PUMPS & PUMPING MACHINERY 1500 BC-1960

Historical Development-2

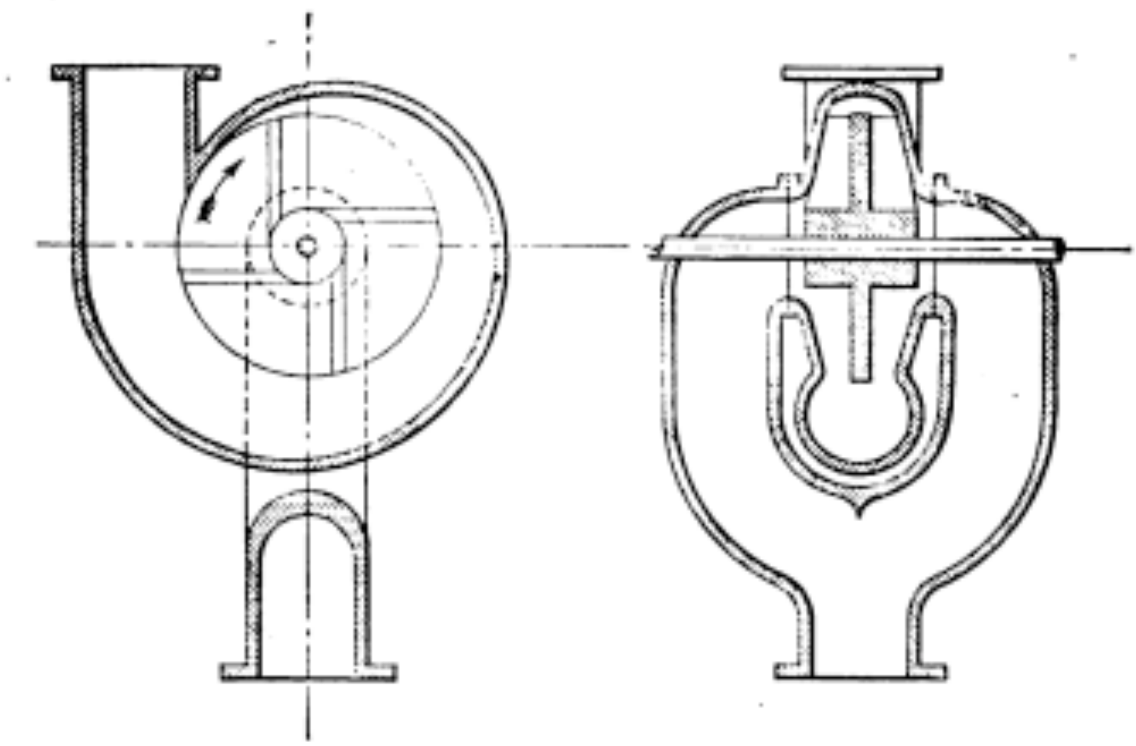

FIG. 39.—The Boston Pump.

From PUMPING MACHINERY, 1919

PUMPING MACHINERY

A TREATISE ON THE

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

BY

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Continued from Part-1

ber, displacing the water. This was followed shortly afterward by a bucket pump, in which the water passed through valves in the piston on the down stroke, as was the case in the later engines of Simpson used at Thames-Ditton.

In 1698 Thomas Savery patented the design of an engine

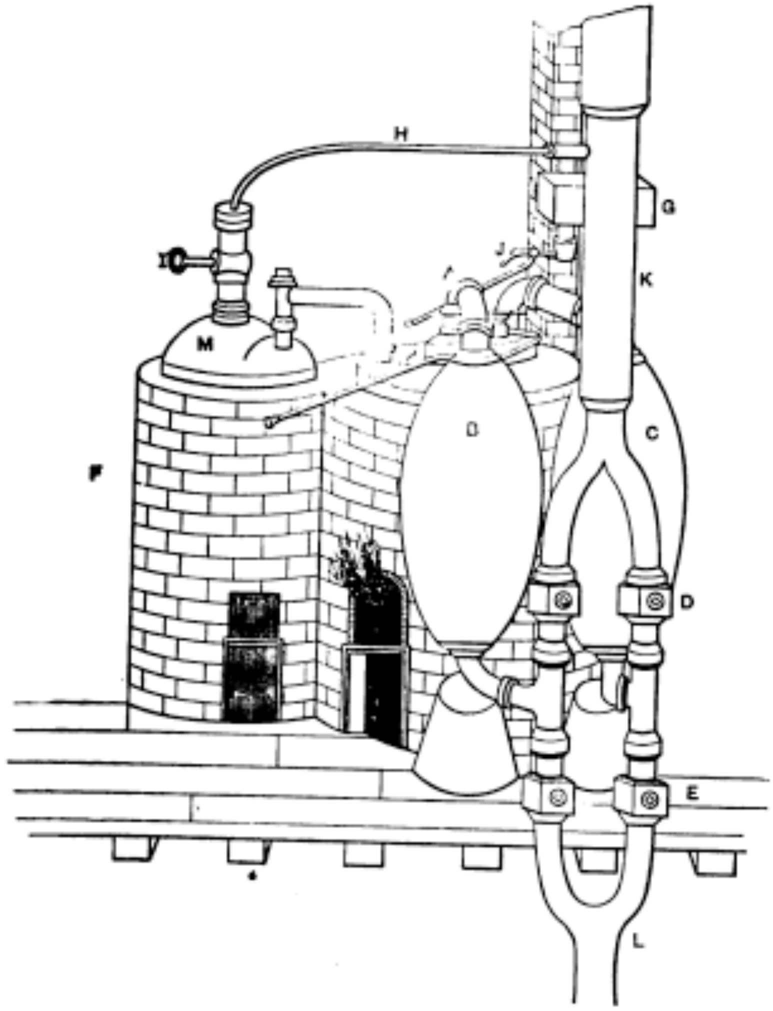

FIG. 29.—Savery's Pump of 1702.

for freeing the mines of Cornwall from water. It was the first steam apparatus applied to this kind of work. In 1699 he submitted a model to the Royal Society of London and successful experiments were made with it. A model fire engine was exbihited before King William III at Hampton Court in 1698, and the success of this led to the granting of the patent which read: "A grant to Thomas Savery, Gent'l., of the sole exercise of a new invention by him invented for raising of water and occasioning motion to all sorts of mill works by the impellant force of fire, which will be of great use for draining mines, serving towns with water and for the working of all sorts of mills, when they have not the benefit of water nor constant winds; to hold for 14 years with usual clauses."

The apparatus is almost identical with that of Worcester, and it is not known whether or not Savery knew of the earlier work. The form of his pump of 1702, which is an improvement on that of 1698, is shown in Fig. 29. It consists of a main boiler *A* and the pumping chambers *B* and *C*. The water from the tank *G* discharges through the valve *J* on one of the pumping vessels, which condenses the steam in that vessel and the vacuum produced thereby draws water through the suction pipe *L* and foot valve *E*. When steam is then admitted from *A* through the steam valve, the water is forced out through the valve *D* into the discharge pipe. When the water is low in the boiler *A*, the auxiliary boiler is filled from the main *K* through the pipe *H* and valve *I*. This water is driven into the main boiler by raising steam in *M*. The pipe connecting the two boilers is carried to the bottom of the auxiliary boiler *M* and the steam pressure on the water drives it over into the main boiler *A*, provided the pressure in *M* is higher than that in *A*.

Savery seems to have been a wide-awake promoter and advertiser, for he began a systematic scheme for making his invention known. He explained it to the Royal Society and presented them with a drawing and specifications which appeared in their "Transactions," and he published a prospectus, called "The Miner's Friend; or a Description of an Engine to raise water by fire described and the manner of fixing it in mines, with an account of several uses it is applicable to, and an answer to the objections against it. London, 1702." This invention of Savery was intended to do away with the great expense in the use of animal power to operate the pumps of the mines, which not only were expensive, but reached their limit of capacity, so that workings could not be carried much farther. In one mine 500 horses were employed in handling the water.

Savery's improvements were the addition of surface condensation, the secondary boiler, and the use of water cocks. It must be remembered that this machine could not be used in deep mines, as sufficient steam pressure could not be carried. The joints of the sheets forming the boilers, pump chambers, and other parts were fastened by solder, and at high temperatures these joints would not hold. Desaguliers reports such accidents.

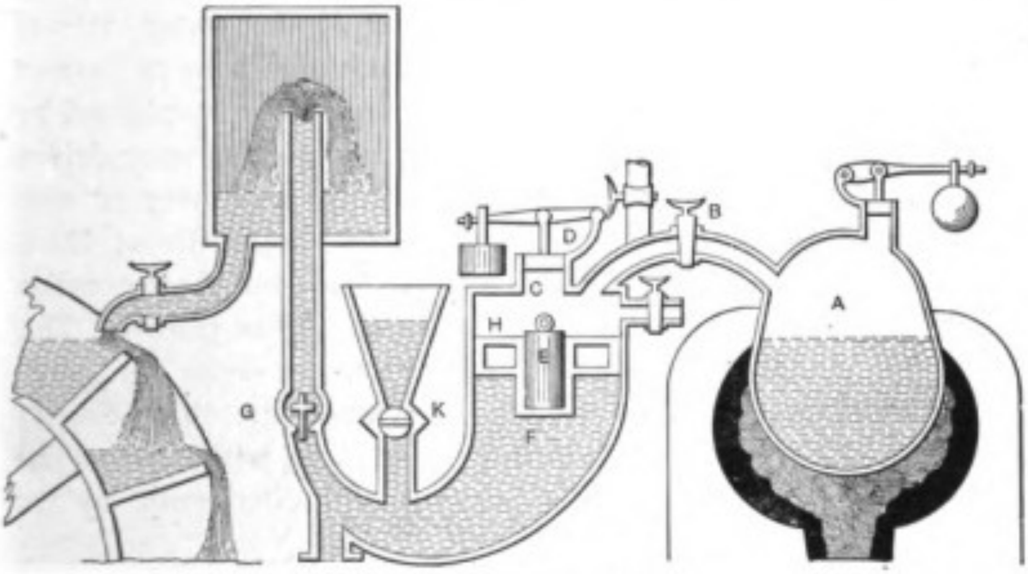

Fig. 30.—Piston Pump of Papin.

