The levers $c'$ and $c''$ have a common axis at $a$, and when separated by a wedge at $b$, they press upon the ends of the ring at $c'$ and $c''$. A pin at $g$ keeps the levers from sliding in the direction $f$, as well as the ring $g'$.

The coupling shown in Fig. 945 $c$ acts both ways, as an internal and external strap brake, and is used on a shaping machine by machinists.

The steel strap $b$, covered with leather, when the arms $c'$ and $c''$ are drawn together, acts on an external strap on the pulley $a''$, and when they are forced apart it becomes an internal strap in the pulley $a'$. The arms $c'$ and $c''$ are carried on sleeves and are rotated to or from each other by a screw action.

**CHAPTER XXIII.**

**PRESSURE ORGANS CONSIDERED AS MACHINE ELEMENTS.**

§ 328.

**VARIOUS KINDS OF PRESSURE ORGANS.**

In distinction from the various kinds of tension organs which have been considered in the four preceding chapters, there exists another group of machine elements of which the sole or principal characteristic is that they are capable only of resisting forces acting in compression. This group includes fluids, both liquid and gaseous, whether limpid or viscous, such as: Water, oil, air, steam, all pungent substances, clay, molten metals; also granular materials, all kinds of grain, meal, gravel, etc. In all these materials the principal feature lies in the fact that the particles are subdivided to such an extent that they can be separated from each other by a very small force, while on the other hand they are capable of opposing more or less resistance to compression. This resistance is varied in many instances, as, for example, in the case of water, almost equaling that of metals. These materials can be used as machine elements in a great variety of ways, and in the following discussion they will be included under the general title of Pressure Organs. Take their counterparts the tension organs already discussed, they are used largely for the transmission of motion in various manners, but are of still greater importance on account of the great variety of physical conditions in which they appear.

**§ 329.**

**METHODS OF USING PRESSURE ORGANS.**

The distinction which has been made between tension and pressure organs enables various points of contrast and comparison to be made as regards the methods of utilizing them, and pressure organs may be divided in the same manner as tension organs (see § 262) into standing and running organs. These divisions have but little practical application in this instance, but the three following subdivisions in § 262, viz., Guiding, Supporting ($t$, raising or lowering), and Driving are here applicable also. We may therefore distinguish pressure organs, when considered as machine elements, into the following classes:

1. For Guiding.
2. For Supporting (including raising and lowering).
3. For Driving.

These various methods of action may be used either separately or in combination, and are found in most varied forms in many machine constructions. The great variety of possible combinations makes it desirable for a general view of the entire subject to be taken before discussing details.

**§ 310.**

**GUIDING BY PRESSURE ORGANS.**

In order to use a pressure organ for guiding, i.e., to compel a more or less determinate succession of motions, it is necessary to use also two other machine elements formed of rigid materials. These latter are for the purpose:

1. Of resisting the internal forces of the pressure organ acting within the desired limits.
2. Of connecting the pressure organ with the external forces to be received and opposed.

**Tubes, Conduits, Canals.**—The tube $a$, Fig. 945, limits the boundary of the particles of the pressure organ, and retains it in the directed form and controls its direction. A tube, therefore, corresponds to a pulley around which the pressure organ is bent, and thus has its direction changed. Even when no change of direction is made, the tube is necessary to oppose resistance to the particle of the pressure organ, and hence at every section it must offer resistance to tension as well as compression. Conduits, or channels, as at $b$, are tubes with one side left open, the force of gravity or the so-called "living force" of the pressure organ serving to retain it within the desired limits. Canals are merely conduits of larger dimensions, as at $c$, and natural streams of water often serve the purpose.

**Driving Organs, Pistons and Cylinders.**—The bodies by means of which the pressure organ is connected with the external forces and resistances with which it is intended to act mechanically may be called generically, Driving Organs, and are very varied in character. Among these are movable receptacles, also moving surfaces or moving conduits (as in turbines), and also moving pistons in tubes or cylinders. A piston serves to oppose the stress in the pressure organ in the direction of its motion, while the walls of the tube oppose their resistance at right angles to the direction of motion. The inclusion in which a piston acts is called, in general terms, the cylinder, and details of construction will be given hereafter. The principal types will here be considered briefly.

A complete working contact between piston and cylinder can only be obtained when both surfaces are alike, and this is only geometrically possible with three forms of bodies, i.e., prismatic bodies, bodies of rotation, and spirally formed bodies. Of these the prismatics are most useful, and among the prismatic bodies the form most extensively used is the cylinder.

The fit of a piston in its cylinder, entirely free from leakage, is very difficult of attainment, and is rarely attempted in practice. In steam indicators the piston is very accurately fitted directly into the cylinder, but in most cases a practically satisfactory result is obtained by the use of some intermediate packing device.

**In many cases a soft packing of hemp or leather is used, Fig. 946. At $a$ is shown a piston with external packing, at $b$ an internal packing. In these cases one entire end of the cylinder is open, the piston filling the entire cylinder and acting upon the internal pressure organ on one side, this constituting a single-acting position. At $c$ and $d$ are similar double-acting pistons. Pistons of the forms shown in $a$ and $b$ are sometimes called plungers, and the shorter inclosed pistons, as at $c$ and $d$, are also called piston-heads. At $e$ is a double-acting piston used in connection with a rod and stuffing box, the rod being connected with external mechanism, and the stuffing box made either with external or internal packing, as indicated at $f$ and $g$. In many instances pistons are made with openings which are fitted with valves, and hence may be called "valved" pistons, while those here shown are termed closed or solid pistons.**

The tightness of the packing is usually produced by the application of some external force, but in the so-called forms of self-acting packing the necessary pressure is supplied by the confined fluid. This is shown in the following illustrations.

**Fig. 947.**

*Fig. 947 a and b, Cup packing for piston or stuffing box; metal*
packing, usually for pistons, but also used in stuffing boxes. The fluid in all three cases enters behind the packing rings and tightens the joint in proportion to the increased pressure.

In the class of self-acting packing may also be included the various forms of liquid packing, some of which are given in Fig. 948. The forms at a and b are practically plungers, while in many cases an ordinary packing has its tightness increased by a layer of water or oil upon the piston, as shown at c.

Another variety occurs when the connection between cylinder and pump is made by means of a membrane or diaphragm, as in Fig. 949.

These are among the oldest forms of transmission organs, but are practically true pistons in principle and action. A is a single diaphragm, known as the monk's pump; b is the so-called bellows' form; c is a series of flexible metal diaphragms, usually of steel, brass or copper, used for pressure gauges or other similar purposes involving but little movement. At d is the so-called bag pump, in which the liquid does not come in contact with either cylinder or piston, but is confined within a flexible bag.

Another class of pistons is that in which no tight packing is not attempted, these usually being used only for air. Fig. 950 a shows a deep piston with grooves formed in it, the fluid endeavoring to pass the piston in the opposite direction to the motion of the latter, becomes entrapped in the grooves, and before it can pass, the direction of motion is changed and this action reversed.* At b is a piston with a brush packing, used for a blowing cylinder at Sydenham. In this class of pistons we may also include floats which rise and fall with the motion of the liquid. Such floats are shown at c and d, the former being open and the latter closed. A solid block may also be used for this purpose, if its weight is nearly counterbalanced by another weight.

Details of piston and cylinder construction will be given in Chapter XXVI. The corresponding machine elements to pistons in tension organs will be found for ropes in Figs. 835-836, and for chains in Figs. 831 to 834. The change of direction from compression to tension dispenses with the necessity for a cylinder.

The combination of a pressure organ and its accompanying guide mechanism forms a pressure transmission system. Examples of such systems are given in outline in Fig. 951. At a is an arrangement for raising the load Q vertically. The plungers b and d are of the same diameter; the pressure on b must be the same as Q, neglecting friction. The column of water is the same diameter as the plungers, and the direction is changed an angle of 120°. It is desirable that distinguishing names should be given to the various arrangements. If we compare these with the corresponding parts in tension organs, Fig. 784 and Fig. 785 a, we may properly call such an angle transmission a hydraulic pulley, or water pulley, but a still better name is the "hydraulic lever" or "water-lever," which will hereafter be adopted.

At b is shown a free water-lever. The plungers b and d are equal in diameter, the load Q is supported on two columns of water, hence, if friction is neglected, the force on each plunger will be 1/2 Q, the angle of change of direction is 120°. At c is a combination of case a with case b. The plungers b, b, b, are of the same diameter, and the load Q is supported on these columns. These three cases correspond in principle with the similar cases at c of Fig. 784. Since the three plungers b, b, of case c all exert the same force, they may also be made to give the same result when made as shown at d, or if the three plungers are combined in one, form e is obtained. The latter form is well known in practice as the hydraulic press. The principle involved in all these devices is the same as appears in the various pulley systems of tension organs.

A comparison of Fig. 951 a with e shows that the same principle exists in both, and case e may be considered as a water-lever of equal arms, and case c as a lever of unequal arms.

The water-lever has been used in more or less complete devices for balancing the weight of pump rods in deep mine shafts. Fig. 952 shows Oeking's water-balance.† The

† Zeitschrift Deutscher Ingenieuren, 1885, p. 545. Oeaming incorrectly calls the device d an accumulator.
pump rod is carried on the two plungers \( d, d_0 \) and its weight counterbalanced by the weighted plunger and cylinder \( a-b \).

In the pump, valves and testing machines water levels of unequal arms are used in connection with metallic diaphragms.

Fig. 553 shows a combination of two hydraulic levers, each of the form of Fig. 554. The weight \( Q \) travels in a straight line, being kept parallel by the four equal plungers \( a, b, c, d \), and crossed pipe connections. This construction is similar to the cord parallel motion of Fig. 784. 

In all of the devices described the rigid body is guided by the motion of the pressure-organ. It must be remembered that motion is merely a relative term, and the rigid body may move through the fluid. An example of the latter is the rudder of a vessel, which acts in one plane; or in the case of the Whitehead torpedo several rudders are used, guiding the torpedo in any direction.

**§ 319. RESERVOIRS FOR PRESSURE ORGANS.**

Reservoirs are used in connection with pressure organs in order to enable a number of applications of a hydraulic lever to be operated collectively and also to enable the pressure to be stored for subsequent service, and in this respect they correspond to the various forms of winding drums used with tension organs, and shown in Fig. 787. The following illustrations will show the use of such reservoirs.

Fig. 554 shows a tank for use with petroleum distribution, as used in the American oil fields, and more recently in the oil district of Baku. The oil wells are at \( a_1, a_2, a_3 \), and the oil is forced to the elevated reservoir at \( c \) by pumps. From the reservoir the oil flows to the point of shipment \( d \), and the supply is regulated by the fluctuations of level in the tank.

The reservoirs used in connection with the water supply of cities are similar in principle. Where the configuration of the land demands it, the pipes are run in inverted siphons connecting intermediate reservoirs. An illustration of this arrangement is given in Fig. 555, which shows the waterworks system of Frankfurt-am-Main designed by Schmick.

The highest spring is at \( a_1 \), Vogelsberg, and the next at \( a_2 \), Spessart. These both deliver into the reservoir \( c_1, c_2 \), at Aspenhammerkopf. The next reservoir is at \( c_3 \), Abshwick, from which the water flows through \( d \), to the reservoir \( c_4 \) and \( a_4 \), from which the city is supplied. The elevations above sea level are given in metres. The flow between the various reservoirs is controlled by suitable valves.

Small tanks are in very general use at railway stations, and the various pools and mill dams are in connection with water wheels are other examples. In many cases the water ways are large enough to serve as reservoirs also, as in the case of canals. Natural reservoirs are found in the case of many mountain lakes, the Swiss lakes afford many numerous examples. Such basins are also formed artificially by constructing dams across narrow outlets, and so storing the water for use. Note

Water may also be stored in accumulators at high pressures from 20 to 50 as high as 200 atmospheres, and can then be used for operating hydraulic cranes, sluice gates, drawbridges, etc. These accumulators may be considered as a form of releasing relay mechanism (see § 250). To this class of mechanical action also belongs the system, used in the Black Forest, by which the streams are temporarily dammed and then suddenly released in order to float the logs down with the sudden rush of the current.

In using high pressure water transmission it is sometimes desirable to transform a portion to a lower pressure in order to operate a lower pressure mechanism, or by a reversed of the same principle, to convert a lower to a higher pressure. This can be done by means of the apparatus devised by the author, and shown in Fig. 556. 

This is a form of hydraulic lever of unequal leverage, but is different from those shown in Fig. 553. Referring to Fig. 556, the high pressure water is delivered at \( a \), and connected with the lower pressure water \( a_1 \) by means of the plungers \( b, b_1 \), the latter being in one piece of two different diameters. The difference in pressure, neglecting friction, will be inversely as the areas of the two plungers, or if they are of circular section, inversely as the squares of their diameters. In this case the pressure then acts in the cylinder \( c \) upon the plunger \( d \), the action of this arrangement may be considered as if the plungers \( b \) and \( b_1 \) were upon the same axis and rigidly connected, and the leverage compounded in a manner similar to that of the rope crane of Fig. 792; this comparison being more clearly shown by referring to Fig. 792 b. This device may also be used as a supporting hydraulic lever, similar to Fig. 551 c.

If a communication is made between the two different water columns, as shown in Fig. 556, the pressure will be equalized. This gives a differential hydraulic lever similar in principle to the Chinese windlass of Fig. 790 a, or the Weston Differential Block of Fig. 796 c.

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* A large inverted siphon is formed by the new Croton Aqueduct, which passes under the Hernon River at a depth of 150 feet below the surface of the river, and a tunnel of 1076 feet in diameter driven through the solid rock. See Mechanics. Nov. 1888, p. 111.

* This is examined in detail in a memorandum on the better utilization of water, published at Munich in 1882 by the German Society of Engineers and Architects.

* The following discussion of this subject the following references may be consulted: J. de les Seins, Recherches sur les arrosoyons sans les pasajes aux pays chauds, Paris, 1826; Ditten, Die Anderungen, Acta Agriculturae et Horticulturae Aragonesiae, 1873; E. de Vries, De irrigatie, applicatie der canalen en irrigatie van het lande zeelandschappen, Den Haag, 1882. Blumenthal, Irrigation in the Indian Empire, London, 1887; Dupuy, Traité de la conduite et de la dist. des eaux, Paris, 1882, Semi-Montroll, Irrigation in northern Europe. London, 1882; Linnier de Ruchamps, Enciclopedia de agricoltura, Pompei, 1879; H. C. Kahn, Uber die Talsperren der Helvetische Binnendelta, Cerna, 1879.

