Silsby engine.

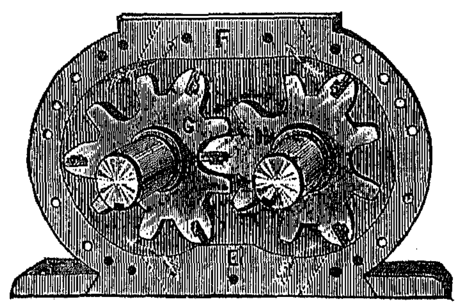


Fig. 103.—Silsby pump.

resistances will diminish the delivery from the nozzles, especially after hard service has worn the contact-surfaces. The rotary engine, moreover, is not economical of steam, as it permits little or no expansive working. They are, however, very largely in use for town and village protection.

Figs. 84 to 92 show the various forms of the steam fire-engine.

Fig. 84 is the Amoskeag self-propeller (page 51).

Fig. 85 is the Gould engine (page 52).

Fig. 86 is the Button engine (page 52).

Fig. 87 is the Ahrens engine (page 53).

Figs. 88 and 89 are the Clapp & Jones engine (pages 53, 54).

Fig. 90 is the Cole engine (page 54).

Fig. 91 is the Silsby engine (page 55).

Fig. 92 is the La France engine (page 55).

Fig. 93 shows a section of the Amoskeag engine and boiler, and Fig. 94 shows the Gould engine (page 56).

Fig. 95 (page 57) shows the Silsby boiler, with the Field-tubes; Fig. 96 (page 57) shows the Clapp & Jones boiler; Figs. 97 and 98 (page 58) show the Latta boiler; and Fig. 99 (page 58) is the La France boiler. Water-tube joints are liable to be damaged by careless stokers. Figs. 100 and 101 (page 58) show the La France engine and pump. The engine is fitted with a side packing-plate to prevent leakage of steam, and there is a take-up plate adjustable from the outside in the pump.

Figs. 102 and 103 (page 59) show the Silsby engine and pump. The sides of the steam-pistons have shallow holes countersunk in them to act as grooves to pack the sides against leakage. The trouble with side-packing strips is their unequal wear, at different distances from the center of motion.

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