The Savery engine was built by others after his time—by such engineers as Desaguliers and Gravesande.

While Savery was using the direct action of steam for raising water, Papin, in Germany, was proposing the use of the piston to separate the steam and the water, thus leading to the further application of two pistons of different sizes, so that the steam pressure did not have to be equal to the water pressure. In 1707 Papin proposed a water pump shown in Fig. 30. This was brought out in Cassel, Germany. In this machine steam was generated in the boiler *A* and was conducted through the cock *B* to the cylinder *C*. It acted on the piston *H* and forced water through the discharge valve *G* into an air chamber, from which it was delivered. Water was admitted through the valve *K* after the piston had been driven to the end of its stroke. Papin realized the cooling effect of the cylinder walls and suggested the introduction of a piece of heated iron *E* to warm up the piston before the introduction of the steam. The weighted cover *D*, similar to Papin's safety valve, served for the introduction of the iron.

Although Papin had in his pump the possibility of making the steam pressure different from that of the water, it was not to him that the honor for the first use of pistons of various sizes is due. Pistons for the forcing of water were explained by Ramelli and Leonardo da Vinci, but these pistons were driven through some mechanical medium from water power or man power, and it was Thomas Newcomen, a blacksmith of Dartmouth, England, who first employed steam for the operation of a water piston of different size from the steam piston. This at once enabled mines to be sunk to a greater depth, as pumping could now be done with greater efficiency. The Savery engine was used to lift water 350 feet, but with the engine invented by Newcomen the height was limited only by the strength of the materials employed.

The engine of 1705 is shown in Fig. 31. Steam is generated in boiler *A* at about atmospheric pressure, and as the piston of the cylinder *B* is drawn up by the unbalanced weight of the pump rod *C* steam is drawn into the cylinder from the boiler through a valve at the top. When the piston reaches the top of its stroke the valve is closed and water is sprayed into the steam space from reservoir *D*, thus condensing the steam in the cylinder and producing a vacuum. The air pressure on top of the piston is then sufficient to force the piston down, raising the pump rod *C*, and with it the pump piston at its lower end. The water of condensation then falls through a pipe *G* into a hot well, the height of the water in the drain being fixed by the vacuum in the cylinder. The walking-beam *E* served to connect the two piston rods by chains and sectors, and the rod *C* could be of any length, as the greater part of its weight and that of the column of water in the discharge pipe could be balanced by counterweights, on a rod such as *F* on either side of the center. Sufficient weight was left unbalanced to cause the piston of cylinder *B* to rise when low-pressure steam was admitted.

Since the engine was really driven by atmospheric pressure and was operated by steam at practically no pressure above the atmosphere, it was known as "the atmospheric engine."

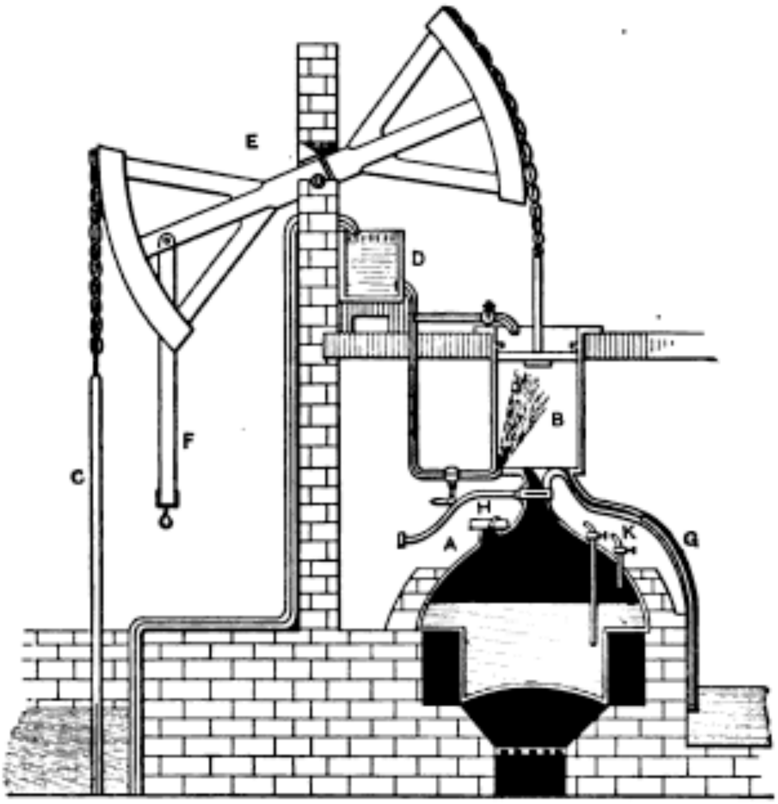

FIG. 31.—The Atmospheric Engine of Newcomen.

Indeed, so low was the steam pressure that the weight of the safety valve *H* was sufficient to keep it closed.

The try cocks *K* served to indicate the quantity of water in the boiler, and the cock above the cylinder *B* was used to introduce water on the top of the piston to keep the edge of it airtight. The use of a spray inside the cylinder to condense the steam resulted from the discovery that leakage of water around the piston condensed the steam more quickly and better than the original method of cooling the cylinder wall by spraying it with water.

It is remarkable that a man of such little training as Newcomen appears to have had should have been able to combine the necessary elements to make such a great machine. He did not occupy a very high position in the town; however, he was a good workman. When he and his colleague, John Calley, wrote to Dr. Hooke, the famous physicist, in regard to their use of a steam cylinder and piston to drive a separate pump, he advised against their plan. They were not to be put down, however, and in 1705 they secured a patent.

The engine was then applied to drain mines and pump water, but Newcomen and Calley did not have sufficient mathematical knowledge to properly design their machines and they had many failures, while their successes were accidents.

In 1713 Humphrey Potter, a boy who operated valves by hand, arranged an automatic method of shutting off the steam and water by the use of beams, strings, and catches, and made the machine independent of an attendant. Henry Beighton improved this in 1718 by substituting a vertical beam with pins which struck the valve handle as it was raised and lowered by the walking beam. The vertical beam was known as a "plug rod," "plug tree," or "plug frame."

These pumps were built for various purposes and were of different dimensions; one in 1714 for Ansthorpe in Yorkshire was 23 inches in diameter and of a 6-foot stroke. It made 15 strokes per minute. One, described by Farey, was 8 inches in diameter on the water side and 24 inches on the steam side. The stroke was 60 inches and there were 15 strokes per minute. This pump lifted water 162 feet and the water column on the piston weighed over 3500 pounds, which with 660 pounds of unbalanced weight of the pump rod necessitated almost 5000 pounds on the piston. Such a pressure could be obtained with a vacuum of 21 inches of mercury. The pump developed 8 horse power. Another engine at Griff in Warwickshire cost £150 per year to operate it and displaced 500 horses at an expense of £900 per year. The first Newcomen engine was introduced on the continent in 1723 at Königsberg, Hungary. In 1735 cast iron was used in place of wrought iron for the parts of the engine.

The engine was improved by many engineers. About 1769 John Smeaton, one of the most distinguished engineers of his day, built several engines with greater strokes than those usually employed. By using the proper diameters for his pistons he was enabled to get much higher speed. Before building pumps he experimentally determined the proper proportions of the engine and so improved its construction.

Before the last quarter of the century these engines were introduced to such an extent that the coal mines of Coventry and Newcastle, the tin and copper mines of Cornwall, blowing engines of the English and Scotch furnaces, the docks of Cronstadt in Russia, the lowlands of Holland and the salt mines of Hungary bore testimony to the success of this invention. The mines were carried to greater depths, the cost of pumping water and air was reduced, and the supply of water to towns was more certain.

One of Smeaton's Newcomen engines is shown in Fig. 32. The figure shows the cylinder *A* connected with the boiler by means of the steam pipe *B*. The boiler is placed in another building. The valve *C* admits steam to the cylinder through the admission pipe, which is carried above the bottom of the cylinder so as to keep the injection water from entering it. When the steam is admitted, the piston is driven or pulled upward and when the top of its stroke is reached the upward movement of the plug tree or working plug *D* acts on the handles *E* through pins, turning the axle *F*, and the Y or "tumbling bob" *G* is thus moved, shifting the rod *H* and handle *I* and thus shutting off the steam. At the same time the handle *K* opens the valve *M*, allowing water from the cistern *N* to enter the cylinder through the spray head *O*. This immediately condenses the steam in the cylinder and the vacuum produced permits the atmospheric pressure to drive down the piston. The pins *P* and the springs *Q* stop the downward motion at the proper point. At this lowest point the