* Charles Grand in "la Nature," 1876, p. 25; also a brief article by the author "Uber die Talsperren." Berlin, 1879. See also an article by the author "Uber die Talsperren." Berlin, 1879.

The opposite extreme to a high pressure accumulator is found in those pools or recepacles of water far below the natural sea level, such as are found in the wells, mines, and culverts of Holland, Lombardy, and parts of Northern Germany.

Reservoirs are not confined to use with liquids. Examples of other fluids are found in the reservoirs for compressed air, so extensively used in mining and tunnelling, and in making the so-called pneumatic foundations. Smaller reservoirs are found in the air chambers on pumping machinery, and in aeroplanes.

The sewage system of Berlin, designed by Von Hobrecht, consists of ten drainage pits, with the water level below the natural level, arranged on the so-called radial system. The sewage is pumped from these pits and delivered by means of pipes to sewage farms at a distance from the city.

Negative receivers, so-called, may be used for air, as in the case of the coal mines of the Black Forest, where a vacuum chamber is used to receive the air already used for driving the machines, and kept pumped out by steam power. The ventilating apparatus for mines also often contains such negative reservoirs for air.

Reservoirs are also used for granular materials, such as being extensively used in connection with grain handling machinery.

A steam boiler may be considered as a physically supplied reservoir, as well as a physical reshapen system (see § 260). A combined physical and chemical reservoir is found in the accumulator, which may properly be called a current-reservoir. A combined physical and mechanically operated negative reservoir is found in the various forms of refrigerating machines.

A modern application of pressure organs, and one which is rapidly extending in use, is that of the distribution of power in cities. Following the impulse given by the introduction of the high pressure water system of Armstrong, the use of gas in mining and power engines has followed, and many other methods of meeting the problem have been applied.

In long distance transmissions of this sort, special reservoirs are often used, in which force may be stored, so to speak, and transmitted distributed in a manner similar to the ring transmission system for rope (see § 301). In this method the pressure organ after use is returned to the reservoir (to be compressed and filled) or may be used as in the line transmission and allowed to escape at the end of the line. The following cases are given as applications of pressure organs in long distance transmission.

1. The London Hydraulic Power Company distributes 300 H.P. by means of water at a pressure of 26 atmospheres (457 pounds) in Leeds and Birmingham. The system is an open line, and 1000 H.P. are used in Leeds, and 600 H.P. in Birmingham.

2. The General Compressed Air Company distributes power by means of air at a pressure of 3 atmospheres (45 pounds) in Leeds and Birmingham. The system is a closed line, and 1000 H.P. are used in Leeds, and 3000 H.P. in Birmingham.

3. The distribution of power in New York by means of steam mains is extensive and well known.

4. A similar system is used also in Paris by the Société anonyme de distribution de force à domicile. This is an open line transmission, operating in 1858, and now 300 H.P.

5. Transmission by high temperature water has been used in Washington, by the National Superheated Water Co., distributing heated water at pressures from 26 to 33 atmospheres (450 to 600 pounds), the water being converted into steam at the point of utilization.

6. The distribution of power by means of gas holders has already been referred to, and the distribution by electric currents is rapidly being developed.

The methods of applying pressure organs to the development of motive power are even more varied. As in the case of tension organs, for this reason a general view of the subject will be taken in order to obtain a classification which will simplify the discussion. The main distinctions are those of the character of the motion of the mechanism, and of the method of applying the pressure organ to the motor.

The great difference in the character of the motion of the mechanism lies in the fact that it may be either continuous or intermittent, so that the motor may be either:

- A running mechanism, or
- A mechanical mechanism (compare § 260). The ratchet pawls for pressure organs are the various forms of valves (see Chapter XVII).

The various forms may also be classified according to the following important distinctions based on the method of driving. The pressure organ may drive, or it may be driven, or the impelling mechanism may itself be propelled.

There is also a third distinction to be made, namely, whether the pressure organ acts merely by its weight, or whether it acts by the direct force of impact. This last distinction cannot be sharply observed in practice, but is especially to be considered in discussing the theory of action of the various machines.

In the following pages the various applications will be shown in a manner similar to that employed in § 262 for tension organs, following the system of classification outlined above, and beginning with running mechanism as the simpler of the two great divisions.

A. RUNNING MECHANISM FOR PRESSURE ORGANS.

Running Mechanism in which the Pressure Organ Drives the Wheel, without the Teeth of the Wheel being Engaged with the Teeth of the Ratchet Pawls

With a few unimportant exceptions the motors of this class are operated by liquids, which act at moderate velocities and practically follow the laws of gravity.

In Fig. 957, a is an undershot water-wheel, and b is a half breast water. The water is guided in a curved channel and the buckets are radial or nearly so. The wheel is so placed that the buckets pass with the least practicable amount of clearance over the curved channel. At c is shown a high breast wheel, and at d an overshot wheel (compare § 47). In these latter wheels the buckets are so shaped that they retain the water in the circular path, being closed at the sides also, while on account of the moderate pressure they are left open above. At e is shown the side-fed wheel of Zuppinger.

Fig. 958, a is an endless chain of buckets, and b is a similar arrangement, using disks running with slight clearance in a vertical tube, and driving a pinion, and in this sense a water wheel may be considered as a gear wheel.

When the water acts only by gravity, these constructions are only practical when the wheel can be made larger in diameter than the full of water, and where small diameters must be used the arrangements of Fig. 958 are available. Very small wheels acting under high pressures may be employed by making use of the so-called "chamber wheel work," of which some examples are here given.

Fig. 959, a is the Pappenheim chamber wheel train. In this the tooth contact is continuous, the teeth being so formed that the continuous contact of the teeth at the pitch circle prevents
the water from passing, while the points and sides of the teeth make a close contact with the walls of the chamber. The downward pressure of the water enters into the spaces between the teeth and drives both wheels. The axes of the wheels are also coupled by a pair of spur gear wheels outside the case, thus insuring the smooth running of the inner wheels. This is the oldest form of chamber train mechanism known, and can also be used as a pump, operating equally well in either direction. Fig. 295 a is Dayton's Water Meter, with evolute teeth. The flow is intermittent, but one contact begins before the action of the previous one ceases.

Fig. 295 c is Buhren's chamber train. The ratio of teeth is 4 to 3, and the flow is also intermittent. The theoretical volume of delivery of all forms of chamber gear trains, whether continuous or intermittent in delivery, is practically equal to the volume described by the cross section of a tooth of one of the two wheels for each revolution.

Fig. 295 d is Buhren's chamber train. In this case each wheel has but one tooth, as is also the case with Reynold's train (described hereafter), and the gears belong to the class of disc wheels or so-called "shelled gears" (see Fig. 241). This arrangement possesses the great advantage of offering an extended surface of contact at the place between the two wheels where, in the previous forms, there is but a line contact. This permits a sufficient degree of tightness to be obtained without requiring the parts to press against each other. Buhren's chamber gear makes an excellent water motor if the impurities of the water are not sufficient to injure the working parts.

The flow of water through chamber gear trains is not uniform, and the inequality of delivery increases as the number of teeth in the wheels is diminished, hence they should be driven only at moderate velocities when used as motors, in order to avoid the shocks due to the impact of the water.

Running Mechanism in which the Pressure Organ Drives by Impact

In driving running mechanism by impact, fluid pressure organs, both liquid and gaseous, may be used, as will be seen from the following examples.

Fig. 296 a is a current wheel, or common paddle wheel. The paddles are straight, and either radial, or slightly inclined toward the current, as in the illustration. The working contact in this case is of a very low order.

Fig. 296 b is Poncelet's wheel. The buckets run in a grooved channel, and are so curved that the water drives upwards and then downwards, giving a much higher order of contact. At 2 is shown an externally driven tangent wheel. The buckets are similar to the Poncelet wheel, but with a sharper curve inward. The discharge of the water is upwards, its living force being expended. At 3 is an internally driven tangent wheel, similar to the preceding, but with outward discharge. The form shown at 4 is the so-called Hardy-Girard wheel. The water is driven through curved spouts, and the form is practically an externally driven tangent wheel of larger diameter and smaller number of buckets. This wheel, from a crude manuscript, has become one of the most efficient of motors.

Wheels with inclined delivery as made in the forms shown in

Fig. 297.

For gaseous pressure organs, of which wind is the principal example, some forms are here given. Fig. 298 a is the German windmill, with screw-shaped vanes. Both forms are similar in action to the above described pressure wheels. At 2 is shown the so-called Polish windmill, with stationary guide vanes; 3 is Halladay's windmill, made with many small vanes, which place themselves more and more nearly parallel with the axis as the force of the wind increases; 4 is the same wheel with a balanced rudder, 5 keeping the wheel in the direction of the wind. The extreme position of the vanes is shown at 6. Anemometers and steam turbines are examples of wheels in which other pressure organs than wind are used.

See Wibelsch-Omann, Mechanics of Engineering, Part II, Section 4, pp. 2-4.

This use of the term "reaction" is hardly desirable for this construction, nor in the proposed name of "action turbine," and the name "pressure turbine" is to be preferred.

This form is well made at 7, M. F. Heidenheim, Wartenberg.

Fig. 298. A Manual of Synthetic Physics, Vol. 1, No. 21, 1889, also from there shown in Henning's Sammlung von Maschinen und Maschinen. Nürnberg, 1818.
there is no necessity for distinguishing in classification between them as pumps for liquids or for gaseous fluids. Fig. 967 c, 18

Fig. 967.

Fabry's ventilating machine for mine ventilation, consisting of a double toothed combination chamber train, with unequal duration of contact. Xoot has also made the form shown at d, which has unequal contact duration, and which has since been made by Greinall as a pump.

Greinall also makes the form shown in Fig. 968 a, with gears of one and two teeth, and rightly claims it to possess the advantages of a greater freedom from leakage. The form shown at b has been used by Ewrai as a blower, but it does not differ in principle from a. Bakert's blower, shown at c, is a triple chamber train, also used by Neel, as a pump.

It has already been stated that Echren's pump, Fig. 969 d, has also been used as a steam engine. As long as ago as 1587 a steam fire engine has been constructed by putting two of these machines on the same axis, one being driven by steam, the other forcing the water.

Chamber gear trains may also be used to be worked in connection. Fig. 969 shows an arrangement in which the chamber train A delivers water to a distant one B, driving the latter and receiving the discharge water from B through a return pipe to be used again. The combination forms a transmission system of the second order (see § 36), and is similar to a belt or chain transmission. The loss in efficiency in this device is not an unimportant consideration.

An important class of machines consists of those made with tension organs for transporting granular materials. For this purpose belts, chains, etc., are used, and when the transmission is horizontal, or nearly so, grain is successfully transported on wide belts. Another application is that of Marolles, using an iron belt, 40 in. wide, 600 in. thick, for transporting mud. Twelve such machines were used on the Panama Canal work, the distance being 200 feet, and the speed of the band 12 to 40 feet, according to the nature of the material. Similar apparatus at the Suez Canal handled material at a cost of 7.6 cents per cubic yard.

§ 318.

RUNNING MECHANISM IN WHICH THE PRESSURE ORGAN IS DRIVEN BY TRANSFER OF LIVING FORCE.

The method of driving pressure organs by a transfer of living force is one which admits of numerous applications, as the following examples show.

Fig. 970 a is a centrifugal pump for moving liquids. The driving mechanism consists of the curved blades, which in

* Large wheels of this sort have been in use in Syria for many centuries, as at Omotes, north of Damascus. The town of Hamam, 40,000 inhabitants, receives its water supply from twelve such wheels.

† A recent installation of such wheels has been made at Atlic, on the Mahamud Canal, in Egypt. Right wheel 22 feet 6 inches, each driven by a separate steam engine lifting water from the Nile 182 feet to the canal. The eight wheels deliver 775,000 cubic feet in 24 hours. See Engineer, 1888, p. 93.

‡ Such pumps, made by Klein, Schwind & Becker, at Frankenthal, deliver water from 15 to 90 feet, the revolutions being from 15 to 22 per minute, and diameters from 20 to 70 inches.

§ The firm of Klein, Schwind & Becker, at Frankenthal, make a line of pumps similar to Fig. 972 a, of a capacity of 175 to 377 cubic feet per minute, and discharge openings from 2 1/2 to 4 1/2 inches. These are driven by belt and used for milling oil, seeds, paper pulp, etc., as well as other purposes.

‖ An excellent transmission is in use at Cologne. See also Trans. Am. Soc. Mech. Eng., Vol. VI., 1879, p. 4, where belt 50 inches wide, running 600 to 1000 feet per minute, carries grain from 600 to 1000 feet horizontally. A 40 foot belt has carried 4,000 bushels per hour.
many instances are made in one piece with the wheel itself, this adding to the efficiency. These pumps have been most successfully made by Seymee, Schiele, Neat and Dumasst among others. Centrifugal pumps have been successfully used as dredging machines for lifting wet sand, gravel and mud, instances among others being the North Sea Canal at Amsterdam, and the harbor at Oakland, California.

Fig. 970. The well known fan blower used everywhere for producing a blast of air, and acting by centrifugal force. When used as exhaust fan this is widely used in connection with suitable exhaust pipes for removing foul air, smoke, and other impurities in workshops, as well as for the ventilation of mines.

At a is shown a form of spiral ventilator, known as Stahl's ventilator, it is similar to some of the preceding forms, but is of limited application, and is better adapted for lifting water, a service to which it has been applied in the polders of Holland.

At d is a centrifugal separator, a device of numerous applications for separating materials of different specific gravity by centrifugal force. A notable example of this machine is the centrifugal separator for removing cream from milk.

Another variety of machines for driving pressure organs by a transfer of living force, is that in which another pressure organ, either liquid or gaseous, is used instead of a wheel as the impelling mechanism. To this class belong the various jet devices, injectors, etc.

**Fig. 971.** a is Giffard's injector in the improved and simplified form made by the Baldwin Steam Applicance Co. In this case steam is used to drive a jet of water into a vessel already containing water under pressure. The jet of steam rushing through the nozzle h draws the water in by the suction tube b, and both pass through the mixing tube c, and are discharged through the outlet tube d, the outflow at e provides for the relief of the discharge at starting, before the jet action is fully established. The regulation of the flow of steam is effected by a steam valve attached above b. At f is Greencourt's automatic injector, which is so made that should any interruption occur in the supply of water at h, the suction action is automatically started, and the entering column of water is lifted again. This is done by the introduction of a movable nozzle b, between b and d, which adjusts its position with regard to b according to the variations in pressure above and below.