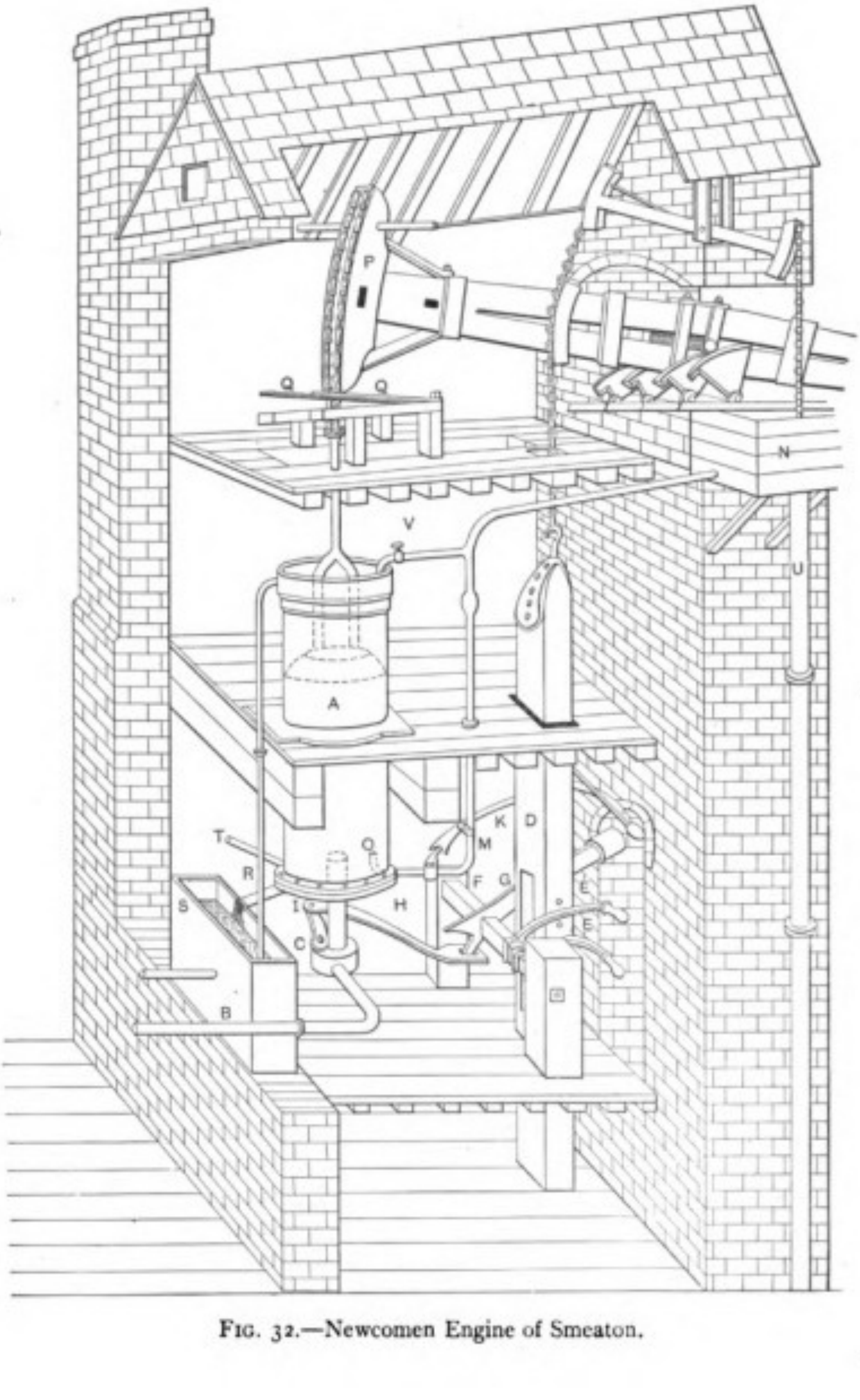

FIG. 32.—Newcomen Engine of Smeaton.

drain pipe *R* is opened, allowing the condensed steam and condensing water to discharge into the hot well *S*. The sniffing valve *T* is then opened, allowing any air to escape. The feed water of the boiler is taken from the hot well. The cistern *N* is supplied by a jack-head pump *U*, driven from a small beam. Both beams get their motion through chains and sectors, so that there is always a straight pull on the piston or pump rods. The cock *V* admits water around the piston so that the oakum packing of the piston is kept in proper condition. The excess of this water is carried off through the drain pipe to the hot well. The main beam is carried on sectors so as to reduce the friction.

To improve the efficiency, Smeaton covered the steam side of the piston with planks and when the injection water contained salts which would form a scale, the water in the hot well was not used for boiler feed, but the clear feed water was passed through a coil of pipe immersed in the hot well.

The next important step in the improvement of the steam engine and pump was that of James Watt. The invention of this man was one of the greatest events in the history of civilization, as it not only improved the existing machines, but in his specifications are contained the fundamental ideas of all modern improvements to the steam engine. This event clearly demonstrates what may be done by a careful and detailed study of existing conditions.

The early history of Watt, who was born in 1736, is one with which every engineer should be familiar. After many trials and successes in the south of England he came back to Glasgow and was employed to repair some of the apparatus belonging to the university. In 1763 he repaired its model of the Newcomen engine, and this led to his making a study of the history of the steam engine. He read the treatise of Desaguliers and the works of others. In this study he learned of the accomplishment of Savery, Newcomen, and those who had preceded them. Watt now began a series of experiments on the action of the engine, determining quantitative relations between the amounts of steam, cooling water, and the heat of steam and water. He discovered the great loss by radiation and absorption and was led to use non-conducting materials for his vessels as well as for the coverings of them. Not having experimental data for this work, he made a series of original experiments on the temperature and pressure of steam at whatever points he could observe these and constructed a curve to give values at other points. He determined the amount of steam used by the Newcomen engine and the amount which should have been used had none of the steam condensed; in addition he compared the amount of injection water used in the engine with the amount which should have been used. These experiments showed him that three-fourths of the steam taken into the cylinder was wasted and that the engine used four times as much injection water as it should have used. His calculation showed him at once that the method of producing the vacuum was a poor one, as the cylinder had to be heated by steam at each stroke so that it could be filled, and then this heat was removed again on the condensation of the steam. He then tried to keep the cylinder hot, which necessitated that the steam be taken from it for condensation. He invented the independent condenser, which made his improvement complete. After constructing a number of experimental machines and after many vicissitudes he took out his patent in 1769 in connection with Dr. Roebuck.

The patent of 1769 gave the following description:

"My method of lessening the consumption of steam, and consequently fuel, in fire engines, consists in the following principles:

"1st. That the vessel in which the powers of steam are to be employed to work the engine, which is called 'the cylinder' in common fire engines, and which I call 'the steam vessel'—must, during the whole time that the engine is at work, be kept as hot as the steam which enters it; first, by inclosing it in a case of wood, or any other materials that transmit heat slowly; secondly, by surrounding it with steam or other heated bodies; and thirdly, by suffering neither water nor other substances colder than the steam to enter or touch it during that time.

"2dly. In engines that are to be worked, wholly or partially by condensation of steam, the steam is to be condensed in vessels distinct from the steam vessel or cylinder, though occasionally communicating with them. These vessels I call condensers; and while the engines are working, those condensers ought at least to be kept as cold as the air in the neighborhood of the engines, by application of water or other cold bodies.

"3dly. Whatever air or other elastic vapor is not condensed by the cold of the condenser, and may impede the working of the engine, is to be drawn out of the steam vessels or condensers by means of pumps, wrought by engines themselves, or otherwise.

"4thly. I intend in many cases to employ the expansive force of steam to press on the pistons or whatever may be used instead of them, in the same manner as the pressure of the atmosphere is now employed in common fire engines. In cases where cold water cannot be had in plenty, the engines may be wrought by this force of steam only, by discharging the steam into the open air after it has done its office.

"5thly. Where motions round an axis are required, I make the steam vessels in form of hollow rings or circular channels, with proper inlets and outlets for the steam, mounted on horizontal axles like the wheels of a water mill. Within them are placed a number of valves that suffer any body to go round the channel in one direction only. In these steam vessels are placed weights, so fitted to them as to fill up a part or portion of their channels, yet rendered capable of moving freely in them by the means hereinafter mentioned or specified. When the steam is admitted in these engines between these weights and valves, it acts equally on both, so as to raise the weight on one side of the wheel, and by the reaction of the valves successively, to give a circular motion to the wheel, the valves opening in the direction in which the weights are pressed, but not in the contrary. As the vessel moves round, it is supplied with steam from the boiler, and that which has performed its office may either be discharged by means of condensers, or into the open air.

"6thly. I intend in some cases to apply a degree of cold not capable of reducing the steam to water, but of contracting it considerably, so that the engines shall be worked by the alternate expansion and contraction of the steam.

"Lastly, instead of using water to render the piston or other parts of the engine air- or steam-tight, I employ oils, wax, resinous bodies, fat of animals, quicksilver, and other metals in their fluid state."

It is to be noted that these claims covered the following points:

1st. Lagging and jackets.

2d. Condensers.

3d. Air pumps.

4th. Expansive use of steam and the non-condensing engine.

5th. A rotary engine.

6th. Packings.

Mathew Boulton became the partner of James Watt, and it is to him that much of the credit of the actual engine is due. He was the owner of one of the most famous manufactories of the day at Soho, near Birmingham, England. Here he manufactured ornamental metal ware, gold- and silver-plated ware and works of art, such as vases, statues, and bronzes. His factories were noted for the good work done, and for the broad policy of management.

Although the arrangement of the partnership was agreed on in 1769, it was not until the spring of 1774 that Watt could go to Birmingham. By November of that year their first engine was built. The form of this is shown in Fig. 33.

Steam enters from the boiler by the pipe *A* and the valve *B* passing to the steam jacket *C*. The condenser *D* is then connected to the cylinder by the valve *E*, and the vacuum thus produced in the space *F* causes the piston *G* to move downward, and steam flows in above the piston. When the piston reaches the lower end of the stroke, the valves *B* and *E* are closed while the valve *H* opens. This connects the spaces on each side of the piston, and the weights of the pump rods *I* and *J* on the outer end of the beam *K* overbalance the weight of the piston *G* and its rod, and so the piston is pulled rapidly

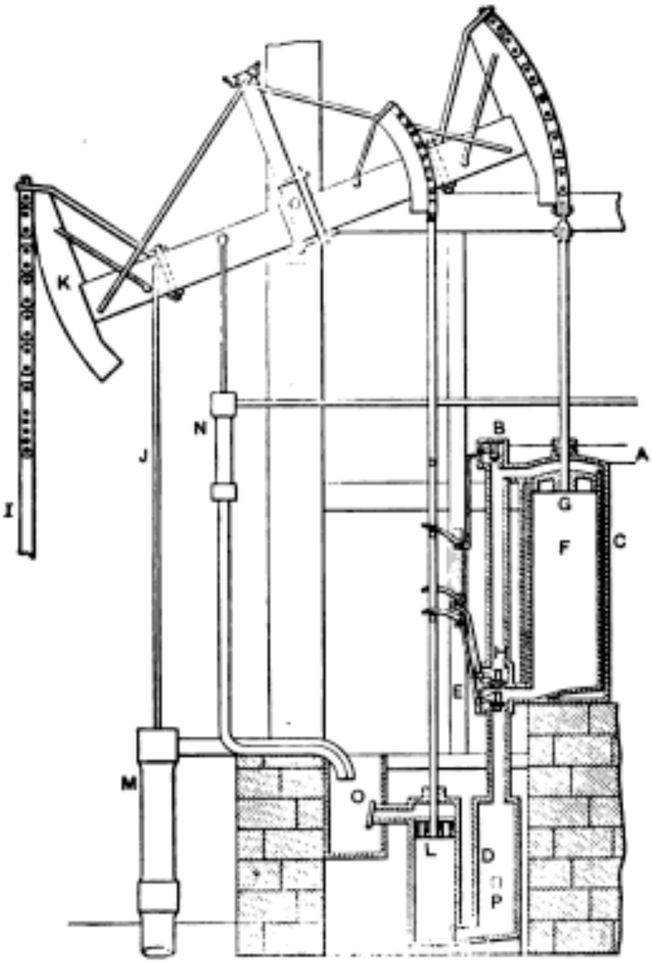

FIG. 33.—Watt's Engine.

upward to the top of the cylinder, the steam above the piston passing over to the lower side.

After closing *H* and opening *B* and *E* the operation is repeated, and the air pump *L* removes the condensed steam and the air from the surface condenser. The pump *M* supplies the cooling water, and the pump *N* takes water from the hot well *O* and feeds the boiler. The pump rod of the air pump contains the pins which operate the handles of the valves.

An outlet *P* is used when the air is driven out from the cylinder and the air pump before the engine is started.

There was much trouble in getting men and machines to make these engines, and it may be said that the demand for better work developed the machinist's trade of that day. Much of the development was made by the firm of Boulton & Watt.

In the building, erection, and operation of their engines, Boulton & Watt were led to take out patents for the following articles:

A letter copy press.

A cloth dryer by the use of steam in copper rolls.

Five devices for getting rotary motion from reciprocating motion without the use of a crank.

The expansive use of steam.

The double-acting engine.

The double-coupled engine.

A rotary engine.

A trunk engine.

A steam hammer.

Parallel motion.

The engine governor.

Mercury steam gauge.

Water gauge.

Steam-engine indicator.

Watt seemed to be one who could always find some means of meeting every need: when it took too much time in copying his reports to Boulton, he invented the copy press; when it was necessary to study the action of steam in the cylinder, he brought out his indicator. These numerous inventions do not indicate that the firm was always successful. Many times they were on the verge of bankruptcy, and had their patent not been extended for twenty-four years, when it first expired, their labor would have been in vain, because of financial straits. The extension gave them the needed relief, and at the expiration of the patent the firm was in good condition. The story of the trials and successes of this firm in the development of the engine is given in the biographies of these two men, and the student is recommended to study these most interesting books.

To gauge the power of his pumps, Watt introduced the term "horse power," in so common use to-day. This, with the term, "duty," gave those using pumps a method of comparing

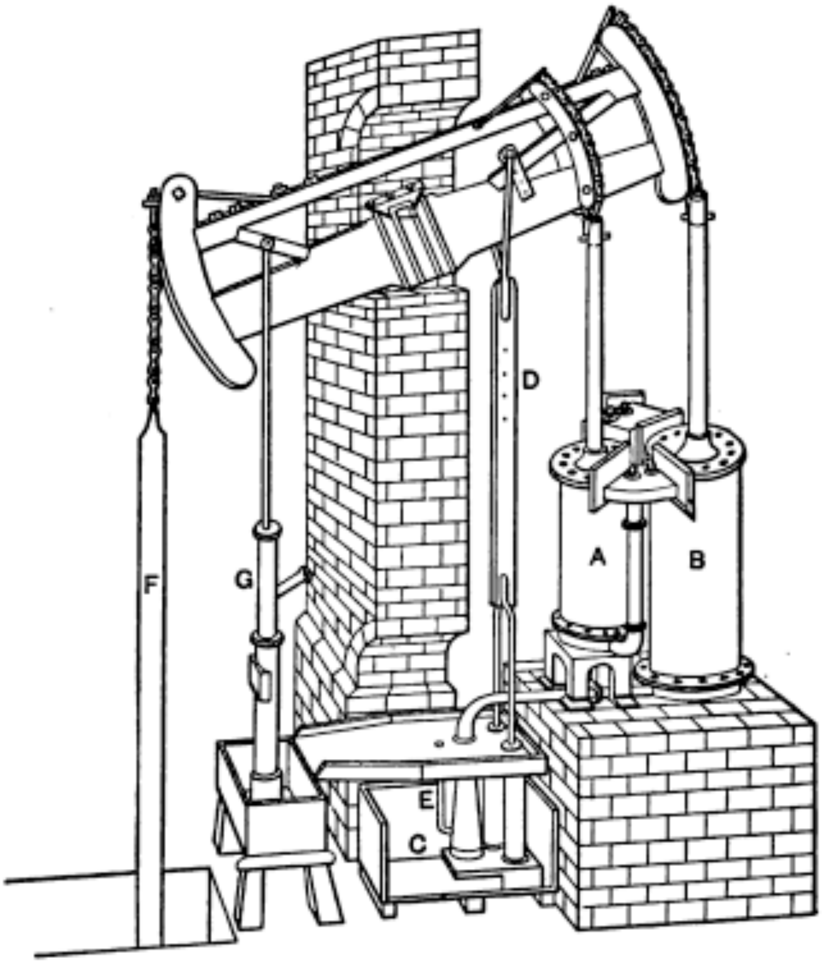

FIG. 34.—Hornblower's Pump.

the operations of various machines. An economical operation was aimed at in all of this work, and in order to interest the engine attendants, monthly prizes were given for the best results in duty during the month. An operative machine had been constructed, and it was now their object to improve the efficiency of it.

Boulton died in 1809 and Watt in 1819, but before that time these men had given the business over to their sons. They enjoyed the protection of their fathers' patents until 1801, during which time others were at work on the improvement of the engine end of the pump.

Jonathan Hornblower patented a compound engine in 1781, although Watt claimed this invention. The engine is shown in Fig. 34. Steam is admitted into the cylinder *A* from the boiler, and from this cylinder it discharges into the cylinder *B* and thence into the condenser *C*, shown in section. The plug-tree rod *D* serves as the rod for the air pumps as well as to operate the valve handles, which are not shown. The operation of the engine is practically the same as that of the Watt engine. To start, all air is driven out by allowing boiler steam to flow through the cylinders and condenser, and thence through the sniffing valve at *E*. The condenser will now condense steam below the piston in *B*, and as the piston descends the valve between *A* and *B* allows steam below the piston of *A* to expand and press down on top of the piston of *B*. The steam from the boiler enters on top of that of *A*. When the bottom of the stroke is reached the boiler and condenser are cut off and the top of each cylinder is connected to the lower portion. The weight of the main pump rod *F* and the boiler feed pump *G* pulls the pistons upward and the operation is repeated. This was declared an infringement on the Watt patent. It did not give a much higher duty than the best single-cylinder Watt engines of the day, although the same idea as applied by Arthur Wolf in 1804 with higher pressure steam gave duties of from 40,000,000 to 57,000,000 foot-pounds per bushel of coal, while the Watt engine gave a little over 30,000,000.

The Bull Cornish pumping engine of 1798 was brought out by William Bull and Richard Trevithick. This type of engine is the one which remained in use longer than any other, as it was much simpler than that of Watt and had all of the elements of economy. It is shown in Fig. 35.

The steam cylinder *A* is carried on the timbers *BB*, extending from the walls of the pump house in such a manner as to bring the piston rod directly over the pump well. The piston rod

C is connected to the pump rod *D*, and this, in turn, to the counter balancing beam *E* by the rod *K'*. A pump rod *G* with its pump *F* is also shown. The counterweight *H* is to balance as much of the weight as is thought necessary. The rod *I*