**Fig. 972.** is Friedmann's jet pump. The mixing tube a is divided into a number of sections, which permits a very free entrance to the water, and gives an excellent action; b is Nagel's jet pump, used for lifting water from foundations by means of another jet of water. The entrance jet is at b, the suction tube at b, and the mixing tube at b'; the regulation is effected by a valve at the end of b.

Steam jets are also used to produce a blast of air, or compressed air may be used for the same purpose, as can also water under pressure. A reversal of the last mentioned arrangement occurs in Bunsen's air pump, in which a jet of water is used to produce a vacuum. Recent devices for utilizing jet action are numerous. Among others, a jet of air has been used to feed petroleum into furnaces as fuel. Dr. W. Siemens proposed to carry the petroleum in the hold of a vessel in bulk, and substitute sea water, as it was consumed, in order to maintain the ballasting of the ship undisturbed. Ornamental materials have been handled by means of jet apparatus, usually impelled by compressed air, sometimes by water jets.

An especial feature of jet pumps, and one which should not be overlooked, is that they act either by guiding the pressure organ stream, or that the driving action of the pressure organ stream itself produces a guiding action, and that the existence of either of a reservoir or some external means of driving must be presupposed. The use of a pressure organ in motion for driving mechanism is in this respect similar to the so-called inductive action of an electric current.

An example of pure guiding action is found in the "Geyser Pump" of Dr. W. Siemens, Fig. 973. The water is to be raised from a depth H to, and the tube b is prolonged downward to a depth H below the sump S.

The prolonged tube b is open at the lower end, and in the bottom opening Z an air tube t is introduced, and air is admitted at a pressure slightly under that of a column of water of being equal to H. The air1

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**(Fig. 974.** a is the so-called "flying bridge," the current flowing in the direction of the arrow, causing the boats to swing across the stream, describing an arc about the anchor to which...
they are held by a chain; 6, a sail-boat, the sail being the driving organ transferring to the boat a portion of the living force of the animal. An 8, a steamboat with side paddle wheels, and 9, a stern-wheel boat; 10, is a screw propeller. A screw driven by a steam engine pressing the water backward and the reaction of the water impelling the boat. At 11 a, is a so-called jet propeller, the reaction being produced by jets of water forced through tubes at the side of the boat, the water being driven by centrifugal pumps. At 12, is shown a current wheel motor. The side paddle wheels are caused to revolve by the action of the current, and by connection with a cable or chain gearing (See Figs. 787 and 794) the boat is propelled up the stream.

Activating reaction jets have been used for torpedo boats, using carbonic acid gas but this method has been superseded by screw propellers driven by compressed air. Rockets and rocket shells are examples of direct acting pressure organs.

**B. RATCHET MECHANISM FOR PRESSURE ORGANs.**

§ 329. FLUID RUNNING RATCHET TRAINS.

The pawls in a fluid ratchet train are the valves. They may be divided into two great classes, similar to those existing in ratchets of rigid materials, viz.,

- Running Ratchets, or Lift Valves, and
- Stationary Ratchets, or Slide Valves.

In the first class we have flat valves, also conical and spheroid valves, etc., etc. In the second, the various forms of cock, cylindrical and disc valves and flat slide valves. In both kinds of valves there exists an analogy to toothed and to friction ratchet gearing, since by use of complete openings the effect of friction is produced, and with half openings it is obviated. This gives a division which does not exist in the case of friction and toothed ratchet gearing.

Voidsed according to the preceding classification, piston-pumps, and piston machines are properly ratchet trains. This idea does not seem to offer any practical difficulties, since it may be made to include an essentially analogous variety without creating more confusion than the former methods of classification. It is not practicable to distinguish between the devices acting by gravity and those acting by transfer of living force, since both are necessarily combined.

The oldest devices are those using air, and the oldest piston is the membrane piston, (Fig. 949) in the form of a bag of skin used as a bellows. In this primitive device the earliest valve was the human thumb, and in the latter bellow the bellows of the operator, these being followed at a later date by valves of leather. The working part of the bag was next strengthened by a plate. (See Fig. 540.) and developed into the common bellows, next followed the disc piston, a very early improvement and later the plunger, from which the numerous modern forms have grown. The following examples will illustrate.

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**Fig. 795.**

*Fig. 795 a* is the common lift and suction pump, a ratchet train similar to Fig. 749; <i>a</i>, is the pressure organ stream (corresponding to the ratchet wheel <i>a</i>) the holding pawl in the form of a valve, <i>c</i>, is the receiver or cylinder for the water and piston, <i>c</i>, is a pawl-carrier in the form of the piston, <i>β</i>, the other pawl, or lift valve. The water here overflows at the top of the cylinder, and if it is to be lifted to a greater height the cylinder may be prolonged upward and the rod proportionately lengthened. If the rod <i>β</i>, is used, the top of the cylinder is closed and the rod brought out through a stuffing box, and the discharge tube only is prolonged. At <i>c</i>, is the so-called force pump with a discharge, and at <i>d</i>, the same form with plunger. In these the discharge valve is in a separate chest. The water column <i>a</i>, is divided into two divisions <i>c</i> and <i>c</i>, the lower being impelled in the upstroke, and the latter on the down-stroke of the piston. A blow or shock is produced at each stoppage of the motion of the water column and to reduce this action the speed of flow must be kept down, and also the shock cushioned by means of air vessels. At <i>d</i>, air vessels are shown both on the suction and force pipes.

The preceding pumps are all single acting, discharging one column of water for each complete cycle of the stroke of the piston. By cylinder of water is here meant the product of the piston area by the length of stroke.† The space between valves and piston is not included, this being merely clearance or water space.

The piston may be so constructed that it remains stationary and the cylinder slides upon it, this forming an inversion of the common form and possessing many applications.

*Fig. 796 a* is Muesenberg's pump (1762) for moderate lifts, <i>d</i>, is Donnadieu's pump for deep wells, especially adapted for

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*Fig. 797.*
By combining two complete fluid ratchet trains in such a manner that they have a common cylinder and piston, a form of pump is obtained which gives two full discharges for each cycle, and which may hence properly be called a double-acting pump.

Fig. 981 a is a double-acting pump with disk piston, and Fig. 981 b, the same form with a plunger. In both cases the suction pipe is at 14, and the discharge pipe at 1. In double-acting pumps it is usually not convenient to put a valve in the piston; this is, however, done in Fig. 981 c, in which we see two single-acting pumps combined in one.

In Fig. 982 a, is shown Stone's Pump, which is much used for ships, as is also Downton's Pump. In this case there are four pistons, operating in two cylinders, the latter being placed one below the other on the same axis. The pistons, e, f, are connected by one rod and connected by the same crank 1-2, and the other two pistons are, in like manner, connected and operated by the crank 1-3-4, which is set opposite the other crank. The action may be more readily understood by examining Fig. 982 b, which is similar to the preceding one, if we suppose the pistons e and f to be held stationary and the other pair e, f, driven by a single crank of double the length of arm of those shown. This will obviously not alter the volume of delivery, and it will be evident that the lower pump is really a double-acting force pump and the upper one a single-acting lift pump, hence each revolution of the cranks will deliver three cylinders of water, two on the up stroke and one on the down stroke. In Stone's pump the pistons e and f are so disposed that for each half revolution 2 cylinders of water are discharged, and in other respects the pump is a double-ratchet train. Fig. 982 c is Audemer's Pump. In this form two double pumps similar to Vose's Pump (Fig. 979 a) are combined to make a double-acting pump.

Franklin's Double Pump. (See Kong, p. 25.)

* See Theoretical Kinematics, p. 862.
† See Poillon, Plate 29.
‡ See Poillon, Plate 6, p. 39.
§ See Poillon, Plate 26.
THE CONSTRUCTOR.

Fig. 983.

Fig. 983 is Norton's so-called V-shaped pump. In this device the pistons and valves form a single stationary piece, and the cylinder and valves are fixed to the moving part. It will readily be seen how neatly the lift pump may be made double-acting.

A double-acting lift pump as used for a steam engine air pump, by Watt, is shown in Fig. 984. This is practically a combination of two different pumps. It has three valves, the foot valve d, piston valve h, and upper valve a.

On the downward stroke the mixed air, water, and vapor passes through the piston from the lower to the upper part of the cylinder, and on the up stroke this is discharged through the valve and a fresh cylinder full drawn in through a. This pump is double-acting, since the piston valve a is both in the up and down stroke. This works the same whether pumping liquid or gaseous fluids, the action being the same as if two valves only were used. The upper valve is required for regulating the velocity, and to control the discharge, as for boiler feeding, etc.

The preceding examples will serve to illustrate the application of fluid ratchet trains with running ratchets. It is important in all cases, and especially with high velocities, that provision should be made to have the valves close without shock. In other words, that the engagement of the parts should be quiet. This problem has already appeared in some forms of ratchet mechanism (see § 240) and here occurs still greater difficulties, especially when heavy moving masses are to be controlled. The question is daily being considered in practical problems of construction and a great variety of valves has been designed. The present indications appear to be leading toward the use of valves operated mechanically by the pump, instead of those operated by the fluid itself, but a final solution of this problem has not yet been reached.

§ 220.

FLUID RATCHET TRAINS WITH STATIONARY RATCHETS.

As already shown in § 255, it is necessary, in ratchet trains with locking teeth, to effect the engagement and disengagement of the pawls by some additional mechanism. As well as the case in those fluid ratchet trains which used stationary pawls, i.e., sliding valves. An example is found in the case of the simple single-acting air pump used in physical laboratories, which since its invention by Otto von Guericke has been made with stationary pawls, and is shown in a crude form in Fig. 985.

The "receiver" d', and its pipe connection forms a negative reservoir, the pump a c d h, a ratchet train for the propulsion of the column of air a. The suction valve is at d, and the discharge valve at h, both being in the form of stop cocks.

The suction valve is opened by hand when the piston is drawn out, and when the end of the stroke is reached the valve a, which had previously been closed, is opened, and the first one closed, and the air expelled on the return stroke. A stop cock, b, is also placed close to the receiver.

There is but little difficulty in applying slide valves to single-acting pumps, and they are also readily arranged for double-acting cylinder pumps. By maintaining the arrangement of check valves in the compress double-acting pump, Fig. 986, it will be seen that the valves a', b', and c, open and close simultaneously, and that the same is true of a and b' and that the two actions alternate with each other. The operation of the check valves is such that the four spaces I to IV are connected alternately in the order I-II and III-IV, and I-II and III-IV.

From this it will be seen that if sliding valves are used they may all be connected together, or united in the same construction. This may be done as shown in Fig. 987 a, which represents the so-called "four-way" cock. As here shown, all four of the passages are closed, this position corresponding to the end of the piston stroke. When the piston is turned to the right, as shown by the dotted lines, and I-III are connected, and also I-II and III-IV, and if it is turned the same amount in the other direction, I-III and II-IV are connected. The portions b and b' may be omitted, as in Fig. 987 b, and the passages I-II and III-IV brought together, shown as c. From this form it readily be seen how the passage / can be converted into a mere delivery pipe, and the radius of curvature of the seating surfaces, made of infinite length, giving the well-known slide valve, Fig. 987 b. In like manner other forms may be developed. It must not be forgotten that this device really consists of four valves combined in one, and in fact recent forms of steam engines contain the four valves made separately, these often again being lift valves.

A noteworthy peculiarity in the forms shown in Fig. 987 a and b is that d' can be considered as both the valve overlaps the port on both sides, this being technically known as "lap." It is also apparent that the gap on the two sides of a port may differ, but that different laps may be used for different ports. By use of this expedient the opening and closing of the ports need not be simultaneous, but may occur successively.

From the preceding considerations the following propositions may be laid down; the latter applying to all, and the former to nearly all lift valves:

The application of slide valves in all fluid ratchet trains depends upon two principles:

1. The combination of several valves into one piece.
2. The control of the time of action of these valves by means of the lap.

The application of a slide valve to a pump is shown in Fig. 988 a. In this case / is the discharge outlet, and / the suction connection. In such pumps it is necessary to provide some mechanism to operate the valve, and such mechanism is termed the "slide valve gear." This valve gear may be arranged in a great variety of ways.

A simple form of gear is shown in the figure, 988 a, in which the arm 6, attached to the piston rod, moves the valve by striking against tappets 5' and 5" on the valve stem.
When the pump is used for pure water, as for drinking supply, the question of wear upon slide valves is not so important as with pressure pumps. A fair comparison can hardly be made, however, between pumps with slide valves and those with lift valves, as the former have been but little used and also not practically designed.

It is a matter of surprise that when occasional applications of slide valves are made in pumping machinery, that such devices should be considered needlessly new. The difference between the action of water and air is well known, and yet even with the slight weight of an air column the shock in blowing machinery is most apparent. It can hardly be supposed that the other form would remain uninvestigated.

The pumps shown in Fig. 98d, e, and f are commonly known as rotary pumps, which name is manifestly incorrect, since in form a there is an oscillating piston which does not rotate, while in form c, notwithstanding the rotary motion the action is similar to form d. Other so-called rotary pumps have been devised with curved piston action, some of those being as early as the 17th century. In some designs a radial slide acts in the pump case as a rack, and is drawn in and out by a cam of appropriately curved profile. A large number of rotary pumps have been made on this principle, many of which will be found in Polloon's treatise. These pumps are usually made with metallic packing only, and are used in Italy and France for pumping wine and olive oil; they are also adapted for brewery pumps.

The undeniable predilection in favor of rotary pumps on the reflecting train principle is worthy of consideration. It is claimed that they have a higher efficiency, but this remains to be established; also the rotary motion gives a continuous uniform motion to the water column, but this is equally accomplished by the arrangement shown in Figs. 98d and 98g. The form shown in Fig. 98g is approximately attained, as must be the case from the nature of the mechanism. The principle is that of a rack train which is intermittent in principle, and hence differs from a continuous running movement. The fact that such pumps give a continuous and uniform discharge is due to the fact that the column of water is operated directly from the part which is driven continuously, but this by no means follows. This combination of a continuous running motion, with an intermittent rack action which is not apparent to the eye, will be shown in other cases hereafter.

**§ 321. Escapements for Pressure Organs**

Ratchet trains found with pressure organs also include escapements as completely as is the case with the preceding forms of rigid ratchet mechanism. The ratchet of Fig. 258, shown again in Fig. 99a may be considered as an escapement if we regard the rotation of a by b to be uniformly opened and closed.