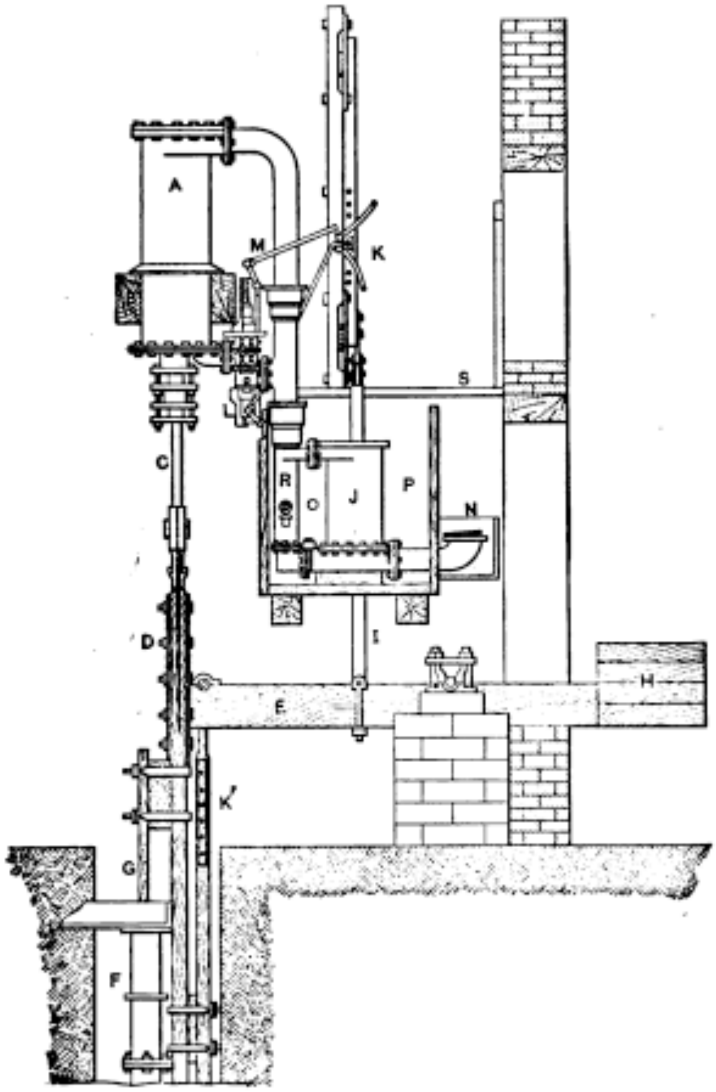

FIG. 35.—Cornish Pumping Engine.

actuates the piston of the air pump and is used as a plug rod. The valves of the air pump are in the base and the piston is solid. The tank *P* surrounded the air pump and the pipe *R*; it was filled with water. The pipe *R* acted as a condenser, but water was admitted through O, making it really a jet condenser. The pins on the plug rod K operated the rods leading to the valves at L and M. In starting, the valves were operated from the floor S and the air was driven out from the cylinder, condenser, and air pump through the sniffing valve N, which was water-sealed.

This engine was adjudged an infringement on the Watt patents, which prevented its introduction for some time, but it was afterward used exclusively in America and Europe with many improvements. It had many advantages over the other engine in its simplicity, but it was objectionable in that it must be placed directly over the opening of the mines. It was of great value further in that by properly selecting the

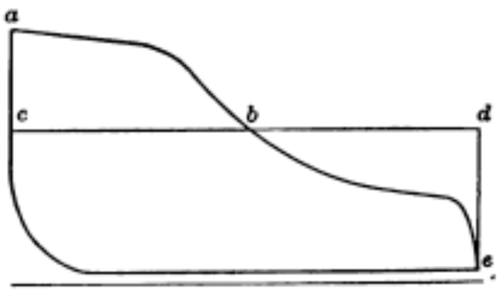

FIG. 36.—Action of Cornish Engine.

mass of the parts the inertia of these could be used to permit the expansion of the steam, although the water pressure or resistance was constant. This may be shown by the diagrams of Fig. 36. The steam pressure in excess of the resistance of the water is used in accelerating the piston, piston rod, pump rod, balancing beam, and counterbalance, and after passing the point at which the steam pressure equals the water pressure the inertia of the parts will supply the deficiency of energy on being brought to rest after the steam pressure falls below the resistance of the water. Neglecting friction the area *abc* will equal the area *bde*. These areas will always be a measure of the energy stored up in the moving parts and will be a function of the maximum velocity and the mass moved, so that by changing the amount of mass the speed of the apparatus could be altered. The use of heavy counterweights at times required all of the steam pressure on the up stroke of the weight to move them, while on the down stroke the excess of counterweight acting with the steam was used to lift the water from deep mines.

It is important to note the advantage of use of steam expansively, as it is this which has made the modern pumping engine with a fly wheel so economical. These early engines were quite efficient, as is seen from the table below, which demonstrates the great advantage of this Cornish engine.

DUTIES IN FOOT-POUNDS PER BUSHEL (94 POUNDS) OF WELSH COAL

In 1769, the Newcomen engine	5,500,000	ft.-lbs.
In 1772, the Newcomen engine, improved by Smeaton	9,500,000	"
In 1778 to 1815, Watt engine	20,000,000	"
In 1820, improved Cornish engine (average)	28,000,000	"
In 1826, " "	30,000,000	"
In 1827, " "	32,000,000	"
In 1828, " "	37,000,000	"
In 1830, " "	43,350,000	"
In 1839, " "	54,000,000	"
In 1850, " "	60,000,000	"
In 1827, highest duty, Consolidated Mines	67,000,000	"
In 1832, " Fowey Consols	97,000,000	"
In 1842, " United Mines	108,000,000	"

This engine was developed into the beam engine and was used for water works. Fig. 37 is a cut of a Cornish engine of 1840 for the East London Water Works, with a capacity of 6,000,000 gallons per twenty-four hours. This represented the best engine of the day.

While the Cornish engine was being used for pumping water from mines and for the water supply of cities, another form of pump was sucessfully operated in 1830 in New York by a Mr. McCarty. This was the **centrifugal pump.** It was a pump which had been known for a long time, as Euler discussed its theory in a paper in 1754. According to one author the invention of it is due to Denys Papin in 1689, who took his idea from Johann Jordan. Jordan designed a centrifugal pump in 1680. Demour in 1730 invented the equivalent of a centrifugal pump. It consisted of a tube, Fig. 38, mounted on a vertical axis so that the lower end entered the water to be raised near the axis. On turning this the centrifugal force overcame the effect of gravity and the water rose. In 1818, a few years before

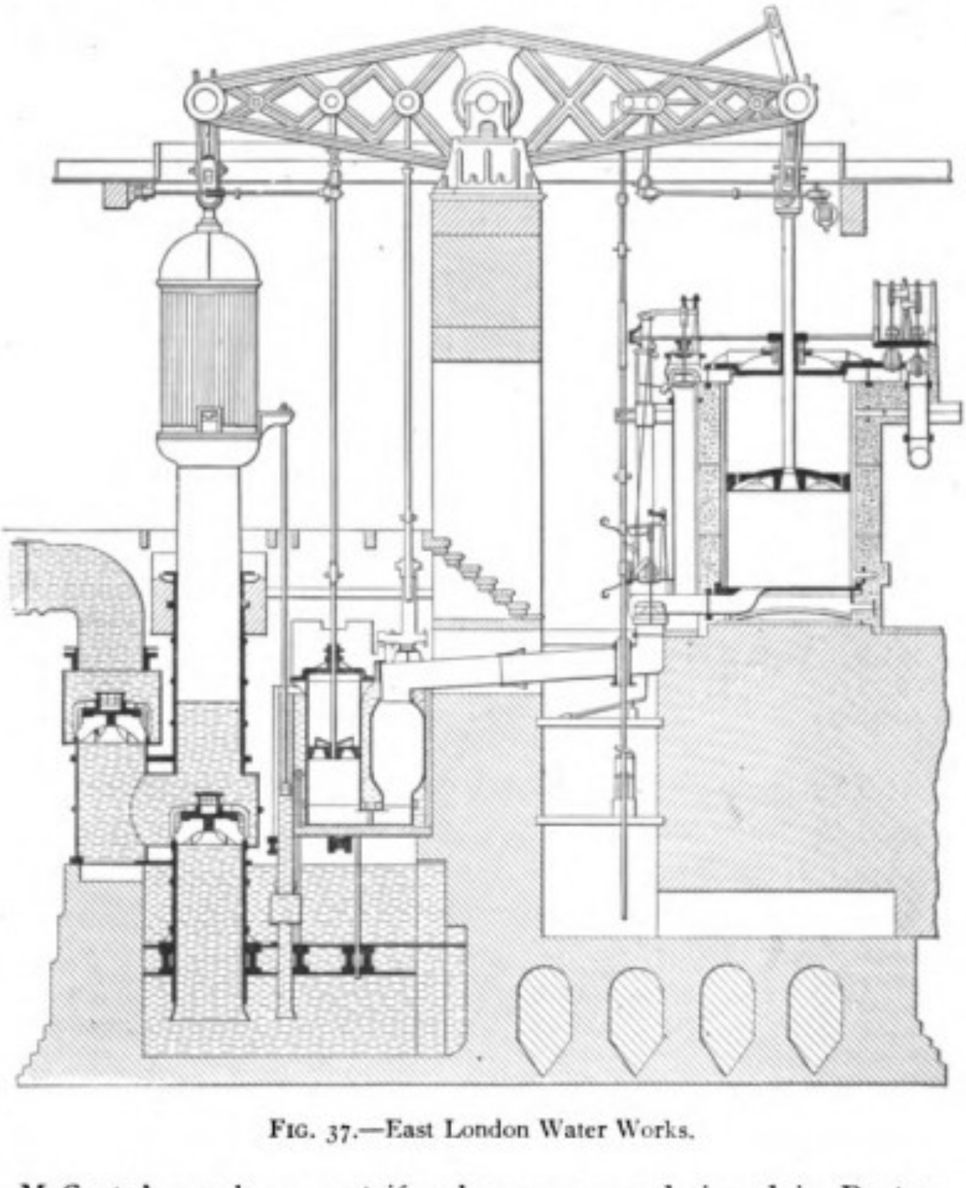

Fig. 37.—East London Water Works.

McCarty's work, a centrifugal pump was designed in Boston and known as the Massachusetts pump. It was a successful machine. Fig. 39 shows the general arrangement of the Boston pump. The vanes were parallel to radial lines and removed several inches from them. They were placed on each side of a disc, and this runner revolved within a casing.

After McCarty the improvement of this form of pump was undertaken by Blake and Andrews in this country in 1831 and 1839, respectively, and by Appold, Thompson, and Gwynne in England. The original blades of the Massachusetts pump were radial, but those of Andrews in 1846 were curved, as shown in Fig. 40. This pump had the vanes held between two discs.

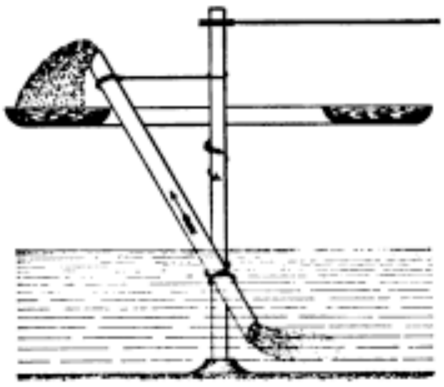

FIG. 38.—Demour's Centrifugal Pump.

This patent was bought by John Gwynne for England, and his firm began the manufacture of these pumps. The development of the centrifugal pump in England is closely connected with

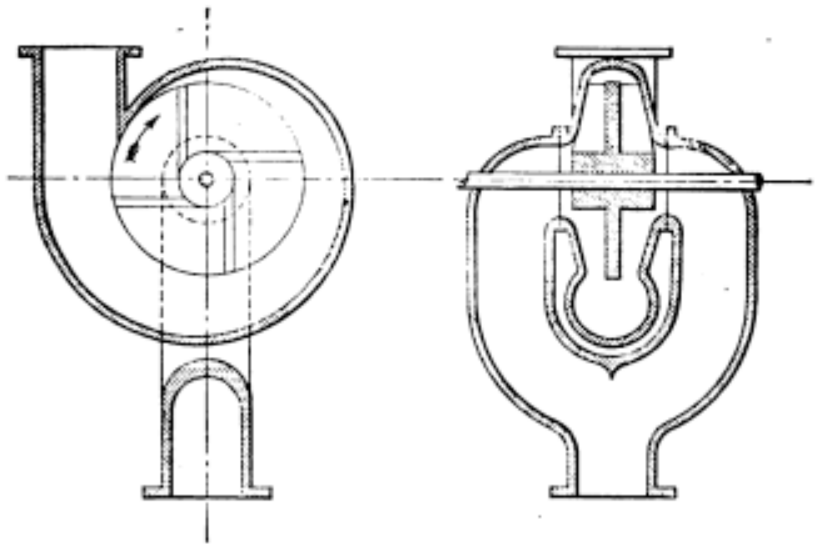

FIG. 39.—The Boston Pump.

the history of this firm. They were the constructors of the most notable installations for many years.

In 1848 Lloyd took out a patent for a centrifugal fan, and Appold began the manufacture of it and applied it to the lifting of water. In 1851 he exhibited this and showed its practicability. The tests of the pump with the curved vanes showed it to be about three times as efficient as that with straight arms. The advantage of this pump is its ability to lift large quantities of water considering the space occupied by the machine, and its ability to pump small solid particles without clogging. It was originally thought that this was only

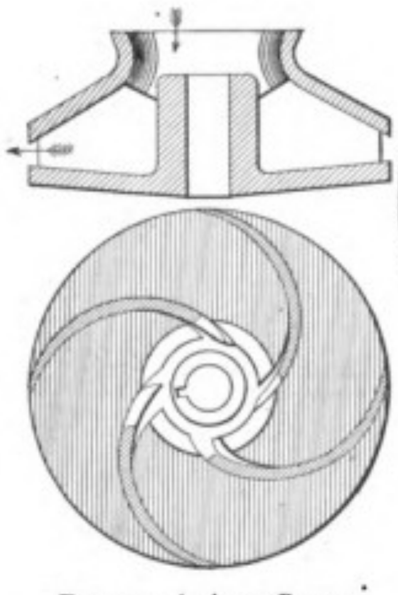

Fig. 40.—Andrews Pump.

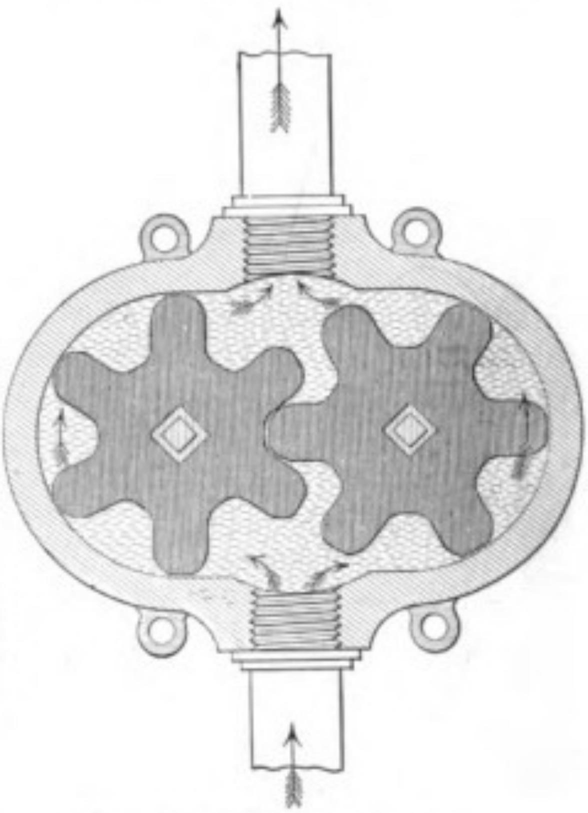

Fig. 41.—Servière's Rotary Pump.

applicable to low lifts, but to-day pumps of this form are used for lifts of several hundred feet.

Another old form of pump in which rotary motion of the parts is utilized is shown in Fig. 41. This is the **rotary pump,** and is an old invention found in the form of Fig. 41 among a collection of models made by Servière, a Frenchman, born in 1593. This is one of the best forms of this type, as will be seen later, when the rotary pump will be examined in detail.

Since the action of this pump is positive, it may be used against

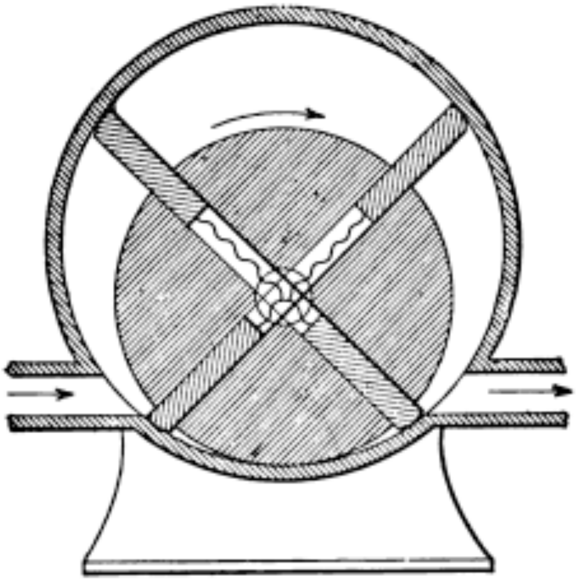

FIG. 42.—Ramelli's Rotary Pump.

high heads, although leakage may be excessive, due to the wear which occurs in the parts. Some claim that this was the invention of Pappenheim, a German, who lived in the seventeenth century.

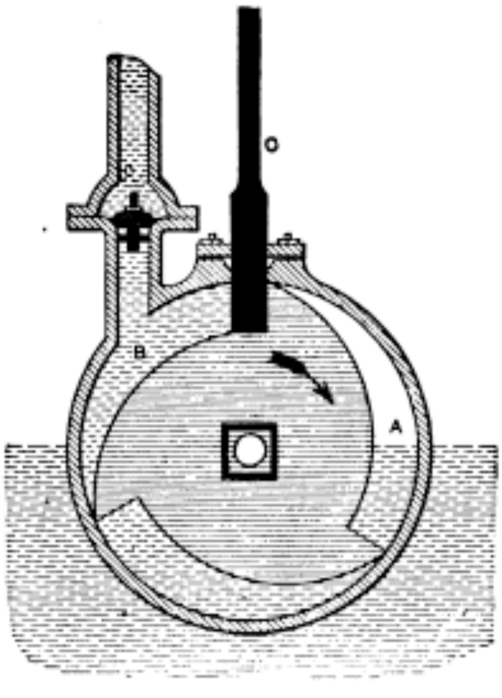

FIG. 43.—Sixteenth Century Rotary Pumps.

Ramelli, whose publication of 1588 illustrates a rotary pump shown previously in Fig. 27, uses a slightly different form from that of Servière. In his pump, Fig. 42, a series of flat pistons are driven by a rotating cylinder which is placed eccentrically within the outer casing. These flat plates are held out by springs, as shown in the figure, and the rotation of the inner cylinder forces the water through the machine.

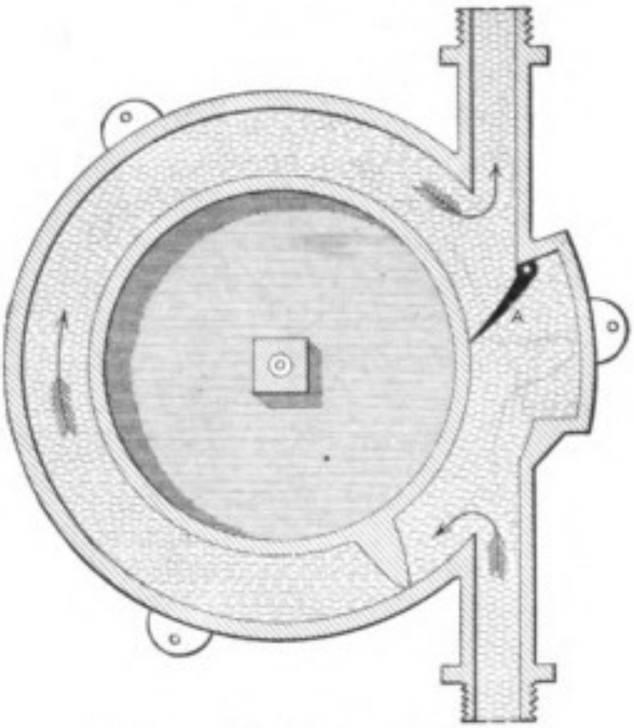

FIG. 44.—Watt's Rotary Pump.