If now, in Fig. 99g, the checked member a is made a pressure organ, such as water, in communication at H with a pressure vessel or with a means of delivery, the regular lifting and closing of the valve b produces an escapement acting in a similar manner to Fig. 99g. By means of such a device the pressure organ a can be constrained in performing mechanical work. The range of such an escapement is not determined by the teeth of a wheel, but by the contrary, is similar to a friction escapement. The applications of escapements for liquids are in principle the same as those formed of rigid bodies, but in practice their nature is very different. We have already distinguished between water escapements and liquid escapements. To these latter, the instance the power escapements are by far the most important. For this reason the latter will be considered first. Unperiodical escapements are shown in the simple form of Fig. 99g, in which the time of releasing and locking is regulated by hand, a form very seldom found in rigid escapements. Periodical forms, similar to water escapements, are used with pressure organs for measurement, but not for measurement of time, but
of volume. To these we may add the adjustable escapements 

on the principle of those described in § 259, and we have the 

following classification:

a. Unperiodical Power escapements.
c. Adjustable Power escapements.
d. Escapements for measurements of volume.

A. \textbf{UNPERIODICAL POWER ESCAPEMENTS FOR PRESSURE ORGANS}

§ 322.

\textbf{FLUID ESCAPEMENTS FOR TRANSPORTATION.}

One of the simplest practical applications of the principle of 

Fig. 991 is Felanding's Postal Tube, shown in diagram in Fig. 

992. The line tube $a$ is connected with a reservoir of compressed 

air at $H$, and at $T$ with a similar negative reservoir. At $a$ is a 

sliding pawl, here shown open; the piston, or carrier, in the 

form of a leather box containing letters, telegrams, etc., being 

driven through the tube. A valve $b$ enables the end of the tube 

to be thrown into communication with a second negative 

reservoir, and this mechanism can be arranged at both ends of 

the line so that the tube can be used for transmission in either 

direction. Such postal pneumatic tubes are well known and 

widely used.

An atmospheric escapement operated by a negative reservoir 

is found in the so-called "atmospheric railway," invented by 

Pinkus in 1834, and put into practical operation somewhat later 

in England by Clegg and Samuda. This was operated on the 

Kingston-Dalby road with a vacuum of 36 in. atmosphere in the 

exhausted receiver, but it is no longer in operation.

When an escapement is intended to control the back and 

forth movement of a piston in the same path, the single valve 

shown in Fig. 991 is not sufficient, but at least a second must 

be used, as is already indicated in Fig. 992. One of the most 

practical of all fluid escapements is found in the lock used on 

canals and shown in diagram in Fig. 993.

\begin{figure}[h]
\centering
\includegraphics[width=0.8\textwidth]{fig992.png}
\caption{Fig. 992.}
\end{figure}

The canal is open on the upper side (see Fig. 993 $b$ and $c$); 

the valves $b_1$ and $b_2$ are of the running ratchet form, and are in 

reality double gates. Smaller by-pass valves $b'_1$ and $b'_2$ are used 

in order to enable the inlet and outlet of the water to be started 

gradually. The boat $b$ forms the piston, and when the motion is 

upward, $b_1$ is the escapement valve, and when downward, $b_2$ is 

used.

The above canal lock device, while extremely useful, possesses 

a very low efficiency, since it not only uses a volume of 

water equal to the displacement of the boat plus the necessary 

clearance, but also discharges the whole lock chamber of water 

each time it is used. Later devices have been made for the 

same purpose, involving a less waste of water. If it is arranged 

for the service to be doubled by making two lifts adjacent to 

each other, it is evident that the descending boat can counter-

balance an ascending one of the same weight, the only require-

ment being that there must be some connecting mechanism in-

volving the overcoming an additional resistance, and capable of 

reversal of 180°. This may be accomplished either by the use of 

tension organs or pressure organs.

\begin{figure}[h]
\centering
\includegraphics[width=0.8\textwidth]{fig994.png}
\caption{Fig. 994.}
\end{figure}

Fig. 994 shows a double canal lift constructed by Green for 

the Grand Western Canal in England in 1829, the connecting 

mechanism being tension organs in the form of chains. The 

boats are carried in tanks $c$ and $d,$ the ends of which are closed 

by valves or gates $g$ and $g'$ and similar gates $h$ and $h'$ also close 

the ends of the canal sections. A small addition to the weight 

on the descending side is sufficient to raise the other tank.

\begin{figure}[h]
\centering
\includegraphics[width=0.8\textwidth]{fig995.png}
\caption{Fig. 995.}
\end{figure}

The substitution of a pressure organ for the chain was first 

made by Mr. Edwin Clark on the Mersey Canal in 1837, in the 

form of a hydraulic lever, as shown in Fig. 995. This shows 

clearly the equivalence of the cord or chain and pulley and the 

water lever, already referred to in § 311. The tanks $c$ and $d$ 

are carried on plungers a foot in diameter, and are 75 feet long 

and 7½ feet wide. A head of 6' 6" of water is sufficient to over-

come the resistance of motion, and a lift of 50 feet is effected 

in three minutes. Smaller installations have been made by 

Clark and by Stanfield, and other large ones at the L'Aigle 

Canal in Belgium, and the Neuvesse Canal at Lons-le-Saunier, 

in France. The lifts are 43 ft. and 50 ft. respectively, and the 

plunger diameters 6½. The loss of water with these lifts is 

only about 1/64 of the quantity used by common locks of the 

same capacity.

The preceding escapement devices are made for open canals, 

but escapements may also be constructed with closed tube con-

nections. This latter type includes numerous hydraulic eleva-

tions for lifting burdens of all kinds.

An example of a direct-acting hydraulic elevator is given in 

Fig. 996. The two valves are combined in one cock. The water 

under pressure enters at $H$, and the discharge against the 

atmospheric pressure is at $J$. The weight of the plunger is 

counterbalanced by two counterweights $G$ with chains and

5 See Diet. Encyclopa. p. 72; also Mohler, Hydraulic Machines, London, G. 

4, 1887, p. 84.
6 See Lavoisier, p. 29; Robinson, p. 69; also Zentrales der p. Bauverwaltung, 

1841, p. 391. Hensel, Schloßkunst in Frankreich; also Schmidt, Kanal 

und Dampfwerke in England, 1871, p. 12. Also Kellner, Flutkraft, Berlin, Springer, 

1885, p. 69. In Green's lift the loaded boats descend and the empty cars ascended, hence an excess of 

water was released, which was permitted to overflow. These lifts enable much 

greater differences of level to be overcome than do the ordinary locks, and make it practicable to use 

long stretches of canal and in large entire lift at one operation. It may be here noted that pneumatic lifts for canals were 

designed in 1825 by the Swiss engineer Seyder.
pulleys, and the plunger operates the valve automatically by means of the rod $\delta$, when the highest position is attained. This form of lift has been much used, sometimes of very large dimensions. The great passenger elevator of the Hamilton St. Station of the Mersey Tunnel has a plunger 16\textsuperscript{1/2} in diameter, with a lift of 87\textsuperscript{1/2} feet, the car holding 50 passengers.

A practical objection to direct-acting lifts of this form lies in the heavy counterweights required, and also in the depth to which the cylinder must be sunk. A different form has therefore been designed in which a piston travels of moderate length is multiplied by the use of a tension organ system, such devices being extensively used for passenger elevators, notably by the Otis Elevator Company.

Hydraulic cranes are also forms of high pressure escapements, first designed by Armstrong, and since used by many others, especially in connection with Bessemer Steel plants, in which hydraulic cranes have proved most valuable.

Fig. 997 shows the mechanism of a hydraulic crane by Armstrong. The piston is double acting; there are four valves $\alpha$, $\beta$, $\gamma$, $\delta$, of the type shown in Fig. 986, the external connections also being necessary in order to complete the escapement. The high pressure water enters at $A$, and passes through the pipe $b$, and is discharged to the atmosphere at $C$. The rod $\delta$, is made of half the area of the piston $\epsilon$.

FIG. 996.

(Compare Fig. 955.) When $b$, and $d$, are open, as in the illustration, the forward stroke is made with one half the full force; when $b$, and $d$, are open, the forward stroke is made with full force. By opening $b$, and $d$, and the return stroke is made by the pull of the load upon the chain. At $b'$ is a safety valve which comes into action should the load descend too rapidly, by the opening of $b'$ alone.

§ 533.

Hydraulic Tools.

Hydraulic escapements, similar to those used for lifting loads are also applicable to machine tools. Among these may be noted the devices of Tweedell, for riveting, punching, bending, etc. (see § 54).

Figs. 998 and 999 show the arrangement of Tweedell's riveting machine; $e$ is the piston, $b$, $d$, the valves, one of which connects with the pressure reservoir at $H$, and the other with the atmosphere at $A$. When $b$, is opened by the lever $c$, the hydraulic pressure enters the piston $d$, and the stroke is made. The return stroke is effected by means of the auxiliary piston $d$, which is fast to $d$, and under which the water pressure is acting at all times. Closing $d$, and opening $b$, enables this to act and lift the main piston. This gives practically a hydraulic lever of unequal arms, the shorter arm always being loaded with $H$, and the load on the longer arm varying between $H$ and $A$. The lever mechanism of $d'$, $d''$, and $d'''$, controls the length of stroke of the die, by means of the tappets $d''$ and $d'''$, which are connected with the lever $c$. This is also used on the lift of Fig. 996, and shows the complete escapement. The arrangement of valves is shown in detail in Fig. 999.

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FIG. 997.

FIG. 998.

The preceding apparatus resembles the hydraulic press. It is in fact quite different, being a genuine ratchet train, capable of all the modifications of such mechanisms as to speed, distance, and arrangement. In account of these points the applications of pressure organ escapements are becoming rapidly more important.

§ 524.

Pressure Escapements for Moving Liquids.

The use of unperiodic pressure escapements for moving liquids in machine construction has been practiced from an early period, and at the present time improved devices for this purpose are much used.

An almost forgotten device of this kind is Brindley's boiler feeding apparatus, Fig. 1000, this being based upon the principles already given in Fig. 997.

The necessary opening of the valve $b$ is made by the float $c$, and the closing by the counterweight $z$ (compare Fig. 950). This apparatus was first applied to Watt's boilers, the feeding of the boilers of Newcomen's engines being effected by a cock operated by the attendant.

Fig. 1001 is Kellwegger's steam trap for the removal of water of condensation. The stop valve $b$ is opened by the float $c$, which, in this instance, is open at the top, so that the water flows over the rim until it sinks, when the float opens the valve. This valve motion is in itself a ratchet train, checked and released by the action of the float. When the valve is opened the water in the float is forced out by the pressure of the steam.

The slow moving float device, as in Fig. 1003, has also been advantageously used for operating steam traps, by Tulip, of Rouen; Handrick, of Buckland; Puschel, of Dresden; Dehme, of Halle, and others. Similar escapements have been designed to separate air from steam, or air from water, as in the devices of Andral, Kuhlmann, Klein and others.

Other examples of escapements of this kind are found in the so-called Montejus, used for elevating syrups in sugar refineries, in the return traps of steam heating systems, and in various other forms of boiler feeders, such as those of Coatesfield, Kither & Mayhew, and others.

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* See Robison.

† See W. K. Heppner, Ill., p. 28; Colyer, p. 14; Robison, p. 83.


†† For illustrations of these devices see Schell's Führer der Maschinen, 20 Reiz, p. 267.

‡‡ See Schell, p. 286.
B. PERIODICAL PRESSURE ESCAPEMENTS.

PUMPING MACHINERY.

Periodical fluid escape trains have a wider application than unperiodical trains, since it is practicable, as already indicated, to use a fluid ratchet train to operate the valves in a simple manner. This makes it possible to produce the opening and closing of the valves in a periodical succession mechanically, instead of by the fluid column. In this construction the fluid column may therefore drive the piston, instead of being driven by it. This idea seems very simple, and yet pumps had been known for two thousand years, and had occupied the inventive energy of the preceding centuries before the simplest forms of the modern steam engine were devised. It is therefore all the more important, in the study of machine design to investigate the fundamental principles involved.

It is impossible, in the limited space which can here be given, to go into this subject in its entirety; the arrangement of the valve gear of the Newcomen engine with tumbling bob gear, is an instructive example.

In Fig. 1002 is shown Belidor's singleacting water pressure engine.6

In the cylinder d is a piston; a, the entrance of the water, c, the discharge outlet. The valves b, and b', are united in a three-way cock (see Fig. 657). This cock is operated by the piston rod p by a tumbling bob gear (see Fig. 742). The tumbling lever E, c, c', weighted at E, is connected with the piston rod at c, and moves about its axis independently of the lever f. When the end of the piston stroke is nearly reached, the lever E passes the middle point, and tips over, when the arm f, strikes the lever f and carries it to the position f', moving the lever of the three-way cock from b to b'. The arm c is behind E. The return stroke of the piston moves the arm c of the tumbling gear towards the right, and as the end of the stroke is reached, the tumbling bob is again tripped, and the three way cock moved again into the position b. A cord secured at the end of the stroke, and pulled at the points a and c, fastened to E, limits the travel of the latter. The piston rod is connected directly to the pump to be operated.7

It will be observed that this machine is a ratchet train of the second order, the piston and valve forming an escapement, and the valve gear a reversing ratchet train each operating the other.

Fig. 1003 is the single acting water pressure engine of Reichenbach. Instead of using a tumbling bob gear to operate the valve, Reichenbach uses a second water escape ment, operating the valve by a piston, the valve itself a piston valve. The double piston valve b, b' of the second escapement is operated by the main piston rod, the tappets s and s striking the lever c, as each end of the stroke is reached. The water under pressure enters at q, and is discharged at s. The tappet s moves the auxiliary valve into the position b' b', which places the space above b, in communication with the discharge, and since d is larger than h, the pressure between them moves them into the position h b'. This puts the main cylinder in communication with the discharge, and the piston sinks by the weight of the load upon it. At the close of the stroke the tappet s moves the arm c into the position c, again, and places the auxiliary valve in the first position and a new stroke is made.

This machine constitutes an escapement of the second order, since the small and large escape parts alternate release each other; the lever device s-s, forms a third mechanism, so that the machine, as a whole, is of the third order.

Fig. 1004 shows the double acting water pressure engine of Roux.8 The double action is obtained by combining the four valves in one, and by communicating the admission and discharge alternately with both sides of the piston. In this case the lever connection c is replaced by an escapement. The small pistons b, b' are actuated on the outer ends by the pressure water through the small passages h, h'. This gives an escapement of the third order. The cup-shaped ends c, c, of the main piston c form the pump plungers. This machine should operate satisfactorily.