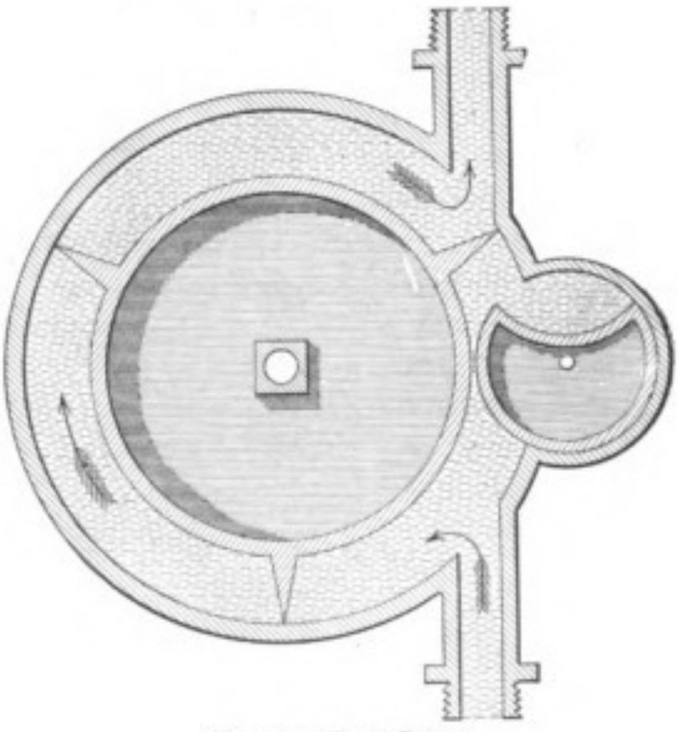

FIG. 45.—Eve's Pump.

Another form of rotary pump of the sixteenth century is given in Fig. 43. As seen in the figure the space *A* is being filled through an opening below the water level while the space *B*, which is closed by the sliding partition *C*, is being discharged. The sliding partition *C* extends from one side of the casing to the other, and slides through the stuffing box. After rising to the highest point it drops by its weight, which is made sufficient to overcome the friction of the stuffing box. The stuffing box shows the form used at that day. The friction of this machine was very great.

A form of rotative pump similar to that patented by Watt in 1782 as a rotative engine is shown in Fig. 44. The operation is clear from the figure; the flap or butment *A* serves to divide the two sides of the pump and when the projecting piece or piston strikes the butment it swings on its pivot. The movement of this butment is controlled by a heavy spring, or by rods and cams, so that it is held against the water pressure from force main, moving only at the proper time. This scheme was altered in 1825 by J. Eve in that he substituted a revolving cylinder for the pivoted butment and inserted three moving pistons for the one. The small drum was driven by gearing from the main shaft at three times the revolutions of the main shaft, as it was one-third the size of the main drum. This is shown in Fig. 45.

In 1805 John Trotter introduced a different form, Fig. 46, in which a plate was driven in such a manner as to touch two fixed concentric drums, its position being radial. The operation of the machine is evident from the figure. There is some chance for leakage after the piston crosses the discharge pipe and before it crosses the suction pipe, so that it is really necessary to have more than one piston. Fig. 47 illustrates another form of this used for water, although it had been used in 1790 for a steam engine.

From these earlier forms a number of new rotaries were developed which finally became a variation of the older form of Servière, as will be seen in the next chapter.

Another old type to be mentioned is the reciprocating

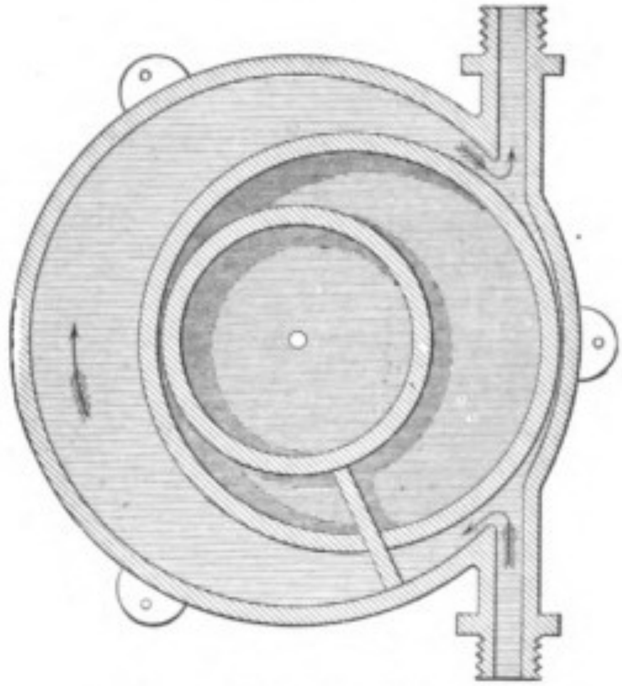

FIG. 46.—Trotter's Rotary Pump.

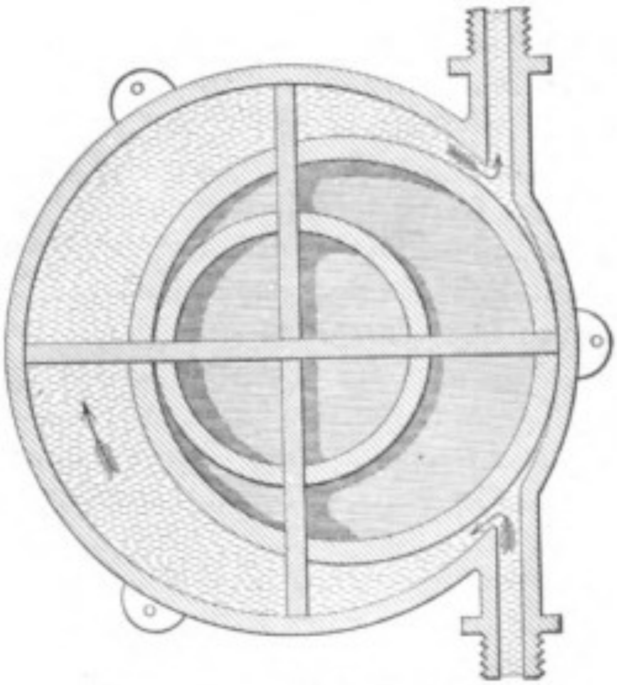

FIG. 47.—Four-Bladed Rotary Pump.

rotary form, Fig. 48. The figure shows the operation of the pump, and a further description is unnecessary. The objection to these and the rotary pumps is the fact that it is very difficult to keep their pistons tight. The rotary pumps have the great advantage that the flow of water is always in the same direction through the pump.

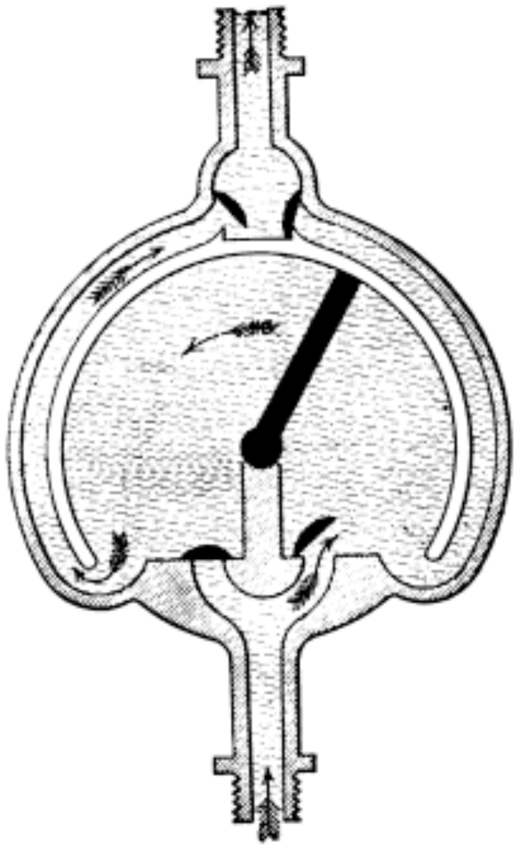

FIG. 48.—Reciprocating Pump.

A pump somewhat allied to the rotary is the **screw pump,** Fig. 49. The pump illustrated was the invention of Révillion, and was patented in Paris in 1830. It consisted of a right- and a left-handed screw meshing together, being driven in opposite directions at the proper speed by means of gears *AB*. The point of one screw touches the root of the other, and thus incloses a definite volume of water between the screw and the walls of the pump chamber, which travels upward as the screw rotates. At the end of the travel this water is forced out at the center.

In passing, it is well to note that the use of pumps for the extinguishing of fires had been common from the earliest times, Fig. 19 being one described by Hero. Until about 1840, however, these were all driven by hand power. Fig. 50 shows a French engine of 1829. This was hauled to the fire by the fire company, which in America was a very important social organization during the first half of the urban history of the last century.

The first steam-driven fire engine of note in this country was one planned by Captain John Ericsson, in a competition for a prize offered by the Mechanics Institute of New York,

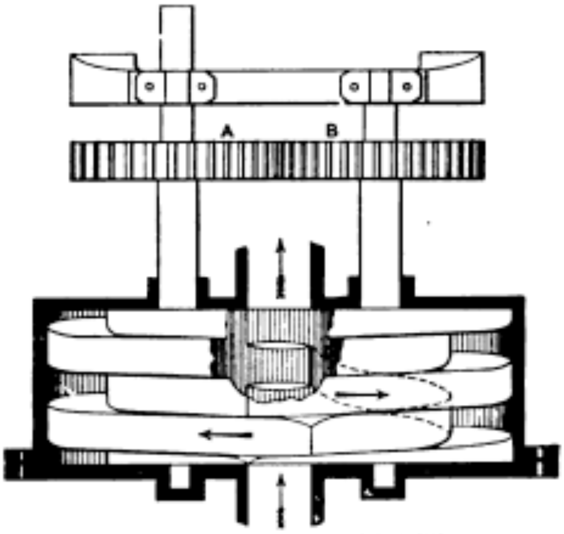

Fig. 49.—Screw Pump of Révillion.