It is readily apparent that the piston steam engine may also be considered as an escapement. The valve gears differ from the preceding forms only on account of the conditions of expansion and condensation. These are reducible to a limited number of simple cases.

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6 Belidor, Architecture hydraulique, Pars. 1772, Vol. II. p. 266.
7 The above described machine, designed by Belidor in 1772, for the water works at the bridge of Notre Dame, does not appear in the altogether praiseworthy work of this hydraulic engineer, which is interesting and doubtless good, and has been reprinted several times. the water works were not new in 1772, having been in Newcomen's steam engine, as was already known to Belidor, since it is described by him in the same volume of his treatise.
8 See Weidich-Herrmann, II. p. 536; also Rothenstein, allgemeine Maschinen Chron., 1. p. 348.
enters at \( a \), and the discharge to the atmosphere is at \( a' \). The opening of the valve \( b \) permits the steam to enter, forcing the piston down, and raising the weight \( G \). The valves \( b \) and \( b' \) are operated by a ratchet wheel released from the tappets \( t \) and \( t' \) on a rod moved by the main piston. The pawls are double-acting, and are of the form shown in Fig. 1051. When \( c \) reaches the bottom of the cylinder the tappet \( s \) releases the ratchet \( g \), and closes the valve \( b' \) by means of the connections \( c, f, c' \). This release of \( g \) opens the valve \( b \), by means of the connections \( c, f, c' \), and permits the escape of the steam from below the piston. This equalizes the pressure above and below the piston, from which the valve \( b \) is called the equalizing valve. The upward stroke of the piston causes the tappet \( s \) to reverse the ratchet \( g \) and operate the levers \( e, f, e' \), closing the equalizing valve and its connections.

The device differs from the preceding in that the principal escapement \( a, b, c, d \) changes in character with the stroke. The two ratchet trains can be seen in principle in the double-acting tumbling gear of Fig. 1052. The mechanism, when lifting the valve, is of the third order, and when closing, of the second order. The gear as shown is Furry's; Fig. 770 shows this principle in a rigid escapement train, the corresponding form in single-acting train is the chronometer escapement, Fig. 770.

If the engine is a condensing one, a condenser valve \( b \) is added, this being opened by the closing of \( b' \) as is also a jet valve in the condenser. When the steam is to be expanded, the lever \( c \), so arranged, the closing of \( b' \), is produced earlier (see the smaller diagram by the position of the tappet \( g \), and the corresponding counterweight lifted. This only operates the ratchet \( g \), and \( g' \), is released by a second train \( S \), which is effected by the tappet rod or by the so-called cataract \( K \), released by a tappet \( c' \); see Fig. 770.

The condenser is a negative reservoir, and was the principal invention of Watt. It involves the use of two field ratchet trains; the air pump, and the cold water pump, and also usually includes a boiler feed pump. The entire engine is composed of a collection of ratchet trains.

Steam pumping engines are by no means always made with lift valves, and a great number of more recent designs are made with slide valves (see Fig. 656). Ritter has applied slide valves successfully to single-acting engines, and they are especially applicable to double-acting non-rotative engines. In the last decade especially have valve motion for steam pumps with slide valves been multiplied, and some illustrations are here given.

Fig. 1066 is Tangye's direct-acting steam pump. The steam enters at \( J \), and the exhaust at \( J' \). The slide valve \( b \) is the so-called \( L \) form, combining the four forms of Fig. 656 in one, and \( b' \) are the auxiliary pistons to move the valve, and form part of the escapement of which the valves \( b \) and \( b' \) are operated by the main piston \( c \) at each end of its stroke. The latter valves communicate with the cylinder ports \( H \) and \( H' \). When \( b' \) is lifted by the piston, the space \( K \) is in communication with the exhaust, and the pressure in \( L \) throws the valve over, equilibrium being soon after established through the aperture \( G \). The reverse action occurs on the return stroke. This is a steam escapement of the second order, with an independent starting lever, the whole forming a combination of the third order.

This has been much developed and shown for steam engines.

Fig. 1077 shows the valve motion of the Blake pump, which is very extensively used in the United States. In this case there is a movable seat \( b' \) under the valve \( b \), the opening through the seat always being in communication with the ports \( H \) and \( H' \), although \( b' \) is moved a short distance at each end of the stroke by tappets on the piston rod. In the position of the parts shown the steam entering at \( J \) will pass through \( J' \) and move the main piston to the left, as indicated by the arrow. Just before the end of the stroke is reached the seat \( b \) is moved as much to the left of the centre as it now stands to the right. In

The seat \( b' \), as shown in the figure to the right, there are additional valves formed, \( b_2, b_3, b_4 \), which act to operate the auxiliary pistons \( b, b_2, b_4 \) under which latter the small steam passages can be partly seen. When \( b_4 \) is moved to the left, a small stop is uncovered by \( b_2 \), and live steam enters the cylinder \( L \) behind \( b_4 \), while at the same time \( b_2 \) connects \( K \) with the exhaust. This causes \( b_2, b_3, b_4 \), to move to the right and reverses the pump. The reverse action takes place at the other end of the stroke, the whole forming a combination of the third order.

Fig. 1088 shows the valve gear of Deane's steam pump, which has also been extensively used. The main valve is moved by means of auxiliary pistons, as in the preceding instance. The auxiliary pistons are controlled by a separate valve \( b' \), which itself is operated by lever connections with the main piston rod. This combination \( b', b, b' \), forms again a mechanism of the third order.

If the last three devices described are compared with the Reichenbach water-pressure engine, it will be seen that the fundamental principle is the same in all. The constructive arrangements which may be adapted are clearly shown in the preceding examples, which may be modified in a variety of ways. Among other widely used arrangements, that of Knowles may also be mentioned; it is the action of the auxiliary pistons is controlled by a slight twisting motion given to the valve stem.


† See Forsyth.
communication with $I$ and $IV$. The whole forms a steam escapement of the second order.

Fig. 1010 shows Harlow's valve gear, also used for pumping machinery. This is also a steam escapement of the second order, similar to the preceding. The valve action for the auxiliary pistons is formed in a prolongation of the piston rod, the grooves $g_1$ and $g_2$, placing the spaces $R$ and $L$ alternately in communication with $II$.

The devices of the third order are capable of a very important modification which can be considered by examining for instance the Dean gear. Fig. 1009, or either of the two preceding it. An inspection will show that it is entirely practicable to use the auxiliary piston to operate a pump cylinder, independently of that operated by the main piston $d$. It is only necessary to make it larger in diameter and of proper length of stroke, and there is nothing to prevent making it of the same diameter and stroke as the main piston.

The valve of each cylinder will then be operated by lever mechanism connected to the rod of the other piston. This arrangement involves the replacing of the $D$ valve by the common $D$ valve, which is not important, but is nevertheless an advantage. The two escapements are conveniently placed side by side for constructive reasons, and the double arrangement is known as a "duplex" machine, this term being given to two combined cylinders, of which the valve of each is operated by the piston movement of the other. This type is now frequently used, having been made for small apparatus very early, in France by Mazellier and yet earlier, in 1859, in the United States by Worthington.

**Fig. 1010.**

By comparing the preceding designs with the water pressure engine of Roux, Fig. 1009, the similarity will be apparent. All the examples given show the fundamental relation existing between these devices and the mechanical escapements of watch movements. The escapement is replaced by the fluid column, the anchor, by the valve; the vibrating member, whether pendulum or balance wheel, has here not a free movement but a determinate one against an external resistance. Similar arrangements include steam hammers, also hammers and rock drills, usually driven by compressed air, these latter consisting of mechanism of the second, rather than the third order. An example will serve to illustrate the general arrangement of such devices.

**Fig. 1011.**

Fig. 1011 shows the arrangement of Githens' rock drill. The curved valve $b$, is operated by the action of the curved outline formed in the piston $c$. The middle position of the valve is a dead point, but this is overcome by the momentum of the heavy piston.

**Fig. 1012.**

The illustration shows one piston $a$, at mid-stroke with its valve $b$, at the end of its travel, and connected to the rod of the other cylinder by the lever $c$.

The work is divided into two portions which is provided for by the doubling of the parts. If the two piston escapements (cylinders, pistons, valves, steam, etc.) are indicated by $1$ and $\bar{1}$, and the valve movements by $2$ and $\bar{2}$, the action will be as shown in the following lines,

\[ \begin{array}{c|c}
1 & 2 \\
\bar{1} & \bar{2} \\
\end{array} \]

whence we have

\[ \begin{array}{c|c|c|c}
1 & 2 & \bar{1} & \bar{2} \\
\end{array} \]

and

\[ \begin{array}{c|c|c|c}
1 & \bar{2} & \bar{1} & 2 \\
\end{array} \]

both being of the second order.

**Fig. 1013.**

Fig. 1013 shows a perspective view of Worthington's Duplex Pump. The arrangement of which is apparent from inspection. The duplex steam cylinders are at the right, and the double acting pump cylinders on the left.

The advantages obtained by using this form of pumping machine practically outweigh the objections which might be made against the duplication of parts. In double acting pumps of the forms shown in Figs. 1009 to 1010, the motion of the water columns is interrupted, at low speeds, at each reversal of
the piston, while with the duplex pump the discharge is practically continuous, because each cylinder begins its stroke just before the other comes to rest.

An objection to all the other forms of direct acting pumps already described lies in the fact that to obtain uniform pumping action it is necessary to carry the initial steam pressure for the entire stroke of the piston, or in other words, the best action of the water end is obtained by means of the least economical action of the steam cylinders.

This defect was overcome in the earlier pumping engines, such as the Cornish mine engines, by using the steam to lift heavy weights, pump rods, etc., the living force of the mass permitting the early cut-off and high expansion, and the uniform descent of the weight being used to force the water. By this method the Cornish engine attained a high degree of economy. This method being single acting, caused the entire column of water to come to rest during the time required for the up stroke of the pump rod, and hence the Cornish type of pumping engine gives us the most economical action of the steam at the expense of a defective action of the pumps.

In the larger sizes of Worthington pumping engines the expansion of the steam has been for a long time effected by using compound cylinders, and excellent results attained in steam economy. The efficiency, however, was by no means so high as was desired. In 1886 the so-called Worthington equaliser was introduced with a view of enabling the desired high duty to be attained.

Fig. 1014.

This device, shown in Fig. 1014, is a ratchet train of the tumbling type, similar to that shown in Fig. 743, the spring being replaced by water pressure from a high pressure air chamber. The air chamber forms a periodical storage reservoir. The plungers p, p are attached to a cross-head connected to the prolonged piston rod, and the cylinders are carried on extensions 7, 7. During the first half of the stroke the plungers are forced into the cylinders, the latter swinging about the centres 7, 7; and during the second half they are forced out by the action of the stored energy.

The resistance and assistance which the pistons p give to the steam piston is shown by a curve of the form of Fig. 1014 d, as has also been obtained by the indicator.

Fig. 1015.

If in Fig. 1015 a, we make P equal the component on each of the pressure Q on the main piston rod, we have:

\[ Q = 2 P \sin \beta = \frac{2 P \tan \beta}{\sqrt{1 + \tan^2 \beta}} \]

in which

\[ \tan \beta = \frac{x}{h} \]

This gives

\[ Q = \frac{2 P x}{\sqrt{1 + \left(\frac{x}{h}\right)^2}} \]

or if we make Q the ordinate y of the desired curve:

\[ y = \frac{2 P x}{\sqrt{x^2 + h^2}} \]

and substituting c for x P x, we have

\[ y = \frac{c}{\sqrt{x^2 + h^2}} \]

Fig. 1016 shows a longitudinal section of a Worthington high duty pumping engine. The equalizing cylinders and their air chamber are seen on the right; the dotted lines c show the rod of the second cylinder, which operates the valve o. As it has already been seen that many forms of the third order can be reduced to the second order, it may be inferred as to the possibility of obtaining a pumping mechanism of the first order. This has already been accomplished by using the steam escapement with a water ratchet train. The device is the Hall Pumpometer, shown in diagram in Fig. 1017.

The steam enters at a, at b, is the anchor shaped pawl, and c is the vessel corresponding to the framework of a rigid escapement, compare Fig. 1015. If the vessel d is closed as shown by the dotted lines and a volume of water c, included, we obtain an action of the first order. The efficiency is very low, about 1/4 to 1/5 that of a piston pump, but the simplicity and convenience is so great that this may often be neglected.

Another escapement of the first order is Montgolfier's hydraulic ram, which is a water checking-ratchet train, the efficiency of which is low. A more recent device is the application of a water ratchet train to drive a pneumatic ratchet train, first used on a large scale by Sommellier in the construction of the Mont Cenis tunnel, and by means of which the efficiency was brought up nearly to 50 per cent. Pearsall has recently improved the hydraulic ram and raised its efficiency to nearly 80 per cent, either for water or for air, but this


The Worthington equaliser was an admirable work, and it is still used in many of the best known pumps for the past 40 years. Since Papin's first machines in 1720, the desired aim has been to combine the action of a variable elastic driving medium and a uniform, non-elastic resistance.
has been done by the introduction of a valve gear, making it a device of the second order."

§ 326.

FLUID TRANSMISSION AT LONG DISTANCE.

When the motive power is intended to operate the piston of a pump situated at a distance, some connecting mechanism must be interposed between the two cylinders. Formerly this was accomplished by using long rod connections; instead of this a pressure-organ transmission may be employed. When water is used as the medium for transmission, this may be termed a "water rod" connection. This is used in connection with water levers (see § 317).

Fig. 1018 shows three devices for this purpose. At a is shown a closed system with pistons of equal diameter; b is a similar one with unequal pistons; and c is a form with combined pistons. Such water-rod connections are adapted for use in mines, and the following example will illustrate.

The arrangement of transmission in the Schwab-Altendorf is shown in Fig. 1019, which represents the engine above ground, while Fig. 1020 shows the mechanism in the mine.

Fig. 1019.

The arrangement is of the same form as Fig. 1018 b. The steam piston c operates the two plungers h, k, which in turn operate the plungers c, c, which are attached to the bottom end of the rod. The depth of the well, the speed from 5 to 60 strokes per minute, with a stroke of one second, giving about 700 feet piston speed per minute. This engine, built by the Henschel Steel Works at Barleben, is considered one of the models of the kind and has operated regularly for 20 years without any interruption.

§ 277.

ROTATIVE PRESSURE ENGINES.

An effective method of obtaining an advantageous action of the steam is to substitute for the reciprocating motion of the Cornish engine a rotating mass. This is accomplished by using the reciprocating motion of the piston to operate a crank shaft upon which a fly-wheel is placed. Since it is practicable to give the rim of the fly-wheel four to six times the velocity of the crank pin, the magnitude of the moving mass can be much smaller, and since the value varies as the square of the mean velocity the mass is reduced at least 16 times. It is therefore possible by this means to give even small pumps an efficiency equal to that of large pumping engines.

It is not practicable to connect single-acting pumping engines into fly-wheels, because the piston speed is too variable. If we draw a curve representing v, the ordinates being the positions of the piston, we have for a connecting rod of finite length a circular curve, as in Fig. 1021 a. When the length of the rod is taken into account these curves are modified, as shown in Fig. 1021 b, which is drawn for a rod four times the length of the crank. This curve also shows the ratio of the tangential force on the crank pin to the pressure on the piston.

The variations in the value of v, which often differ widely from the mean value, must necessarily be communicated to the mass of water, and hence great variations occur in the water. For this reason the velocity of the column of water must be kept within moderate limits, notwithstanding the use of air vessels. These variations become much less serious when two pumps are connected by cranks set at right angles with each other. The corresponding velocity curves are shown in Fig. 1021 c. and many pumping engines are now so made. More recently triple cylinder engines are made with cranks 120° apart. The velocity curves in this case are shown at d. It is evident that both these forms involve complications in construction which compare unfavorably with the direct-acting pumps with equalizing cylinders (see § 325).

Instead of using a revolving fly-wheel, the mass of metal may be arranged to swing in an arc of a circle of large radius. An ingenious application of this principle has been made by Krey, in his water works engine with auxiliary crank motion. The proportion between the steam pressure and the vibrating mass is so arranged that the auxiliary crank comes to rest either a little before, or a little beyond the dead point, so that the return stroke in each case can be effected by the action of a catch. In the first case, the fly-wheel swings backward after

"The Gaskill pumping engine is a duplex pump with fly-wheel, and cranks at right angles, and has given excellent results. See Porter's "Report of the Gaskill Pumping Engine at Kensington."

† Referring to the designations in Fig. 1007, we have

\[ e = \sin w + \tan u \cos w. \]

Since \[ \tan w = \frac{d}{\sqrt{d^2 - \sin^2 w}} \]

the ratio \( \frac{d}{e} \) is also equal to the same expression. Hence the curves above given also show the ratio of the force in the path of the crank to the pressure on the piston.

The double-action engine is represented by Fig. 1022 a. In Fig. 1022 b, c, d, and e are represented by Fig. 1022 c; in Fig. 1022 d, e, f, and g, the ratio of connecting rod to crank is again taken as an indefinitely great. The curves are adapted for double-acting pumps. When two single-acting pumps connected at right angles are used, the second half of the curves of Fig. 1007 become the same form as the first.
the pause, and in the second case, forward. The valve motion of this form of engine is considered in the following section.

§ 328.

VALVE GEARS FOR ROTATING ENGINES.

Rotative engines are distinguished from pure reciprocating pressure organ escapements in that they deliver their effort in the form of rotary motion adapted to be used for driving running machinery. Between the two forms there is also the intermediate kind, with merely auxiliary rotative mechanism, such as have been already referred to. The translation of reciprocating and rotary motion may be accomplished in a variety of ways, but by far the most usual and best known is that by which the rectilinear motion of a piston is transmitted to the shaft by crank connection.

The variations in the tangential component of the pressure $P$ on the crank pin, Fig. 1024, becomes still greater when the pressure $P$ on the piston also varies by reason of the expansion of the steam. For this reason some form of equalizer is required in the form of a fly wheel. This latter becomes a reservoir for the storage of living force. Extreme examples of this action are found in rolling mill work in which within a brief time a 100 H.P. engine may be called upon to deliver 2000 H.P., a demonstration of action of the fly wheel as a reservoir of power.

The valve gearing for rotative engines is an important and extensive subject. In the preceding sections a series of valve gears have already been described. These have all been based upon the principle of operating the valves by a direct reciprocating motion, either of the piston or piston rod. With rotative engines another method is used, the motion being taken from the revolving portion of the machine, and this method may also be adopted for pumps with auxiliary crank action. We may then distinguish between:

Reciprocating valve gears, and
Rotative valve gears.

Reciprocating valve gears are desirable for direct acting pumps, but in a still greater degree are desirable for rotative engines. Watt's rotative engine was made with a reciprocating valve gear, and this form has one advantage in that it is adapted for rotation in either direction.

Hornbower, the inventor of the compound engine, also used a reciprocating valve gear. The slide valve, invented by Murdoch, in 1799, led the way to the introduction of the rotative valve gear in 1808, but the old reciprocating gear still continued to be used, and is even re-invented at the present day. The later direct acting steam pumps with auxiliary rotative mechanism are almost always made with rotative valve gear. Kley's pumping engine, referred to in the preceding section, is made with a reciprocating valve gear, since its motion is both before and behind the dead points of the crank.

The use of the slide valve, combining four valves in one member, can never be made for the simple double acting escapement, as the diagram of a plain slide valve engine, Fig. 1023, clearly shows.

Fig. 1023.

The use of an eccentric $r$ and rod $j$, to operate the valve $b$, is not the earliest form of gear, the first method being the use of an irregularly shaped cam which brought the valve to work except at the time of opening or closing. A feature of the slide valve which was long overlooked was the fact that the time of closing the steam ports $f f$ and $f f'$ could be regulated so as to effect the proper expansion of the steam. In order to accomplish this result without impeding the exhaust of the steam, the eccentric $r$ must be given the so-called angle of advance $2 r$ beyond the mid-position. The direction of rotation of the crank is then governed by this angle, the arrangement above giving rotation to the left, and the position $1 1'$ for $r$, giving right hand rotation.

The action of the slide valve may readily be represented graphically. The angle of advance and lap being given the point of cut-off can be determined by the following method.

Fig. 1024.

The circle $C$ represents the circle of the eccentric and may also be taken as the crank circle on a reduced scale. $C_1$ and $C_2$ are two symmetrically placed positions of the piston at which it is desired that the cut-off shall take place. Through these points with a radius $1 3 = a$ describe a circle, the centres $3'$ and $3''$; their intersections $E_3$ and $E_2$ with the circle give the angles at which the expansion $C_1 C_2$ and $C_2 C_1$ occurs, in this instance $1 3$, of the stroke. We now select the point $3$ of the crank circle at which the admission shall begin. Join $V_1 E_3$ and draw the circle $a 1 3$ parallel to it, and the angle $a 3$ will be the angle of advance $S$, and the distance of $a 1$ from $E_3 F_3$ the outside lap $e_3$ for the port $1 1'$. The width of port $a$ must also be chosen, and must be so taken that it is less than $r_1 - e_3$, and is represented by the parallel $A_1$. When the crank reaches $E_3$, in this instance at $E_3$, the stroke, the exhaust begins, and the distance $E_3 E_2$ of the parallel $E_3 E_2$ from the equator is the inside lap.

The construction is similar for the other half of the stroke. The angle $a$ is already known, and hence the parallel $A_1 E_2$ from $E_2$ can be at once drawn, and the admission point $F_2$ determined. The outside lap $E_3 E_1$ is somewhat less than $r_1$, this giving a correspondingly wider port opening. The inside lap $E_2 E_1$ is made equal to $r_1$, and the bridges $b$ and $b_1$ are made equal, thus giving a symmetrical valve seat. A certain amount of discretion is permissible in the selection of $a = b_1$, care being taken that there is sufficient bearing at the extreme valve stroke to insure tightness. The points $S_1$ and $S_2$ are also of importance, as they determine the closing of the exhaust. The corresponding piston positions $C_1$ and $C_2$, as previously specified, because $f_1 = f_2$, but the inequality in the compression is not serious.

The above method of considering the influence of the ratio $\frac{a}{r}$ is very simple. It is easy to substitute any desired ratio $\frac{a}{r}$, but the variation is slight. It must be noted that the distance $1 3$ must be laid out to the actual scale of construction.

The application of Zenner's diagram to the same case is made in the following manner, Fig. 1025. The circle $C$ represents as before the eccentric circle and the crank pin path. The angle $C_1 1 2 = C_1 1 2 = 90 - \delta$. With $a$ as centre, describe circles with radii $a$ and $a_1$, here made alike for both ends of the valve, also one of radius $a + a_1$. Upon $1 1'$ and $1 2$, as diameters, describe circles, called the valve circles.

Fig. 1025.

1 Formerly the so-called "valve ellipse" was used; since 1855 Zenner's diagram has superseded these, see Zenner, Schriften über die Dampfmaschinen, Freiburg, Engelsbarth, first published in Civi Ingenieure, Vol. 3, 1855.

2 See Pavy, Treatise on the Steam Engine, London, 1857, p. 294. Engines with slide valves were only made by Baudot and Watt, after James Watt retired to private life.

3 See Pavy, p. 297.
The intersection of radii from 1, with these circles, give the distance of the valve from its middle position, for various crank positions. For the position 1 Ε, for instance, the admission for the left stroke begins at 1 Ε, the expansion, at 1 Ε the exhaust, etc.

The Zeuner diagram gives the valve position by means of polar co-ordinates, while the writer's diagram is based upon parallel co-ordinates. To be strictly correct, the valve circles 1, 2, 3, and 4, of the Zeuner diagram should fall upon each other. The arrangement shown has been adopted by Zeuner as more convenient in practice.

It will be seen from the preceding that the rate of expansion can be varied by altering the eccentricity and the angle of advance. This may be carried so far that the direction of rotation is changed, giving what is termed a reversing lever. A variety of reversing motions have been devised, which accomplish the desired relation of parts by shifting a reversing lever. Of these the most practical are the so-called link motions, of which a number will here be briefly shown.

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**Fig. 1029.**

Fig. 1029 a, is Brown's valve gear, which differs from the preceding by the substitution of a straight link of adjustable angle, for the curved gear link.

Fig. 1029 b, is Angstrom's valve gear. The point 3 of the preceding gear is guided by a parallel motion, and the point 0 is between 2 and 3, instead of beyond 3.

The eight preceding valve gears operate the valve approximately in the same manner as if a single eccentric of variable eccentricity and angular advance were used, the eccentric being assumed of infinite length. The successive positions of the middle point of this imaginary eccentric is called the central curve of the valve gear.

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**Fig. 1030.**

Fig. 1030 shows the form of this curve for link motions in general. Form a, is that for cases 1, 5, and 6; form b, for case 2, when the eccentric rods are crossed, and form c, in which the curve becomes a straight line, is for case 2, 5, and 6 to 8.

In the latter instances, the idea of a valve having a stroke constant at the beginning of the stroke is constant, a point considered by many to be of much importance.

It is possible to arrange the mechanism in such a manner that the centre of the valve motion may move directly in the desired central curve, as shown in Fig. 1031.

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This construction involves the rotation of the link about the crank axis. The only point to be accomplished is to guide the centre 2 in the path 2, 2'. Form a in Fig. 1031 is a direct guide for the eccentric with a single adjustment; A is Slew's valve gear, in which the position of the eccentric is determined by a central governor. This only uses the central curve from

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*Fig. 1028 a, is Hensinger's link motion. The link 4, vibrates upon a fixed centre 5, and is operated by an eccentric 1. The valve rod is moved from the main cross head by the connections 10, 11, 10, and by the radius rod 5, 6, which latter is suspended from the bell crank S. 127.

Fig. 1028 b, is King's valve gear, known in England as Marshall's. The curved link 4, is rigidly secured and does not*
2' to 20, and the path is a curve produced by a radial arm as in Klug's valve gear. The valve is balanced, in order to reduce friction to a minimum.

The last described valve gear possesses the advantage of great simplicity but retains the disadvantages of all single valve gears when used for a high expansion ratio, i.e., the admission and exhaust of the steam do not remain uniform, and are often unsatisfactory. For this reason many valve gears with independent expansion valves have been designed.

Fig. 1032.

Three forms of gear with separate expansion valves are shown in Fig. 1031. The form a, known as Conzenbach's, that of b, by various names, c, is the widely used Meyer valve gear. In France, Farolet's gear is used, having two loose cut-off plates carried on the back of the main valve, and in America, the excellent Porter-Albee engine with double valves operated by two eccentrics is much used. A valve gear for a modification of Meyer's, Fig. 10324. The cut-off plates form reverse spirals, and slide in a concave seat on the back of the main valve, the valve being also spiral-shaped and cut-off varied by twisting the cut-off valve axially.

Instead of using eccentrics to operate the valves, cams of irregular outline may be adopted, these permitting a rapid opening and closing of the ports, as in the Hurlbut cylinder. Cam valve movements are to be found in the steamboats of the western and southern States in America. In its original form of a cock or cone a slide valve may be operated by an alternating motion as well as by continuous rotation. Such valves have been used in steam engines by various builders, among others the firms of Dluger in Zweibrucken, but the cost prevents wide use. A most extensive use of oscillating cylindrical valves has been developed by Coriass and his followers.

The forms of oscillating and rotating chamber gear trains already described involve other means of operating the valves than are used for reciprocating engines, and shown in Fig. 1029. As an example, the water pressure engine of Schmelt, of Zurich, Fig. 1033 is shown. In this instance the valve b is formed in the frame of the machine instead of the machine, as in the example shown in Fig. 959. The regulation of steam engines may be a much more difficult matter than in the case with steam engines partly on account of the lesser fluidity of the water and also because of its slight elasticity.

An air chamber in the admission pipe as shown in Fig. 1033 is therefore desirable, and when extreme changes of load are anticipated the valve gear should be modified. If desired to cut off the admission of water before the end of the stroke is reached, it is necessary to arrange a special valve to accomplish this purpose. Excellent engines with this arrangement have been made by Hooper, of Berlin, for the Mansfield mines, and for the Frankford railway station.

Another method is applicable to power driven pumps, an illustration of which may be found in the design of Mr. H. H. Hendenberger, of Rotherhithe. This is made with a hydraulic ratchet mechanism arranged in the crank disk in such a manner as to move the crank pin to and fro from the centre, the ratchet being operated by tappets which strike each time the crank passes the dead centers. The throw of the crank is thus varied to correct for variations of speed, the mechanism being controlled by a regulator. The motion is very satisfactory, giving results varying from 90 to 95 per cent for a change of power from 1 to 8, according to the investigations of Auehneimer, published in Karl, in 1885.