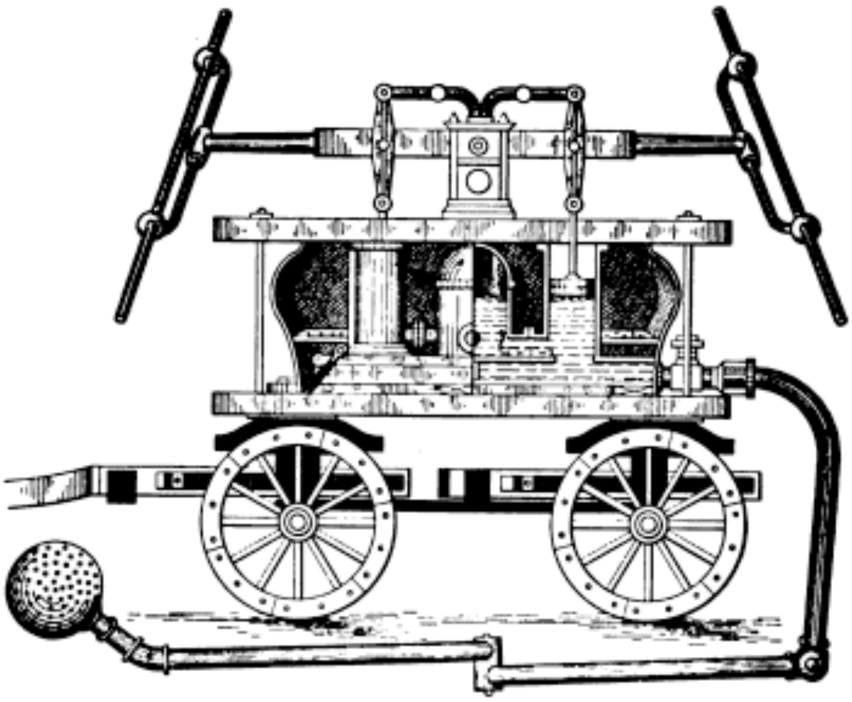

Fig. 50.—French Fire Pump of 1829.

in 1840, although in 1830 Braithwaite and Ericsson brought out a steam fire engine in London. The pump developed

6 H.P., and pumped 150 gallons per minute a distance of 80 or 90 feet. It was drawn by horses and practically was the same as that designed by Ericsson for New York. Before this time stationary steam fire pumps were used.

Fig. 51 gives a view of the Ericsson engine. The boiler was of the locomotive type, the barrel *A* being connected to

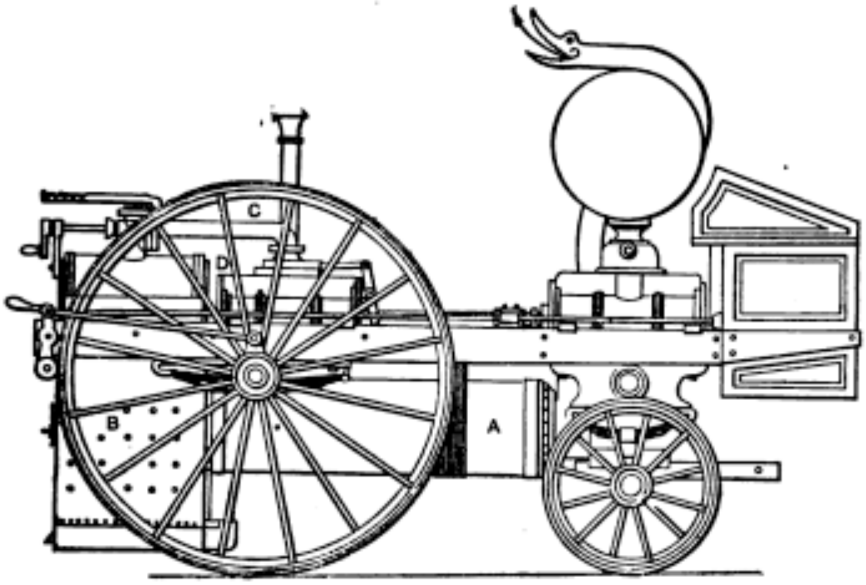

Fig. 51.—Steam Fire Pump of 1840.

the firebox *B*. The steam pipe *C* supplied the cylinder *D* with steam. The water cylinder was in line with the steam cylinder and above it was placed an air chamber. The smoke pipe from the boiler was carried around the air cylinder in the form of a serpent. On the front of the engine was a blowing box which could be worked by the cross-head of the steam engine, or by hand or by a crank attached to the wheels of the engine. The latter arrangement served to force the fire within the firebox when the engine was on its way to a conflagration. This is a forerunner of the modern fire engine, and it is noteworthy that the design was most thoughtfully and carefully made.

The first record of the **hydraulic ram** was that of Mr. Whitehurst of Derby, England. In 1772 he erected a machine shown in Fig. 52. *A* was a spring or reservoir supplying the cock *C* through the pipe *B*, which was about 600 feet long and 1½ inches in diameter. The cock was 16 feet below the level in *A*, and on closing this after drawing water the momentum of this long column of water was sufficient to force the water

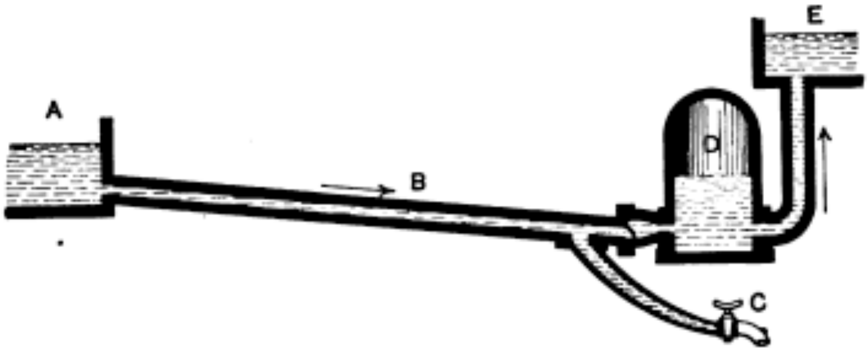

FIG. 52.—Hydraulic Ram of Whitehurst.

into air chamber *D*, which was under the pressure of the higher reservoir *E*.

It was Montgolfier in 1796 who independently invented the same scheme, but made it of more value by using a device

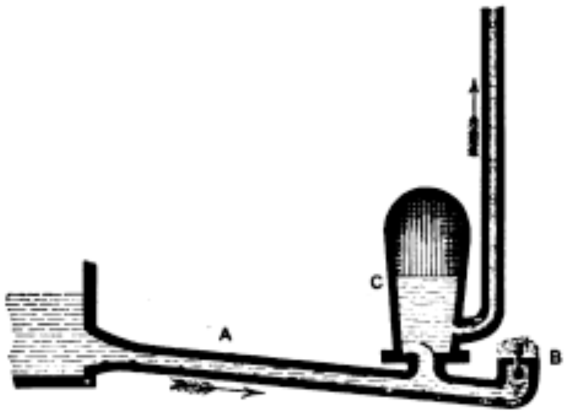

FIG. 53.—Ram of Montgolfier.

which worked, continuously and automatically, in place of the cock *C*. His scheme is shown in Fig. 53. The water descends from the source of supply through *A*, escaping at *B*. When the water has acquired a certain velocity it raises the ball and closes the opening at *B*. The momentum of the water causes an increase of pressure, and this is finally sufficient to open the valve in C against the high pressure of the discharge. The valve at B may be of the disc form, but opening downward; the principle, however, is the same in all cases.

The development of the ram in the years which follow the work of Montgolfier consists in improvement in details, the

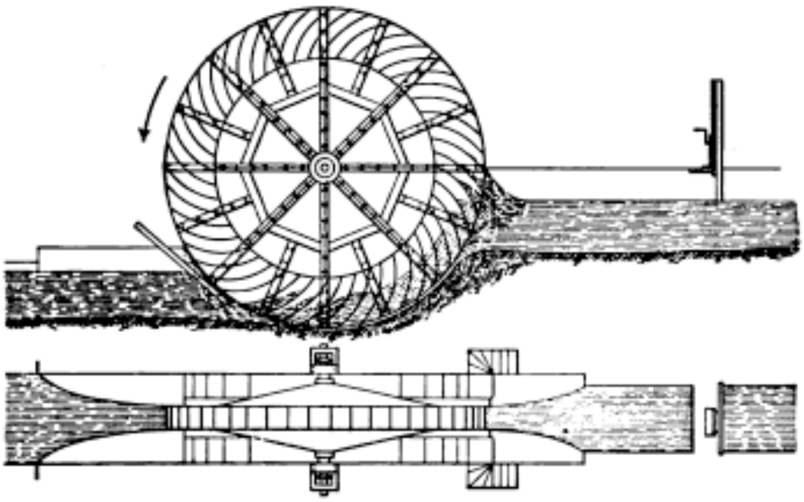

FIG. 54.—Flash Wheels.

latest forms of the present day being quite similar to this early type.

Scoop wheels or **flash wheels,** Fig. 54, were used from early times. They were in reality water wheels turning backward. These, as will be seen, have been used to some advantage in later times. They were used extensively in Holland about the time of the introduction of the steam engine.

Continued in Part-3