A later device is that of Rigg, which also acts by varying the stroke. The machine is a so-called "chamber crank train," described in his "Theoretical Kinematics," p. 339, English ed., p. 601, with four single acting cylinders on a common wheel in the same manner as the machines of Ward, Schröder and Molnac. The length of stroke is controlled by a regulator, similar to Swed's, as shown, Fig. 1034 A, which operates a hydraulically operated escapement and adjusts the radius. This device is used by Rigg for steam and air engines to control the degree of expansion.

These latter machines are operated as high as 2000 revolutions without producing trembling.

Besides the various forms of valve gear which have already been described, there are also the numerous "trip" gears, of which some examples have been given in § 292. These gears are made in many forms. The valve is made in four parts, as indicated in Fig. 986, on account of the facility with which the face can be controlled by the regulator.

The varieties of trip valve gears are most numerous, and there can be little doubt that the subject has been overdone, when it is considered that in many instances the entire mechanism of the engine has no other aim than to determine the opening and closing of the valves. In America, where this form originated, the reaction has already set in, and there is a dis- position to return to the single slide valve, especial care being taken, however, to secure relief from pressure and to produce correct motion.

There is a proposal in some parts of Germany a form of valve gear which may be called an "inner" and "outer" gear. This proposal does not possess sufficient merit to warrant application in any case, but may be briefly noticed. The mechanical action of parts is quite different, whether the "inner" or "outer" construction is used, and either arrangement may be adopted, at the discretion of the designer. The following examples will make the arrangement apparent, as well as the illustration already given of Schmelt's water pressure engine, Fig. 1033. Fig. 1035 is a valve for a blowing cylinder, and Fig. 1036 is a valve for a vacuum pump. Another example is Crevet's valve, which is placed entirely outside of the steam cylinder, as also the valve of Leclerc. The ordinary slide valve is partly without and partly within the machine, being outside the cylinder and within the steam chest.

C. ADJUSTABLE POWER ESCAPEMENTS

§ 293.

Adjustable Pump Gears.

The principles of adjustable escapements have already been discussed in § 259, and examples of rigid construction given.

A third system is that devised by Bastle, of London (see Engineer, August 1893, and April 1896), p. 14. Bastle controls the position of the crank pin by means of a gear turned cone which acts against increasing external resistance and opposed by a spiral spring for diminishing resistance; i.e., in order that the eccentric moment of the increasing resistance on the driving force on the crank pin shall be equal, the spring must act in that sense which shall bring the eccentric moment to the minimum. This can be approximately accomplished by a careful arrangement of the concentric cylinders, but only approximate. Under this arrangement, however, there is a tendency for the pin to move outward when the driving force is increased instead of moving somewhat inward as would be the case in the sliding eccentric. An attempt to correct for this error reverses it. A negative velocity of a crank pin does not a long time upon the impelling force, i.e., the machine runs fast or slow as the case may be. This fact also appears in practice. This is another case of friction errors which the effects of "dynamometric experiments" have fallen, even in France, although having been done in some of their dynamometric experiments.

See Rigg, Obscure Influences of Reckration in High Speed Engines, Trans. Soc. C. E. 1884; also Professor H. G. See, p. 85. These engines are used on the compressed air systems of Birmingham and Leipsic.

The general scheme of such an adjustable gear for a steam pump cylinder is shown in Fig. 1035. The valve chest B is made separate from the cylinder and is capable of movement parallel to it, the connections a, a, being made flexible. The slide valve A is operated from above by the lever B. When the lever B is lifted the pressure is admitted under the piston C through the port II, while the space above the piston is in communication with the exhaust I. This causes the piston to move upwards and生动 the lever also towards the valve ports and checking the movement of the piston. If the lever B is again lifted this action will again take place, and so on until the upper limit is reached. A reverse motion of the valve lever produces a corresponding reverse motion of the piston. The same action may be obtained by using the arrangement shown in Fig. 1036. In this case the valve chest is fast to the steam cylinder, while the valve is arranged so as to be moved both by the hand lever B and by the piston rod C. When the valve is moved by B, the piston also moves and closes the valve by the lever B, thus bringing itself to rest again. The piston C follows the motion of the lever B in either direction; starting when the lever is started, and stopping when it is stopped. Any resistance not exceeding the force of the pressure at P, can thus be overcome while the resistance to the operator is only that due to the nature of the valve and connections. The practical value of this device in many directions will be evident, and the examination of the above simple forms will explain the action of the various modifications.

Two constructions, designed by the author in 1866 for regulators, will be found described in the Civil Engineer. One of the lever is connected with the valve by means of a double parallel motion which is moved by the piston motion back into a position parallel with the base line. The operation was satisfactory, but the apparatus was cumbersome. In 1868 Parrot constructed a similar device, using an approximately parallel motion, but the apparatus was not so complicated as to be practically satisfactory. A somewhat simpler construction was afterwards made by Parrot, but this was also too complicated for practical use. Other designs have been made by Parrot.

Fig. 1037 shows the hydraulic stirring gear of Bernier-Foumelle & Widmann, which is similar in principle to Fig. 1036. In this case the controlling gear U, consists of a gear fixed to the driving piston. The water-pressure is admitted to it through the pipe a, and is opposed by the spring a'. The two plungers C and C, set as a double acting piston, the hydraulic pressure being supplied from an accumulator. The valve B is operated by the plunger B against the pressure of the springs F, and again reversed by the pistons G and G, and connection S. The piece at B is a lever but is a cross-head connected with the valve. The admission and release of water pressure through B for a long distance transmission involving the use of another escapement; the whole thus forming a gear of the second order.

Fig. 1037 is a neat regulator for steam engines by Gehrke & Wagner. In this, as in Fig. 1036 a, the valve seat is capable of movement in a direction parallel to the piston C, and is made concentric with the piston rod, the valve B, being a piston valve or rod moved by the governor. The piston C is subjected to full steam pressure from a on both sides through the ports II and III, but as soon as the valve B is moved up or down, the holes B, relieve the pressure on one side or the other, the equilibrium is disturbed and the withdrawing of the steam through the small ports II or III prevents sudden action and the piston moves until the holes are closed. As might be expected, this device is very satisfactory in practice.

Devices of this type are well adapted for steering gears as well as for regulators and a very delicate application of the principle is found in the Whitby steamer, in which the steering gear which determines the depth of the torpedo beneath the water is thus controlled by a barometric device.

\[ \text{3.30} \]

**ADJUSTABLE GEARS FOR ROTATIVE MOTORS.**

The principles of the gears described in the preceding section, are also applicable to rotative motors although the arrangement is not so simple as with direct reciprocating cylinders, since the motion of the valve gear has also to be controlled. At the same time it must be noted that the application of adjustable gears to direct-acting reciprocating motors is the more recent of the two. The earliest rotative gear of this sort, so far as the author has been able to ascertain, is that designed by P. E. Sickles, of Providence, R. I., in 1868 (See also 4, 552).
Sickles’ machine was made with two oscillating cylinders. Both eccentrics were fastened together and were loose on the crank shaft and operated by a hand wheel and spindle. The steam chests oscillate with the cylinders. The crank shaft revolved in the same direction as the hand wheel was turned, but as soon as the motion of the latter was stopped, the valve seat moved under the valve and the ports were closed.

The more recent forms of adjustable valve gears for rotative engines are made after two distinct and important principles. The first form is that in which a double engine, without a fly wheel and with ordinary slide valve gears without angular advance is used, in order to permit rotation in either direction.

The valves 1 and 1' are then made so as to be interchangeable, so that I can be connected either with the admission 1a, or exhaust 1a, and IV with the exhaust 1a, or admission 1a, at will. This change of connection is effected by means of an auxiliary valve sometimes known as a “hunting valve.” This hunting valve can readily be controlled by hand for a steering engine, for which it is well adapted, since the angular motion of the rudder pin is limited, seldom exceeding 90°. The adjusting valve can then be arranged according to either of the principles of Fig. 1035 a or b. The following designs will illustrate the construction.

Fig. 1039 shows the steering gear of Dunning & Boissière.* The adjusting valve a rides upon a moveable valve seat a'. The lower port A is always in communication with the seats of the two engine cylinders, while the upper port j is in communication with the central port under the valve. The lever b' is connected with the spindle b'' by an internal gear. This spindle has a screw thread of steep pitch, and is connected to the adjusting valve b'. The moveable valve seat a' is connected to a spindle b', which has on it a much slower screw thread, and is also geared by a worm wheel to the axis c' of the drum of the tiller chains. Whenever the engines are started by moving the lever b', the chain drum revolves and shifts the moveable seat a' until the ports are again closed. The parts are so proportioned that the angle through which the rudder is moved is equal to the angle through which the lever b' has also been moved. This enables the position of the rudder to be determined at once by noticing the position of the adjusting lever.

The moveable valve seat a' will be recognized as the same in principle as the moveable steam chest of Fig. 1035. The spindle b' can be prolonged to operate an indicator on the bridge for the inspection of the officer in charge of the ship.†

Fig. 1039 shows Britton’s steering gear.‡ The adjustment is effected by a hand wheel and screw b' operating the lever b' at 6, and thus moving the valve b. At 7 this same lever is connected to a nut on a screw thread on the axis c of the chain drum, so that the motion of the latter closes the valve after it has been opened by b'. This corresponds in principle to Fig. 1034 a.

Fig. 1040 shows the steering gear of Douglas & Collison. This is another application of the same principle as the one just described. When the adjusting screw b' moves the nut, lever and rod d out of the mid position, the revolving axis e of the chain drum turns the nut b by means of the spur gearing until the dead position is again reached.

Fig. 1041 is a steering gear designed by Davis & Co. This is a simple application of the principle of Fig. 1039. The hand wheel shaft b' has a screw thread at 6, the nut being in the hub of the worm wheel c', the latter being driven by a worm on the crank shaft. Any adjustment of the valve rod b by turning the hand wheel results in a corresponding readjustment by the motion of the worm wheel and nut derived from the engine.

The second kind of adjustable gear for rotative engines is much less frequently used than the first form. In this arrangement the adjustable valve is not connected with the main valve gear, but is operated independently, so that the crank will make any desired number of turns in either direction, according to the motion which is given to the adjusting valve.

Fig. 1042 shows Hasle’s steering gear.§ This is based on the principle of Fig. 1035. The moveable valve seat b', is operated by the piston e, the eccentric c' being so placed that b' has a reduced motion coincident with that of the piston e. The valve b is operated by the eccentric b'', which

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* See Revue Industrielle, 1886, p. 242.
† Also that of Holt; see Engineer, Sept., 1877, p. 311.
‡ See Revue Indurstrielle, 1884, p. 242.
§ See Revue Industrielle, 1884, p. 242.
§ See Revue Industrielle, 1884, p. 242.
has the same throw as \( c \), and is moved by a hand wheel on \( b \). The action which follows is that the crank shaft follows the movement which is given to the hand wheel both in direction and in revolutions. This action is similar to that of duplex pumps. Any number of revolutions may be made in either direction, and the device is a genuine rotary gear, as was also described at the beginning of this section. It would not be difficult to design a similar gear on the principle of Fig. 1054, but the author has no knowledge of how such a gear has been designed.

Adjustable valve gears for rotary engines have generally been limited to the use of steam engines, and in some of the recent naval marine engines they have also been designed to shift the link motion. There are many other applications which might be made. The speed can also be regulated by the adjusting lever or lever \( b \), if desirable, by suitable connections to the steam valve. The simplicity in construction is one important, steam economy is not considered in designing machinery of this kind.

II. ESCAPEMENTS FOR MEASUREMENT OF VOLUME.

### 331. Running Measuring Devices

In the classification of running mechanisms operated by pressure organs, it was noted that these devices could be used for measurement of volume. As shown in Fig. 321, fluid escape is a better adapted for measurements of volume than for measurement of time; but there is a close resemblance between the two operations, and many fluid meters might properly be classed as timepieces. When the fluid to be measured has a liquid volume and weight as well as a direct proportion. With fluids which are not homogeneous, such as gases and liquids, the density of the gas is necessary to determine the quantity from the measured volume. If the density is also to be determined at the same time as the measurement, the problem becomes much more complicated, and may be hereafter be seen.

Liquid are frequently measured by means of continuous running devices, but the choice of construction is very limited. Among the open wheel devices there is available practically only the instrument in Fig. 1057, and that only when the liquid is under moderate pressure. If, however, the liquid is slowly convexed below the horizontal plane of the axis so that the acceleration of the wheel is uniform, then the continuous rotation of the wheel will be proportioned to the volume of the liquid passing through it.

An instance of this construction is the measuring drum in Siemens' meter for spirits. This is made with three buckets, and has inward delivery. Since the density of the gas is in this case important, Siemens has devised a very ingenious float arrangement by which the counting mechanism is regulated for the volume of flow.

When liquids are to be measured by such a device, the wheel must be inclined to a case in which the weights of the buckets must be proportioned under a correspondingly high pressure, which is usually inconvenient. For measurements of high-pressure liquids, the chamber gear trains already described are preferable, especially when it is practicable to make the weights tight. With these weights, the liquid is then the liquid which the force of the water acts are also adapted for this service, either as bucket wheels or in the form of reaction wheels (see Fig. 325). Siemens has constructed a meter of this kind, in which a reaction wheel is used, and the error of which does not exceed 1 per cent., plus or minus.

Another form, giving better results for open channels, is based on Kulm's derivations. Gaseous fluids of small and slightly varying density can be well measured by modifications of bucket wheel devices; the long periods are expressed from those considered, and the water now being the surrounding medium, and the gas the one to be measured.

One of the most known and most widely used devices for this purpose is the "air" meter of Clerc and Croxley, shown in Fig. 1054. The revolving drum is a wheel with four buckets, which is driven by the passage through it of the gas. The gas is introduced just above the horizontal plane through the axis, and the liquid used is water; or, if there is danger of freezing, glycerine may be substituted. If the level of the water is lowered through evaporation or leakage, the volume of gas passing through the meter at each revolution will be increased, and to avoid this a float is so arranged that the gas will be shut off if the water level falls too much.

![Fig. 1054](image)

For very accurate measurements of gas, Sanderson's meter is used. Fig. 1055 is in the water level remains unaltered so long as the vessel is kept empty. The float is pivoted on the axis \( C \) and is so constructed that the centre of gravity of all the sectors is the same as if the sheet metal body were homogeneous. If the float moves through an angle \( \alpha \) with the sector \( \angle A B \), the thrust of the sector \( A C D \) of an angle of 180°-2\( \alpha \) will pass through the axis, with force \( F = \) for the sector \( A C B \). The weights of the two equal sectors \( A \), \( B \) and \( A \), \( C \) act downward through their centre of gravity, and are also equal to \( F \). In order that there may be equilibrium, if for any chosen value of \( a \), \( F \) shall exact a specific gravity of the 'float' (assumed to be homogeneous) must be equal to one half of that of the liquid in the trough. The relation is, \( \text{for water, } a = 0.03 \), for glycerine.

The preceding meters have heretofore been used only for gases under low pressure, but are equally well adapted for gases at high pressures, such as compressed air for power transmission, simply by increasing the strength of the case. This has been done at the author's suggestion in connection with the compressed air system at Birmingham, as has also been the case with the "dry" meter described in the next section.

Anemometers, used for measuring the flow of air, generally belong to that class of running devices which are driven by the living force of the pressure organ (see Fig. 325). They are usually screw turbines, or some modification of them. It is always necessary to take into consideration the exact distance the drum, in order to obtain the desired measurement, since the apparatus only determines the volume.

### 332. Escapements for Measurement of Fluids

There exist certain defects in running devices when used as fluid meters, such as the journal friction, and in chamber gear trains the surface friction, which renders the results inaccurate for fluids of weak flow. For this reason piston meters have been devised, these also utilizing the power of the fluid, and for these the application of escapements is necessary. Meters constructed on this principle have been used especially for measuring water. Among these may be mentioned Kennedy's water meter, a form which has been extensively used. This is usually made with a vertical cylinder, the valve being a four-way cock operated by a tubular gear similar to that of Belcher's water-pressure engine (Fig. 325). Jopling's water meter is a piston escapement of the second kind.

Running devices may also be used to measure time as well as volume, and in fact the oldest constructions for this purpose, the clepsydra, the sand glass, etc., belong to this class. Escapement clocks were introduced only in the middle ages. There have been numerous recent attempts to make running timepieces. See Ref: "Mechanical Mechanisms," Heldeman, Berlin, 1954, pp. 324, 325. Also Bromwich, Automatic Machines, London, 1954, p. 325. The problem is a difficult one, since it involves the construction of a running device which shall operate both with a uniform and a determinate velocity. Examples are found in the driving mechanism of astronomical instruments, in which the motion is transmitted by friction, controlled by revolving wheel devices. With these may be included the "frie" regulators for the driving mechanism of clocks, and similar applications.

order. There are two parallel horizontal double-acting cylin-
ders, each operating the valve of the other.

Fig. 1044 shows a section of Schmidt’s water meter. This is
made with two single-acting pistons, each also being the valve
of the other, and the whole forming with the crank connection
an escapement of the third order.

Escapement meters are also used for gaseous fluids. A very
extensively used form is the so-called “dry” meter used for
measuring illuminating gas. These have, in many cases, super-
seded the “wet” meter, since the use of the liquid seal is
avoided. In order to prevent friction, these meters are con-
structed with flexible diaphragms instead of pistons, much like
the diaphragm pumps shown in § 317. A good example is
Glover’s dry meter, which is an escapement of the second
order connected to a crank shaft which operates the counting
mechanism. The diaphragms are made of linen, made imper-
vious to gas by a gelatinizing process. These meters do not show
a higher degree of accuracy than the wet forms.

§ 333.

TECHNOLOGICAL APPLICATIONS OF PRESSURE ORGANS.

The applications of pressure organs for technological uses
are not so numerous or important as those in which they act
in connection with the help of various machines. These applica-
tions are not dissimilar from those of tension organs, which
have already been discussed in § 394. A general survey will
be of value for the better understanding of the whole sub-
ject.

The use of a pressure organ from a technological standpoint
consists in so using it that the result is a modification in form
or shape either of another body directly by the action of the
pressure organ or of the pressure organ itself by the other
body. This “forming” action adds a fourth manner of action
for pressure organs to those already classified in § 395, so that
we now have:
1. Filling
2. Supporting
3. Driving
4. Forming

as the four methods of action or application. Of these the
first three belong to all classes of machine elements used
in construction; the fourth falls within the domain of technol-
ogy.

In order to speak comprehensively of the action of pressure
organs, we will arrange them in five groups, according to the
method of action, viz.: by Filling, Discharging, Internal Flow,
Jet Action and Inclosing or Covering.

a. Filling.

1. The case with which pressure organs can be led into de-
sired channels on account of their fluidity is applied in the
operations of casting. Metal which it is desired to make into
given forms are rendered fluid by heat, and thus converted
into pressure organs which can readily be run into moulds.
In similar manner wax, stearine, paraffin, etc., are cast, in
making candles and the like, the formed material retaining
its solid state on cooling. Plaster, cement, magnesia or similar
materials may also be made fluid by mixing with water, and
then cast into forms which afterwards become hard by com-

bination with water and carbonic acid. Other and similar
methods are adopted for other materials.
2. Glass, in a plastic state, is formed by pressure in moulds
by means of pistons, each also being the valve of the other,

3. In cases where complete fluidity is unnecessary, the ma-
terial may be softened by heat, and then shaped in suitable
presses, the slight fluidity of the material being overcome by
the mechanical pressure of the machine.
4. Lead is sufficiently soft to be readily formed by the action
of a plunger press, and is thus formed into bullets in arsenals,
and also made into pipe.
5. The forming of a pressure organ by cooling is shown in
the action of an ice machine, by means of which water may be
given the form of sheets, rods, blocks, etc.
6. Copper, tin, zinc, etc., and also gold and silver are formed
under the drop press in dies. Steel and wrought iron are
heated for this purpose; but sheet steel is stamped cold.
7. Wire, already considered as a tension organ, may also be
formed as a pressure organ, having great similarity to a flowing
stream with its curves. Examples are found in the ingenious
machines for making hooks and eyes, and also wire chains,
made by William Frye, of Stockberg. Another illustration is
the machine of Hofr & Vogt for rolling spiral springs.
8. Hydraulic or lever presses are used to press clay in a
plastic condition into various dies to make bricks. Bricks are
also formed by means of compressed turf, ensil, etc. Chocolate and
cocoa are also compressed in moulds.
9. The so-called art work in pressed wood is composed mixture
of sawdust formed into a solid mass by great pressure in
suitable moulds.
10. Papier mâché is formed into shape from paper pulp re-
duced to a doughy consistency, and then subjected to heavy
pressure.
11. In the use of moulding machines the pattern is first
pressed into the moist sand, this being a granular pressure
organ, this being followed by the casting of the plastic mass
in the mould thus formed. This gives two applications of form-
ing—the first in moulding, the second in casting.
12. Compressors, such as those used for packing the powder of
powdered or fibrous nature, are also examples in point. These
are used for baling hay, cotton, wool and similar materials
under very great pressure.


When a pressure organ is contained in a guiding enclosure,
and by properly directed pressure is forced out through a suit-
able mouthpiece, the jet which is emitted is formed with a
cross section corresponding to that of the mouthpiece used.
Jets may be formed in this way not only from materials which
flow readily, but also from those which are of a tough or
doughy consistency, so that even moderately dense substances
may be thus formed:
1. Clay presses made by Schleyvseren and others are
used to form tiles, drain pipes, etc., by this jet method of form-
ing, the issuing stream being cut off at regular intervals by a
water jet. The clay in such machines is effectively forced
through the discharge opening by an arrangement of screw-
propelling blades.
2. In the mold press the dough is forced by a piston up through
a die plate in which certain shaped holes (such as stars, circles and the like)
are made, and the issuing streams are sliced off by a wire cutter and dried.
3. The so-called artificial silk of De Chardon in is jet forma-
tion of nitro-cellulose. This is made in a semi-fluid mass
with iron or tin chloride and alcohol, and forced through a
tube of glass or platinum of about a sixteenth of an inch bore
down to a fine aperture, whence it issues in a hair-like thread.
It is then toughened by passing through acellulose water, after
which it is wound on a reel.
4. In the manufacture of paper the liquid pulp is discharged
in a broad, flat sheet by its own pressure and the superfusious
water first removed by absorption, after which the paper is
dried and made into sheets.
5. Lead pipe is made by a process of jet formation in a pipe
press. The mass, which is only moderately heated, is forced
by piston pressure through the die in a continuous stream.
6. The insulating covering of cotton is formed upon wires
used for electrical conductors by a jet action.
7. The common punching press, used for punching rivet holes
in plates, really works with a jet action, as has been shown
by the several researches. It is really nothing but a kind of jet
action on one part of the mouthpiece being forced against the other.

The power is taken by Britmann Kircheis at Aue, and by the Oberhager Machine
Works, operate by means of cranks and cams, while those of
There are a number of pressure organs which are not homogeneous, being composed of granular and fluid materials, or of fluid materials of different density. It is a frequent problem in technology to separate such substances so as to divide the liquid from the solid, the large from the small, the light from the heavy, etc. In general, this can only be done by some variation of the method of internal flow in the mass of the pressure organ. The methods include the use of artificially produced high pressures, the natural gravity of the material, or in some instances by vibratory or other motion, etc., by the force of the impact of the material, or rather the unequal action of the various portions. The following examples will illustrate the various methods:

1. Filtration for the extraction of liquids (such as wine presses), presses for seed oil, olive oil, also for oil cake, steam, beet root, yeast, etc., all act to separate the liquid from the solid. The heat of the action of internal flow.

2. Filter presses act to separate the fluid from the more sluggish portion of the mass, the liquid passing through the minute openings of the filter under the action of the high pressure, while the slurry mass remains behind. Filter presses are used for separation of: starch, yeast, starch, sugar, potatoes, clay, etc.

3. The purification of water under natural pressure is effected by conducting it through settling and filtering tanks, or also by special devices as that of G. Niemax, of Cologne, German Patent No. 209,712, by which the water is rendered harder or softer, as may be required.

4. In mining and machine shop operations, the separation of mingled pressure organs by difference of internal flow is effected in various ways, showing very effective applications of the laws of hydraulics.

5. Various applications of slaves are used to separate granular materials of different sizes, as are also different devices which act by shaking or jiggling the material, the separation being effected by differences of living force.

6. Finishing machines are used for finishing yarn, wet clothes, etc., although the action in this case might be more properly termed external, rather than internal flow.

7. The separation of the central machine is for the separation of materials by their difference in specific gravity, as in the case of the machines for separating cream from milk.

8. In the Bessemer process the molten fluid mass of iron is penetrated by a gaseous pressure organ, i.e., air, under high pressure, producing a violent internal flow and agitation, and burning out the carbon of the iron.


A considerable amount of living force may be stored up in a fluid jet. The may be utilized in a limited number of ways, a few of which are here given:

1. The system of hydraulic gold mining used in California, to a great extent, is an important application of the jet.

2. Tilghman's sand blast acts by means of a jet of air which acts on a stream of sand particles in motion. This sand blast is used in metalworking, surface metals, and metal castings. It has many other useful applications.

3. Machines for cleaning grain are made to throw the grain against frictional intercepting surfaces, thus removing dust and other impurities.

4. The impinging of a rapidly issuing jet of air against the bell of a whistle causes a series of rapid vibrations, producing sound in music.

5. In the reed pipes of organs and similar musical instruments, the notes are produced by the action of a jet of air causing the reeds to vibrate, and sound is produced. In the organ, the jet of air is produced by a bellows, and the sound is produced by a series of pipes, each producing a different pitch or note.

6. In the simple organ pipe a jet of air is set into muscular vibration by a jet of air. The organ is probably the oldest type of pressure organ escapement, the release being effected by the hand of the performer. The modern church organ consists of a series of the fifth order, namely: a water motor (hydraulic escapement), bellows (escapement) and regulator (check escapement), stops (escapements), and key board with pneumatic action (escapement). In an organ manual of 10 octaves there are 120 escapements, each with a different pipe connection arranged together. In this connection also may be mentioned barrel organs, in which the closing and releasing of the escapements is effected mechanically.

e. Inclining at Covering.

As a counterpart to the inclining of a pressure organ in a pipe or vessel, we have the inclining of covering of a solid body by a pressure organ. This occurs when a body is submerged in a liquid, when its surface is at least covered with a liquid. A partial covering may also take place, as, for instance, one side of a flat piece, or by distribution after any particular plan. These conditions appear in a number of technical operations, as will be shown.

1. In the operations of dyeing, the articles are immersed in a liquid containing the coloring matter, many machines having been devised to assist in this operation.

2. In the various operations of finishing fabrics, heavy flowing liquids are used, distributed by various brush devices, this forming at least a combination of the second order, since the liquid must first be distributed to the brushes, and then to the fabric.

3. In coating paper with gum, the gum is distributed in the form of a liquid solution.

4. In the manufacture of colored papers and leathers, the color is distributed in liquid form over the desired surfaces.

5. The various operations of printing from surfaces of stone, copper, zinc, steel, etc., involve devices of the third and fourth order for the distribution of the printing material before it is finally transferred to the paper.

6. In the operation of printing fabrics and paper hangings, the printing surfaces are charged with color by a distributing system usually of the third order, and then impressed upon the fabric. The printed fabric is dried, usually, by a current of warm air, which is merely a gaseous pressure organ. In some instances the printed surfaces are dusted with felt dust while yet wet, and then finally dried.

7. In printing woven fabrics, the processes of (5) and (6) are used with a mordant liquid, and the material then immersed in a liquid of color, and finally the color washed out of the unsprinkled portion with water.

8. The operations of electro plating surfaces with gold, silver, copper, brass, nickel, etc., involve the use of a physical agency, i.e., the galvanic battery. The disposition of the covering may be modified by covering portions with a nonconducting material. Another operation in electrotechnics consists in the decomposition and deposition of minerals by means of electric currents generated mechanically.

9. In the use of illuminating gas, the method of making a gas poor in carbon, and then enriching it either with a rich hydrocarbon gas is a form of combination in the line of inclining. The incandescent gas lamps operate by the surrounding of a network of magnet or iron to the flame of a weak illuminating gas.

10. The jet condensor acts by surrounding the discharge of exhaust steam with cold water.

As the surface condenser the tubes are surrounded with water and filled with the steam to be condensed, an arrangement of the second order.

11. The apparatus for cooling beer consists of an arrangement of parallel plates of sheet metal between which the cooling water flows, thus forming an apparatus of the second order.

The above outline of technological applications of pressure organs is only an indication of the systematic treatment of which the subject is capable, but cannot here be carried farther, as it does not properly belong to this subject.