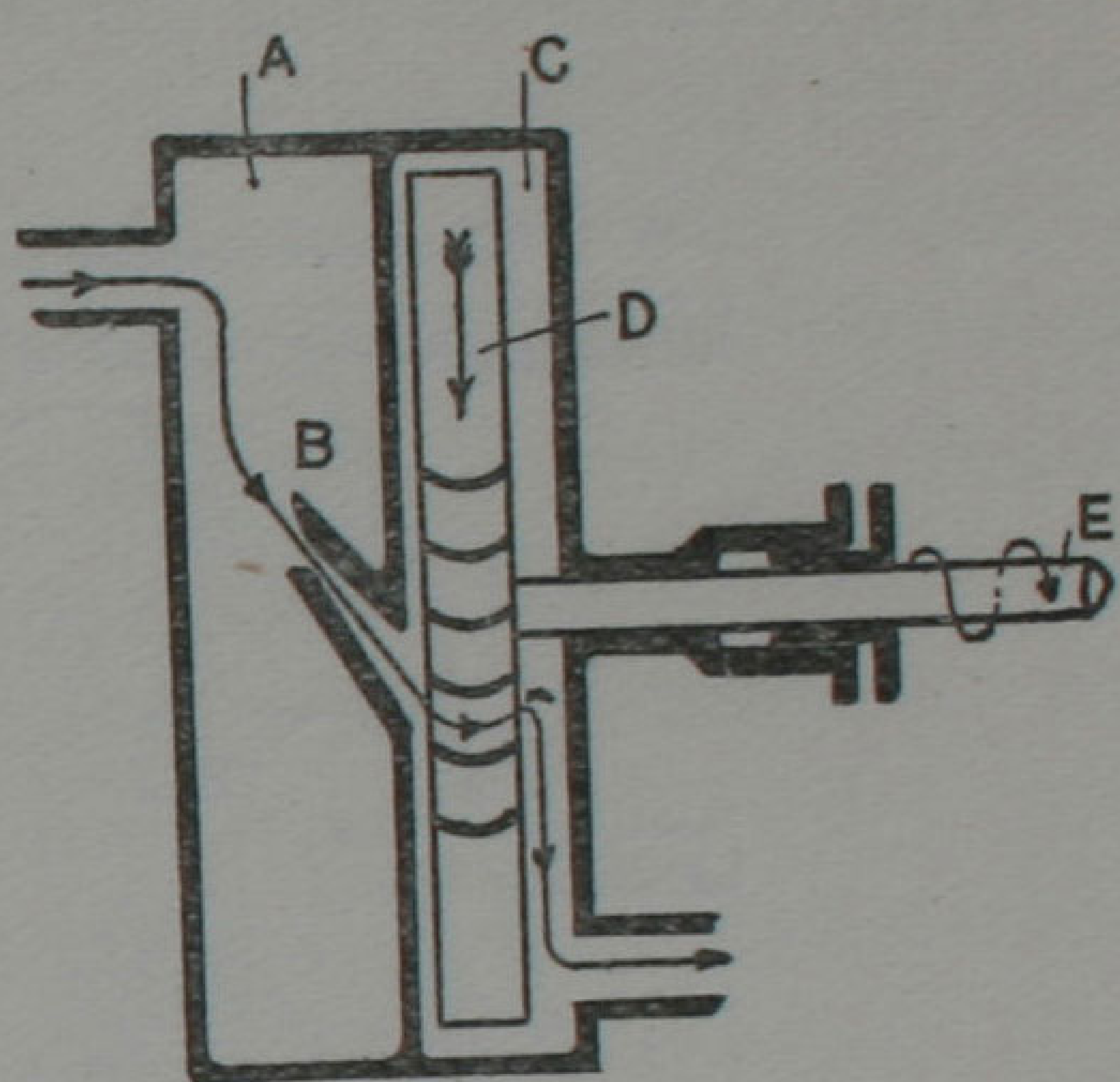
In the turbine the moving force arises chiefly from the high speed of the jet of steam. We think rightly that steam is very light, much lighter than air even, but we must remember that it is just as heavy as the water from which it has been formed. One pound of water makes one pound of steam.

We know that a jet of water exerts a great force. A jet of steam, if it be moving at a high speed, will act with a very great force too.



Simple Form of Steam Turbine

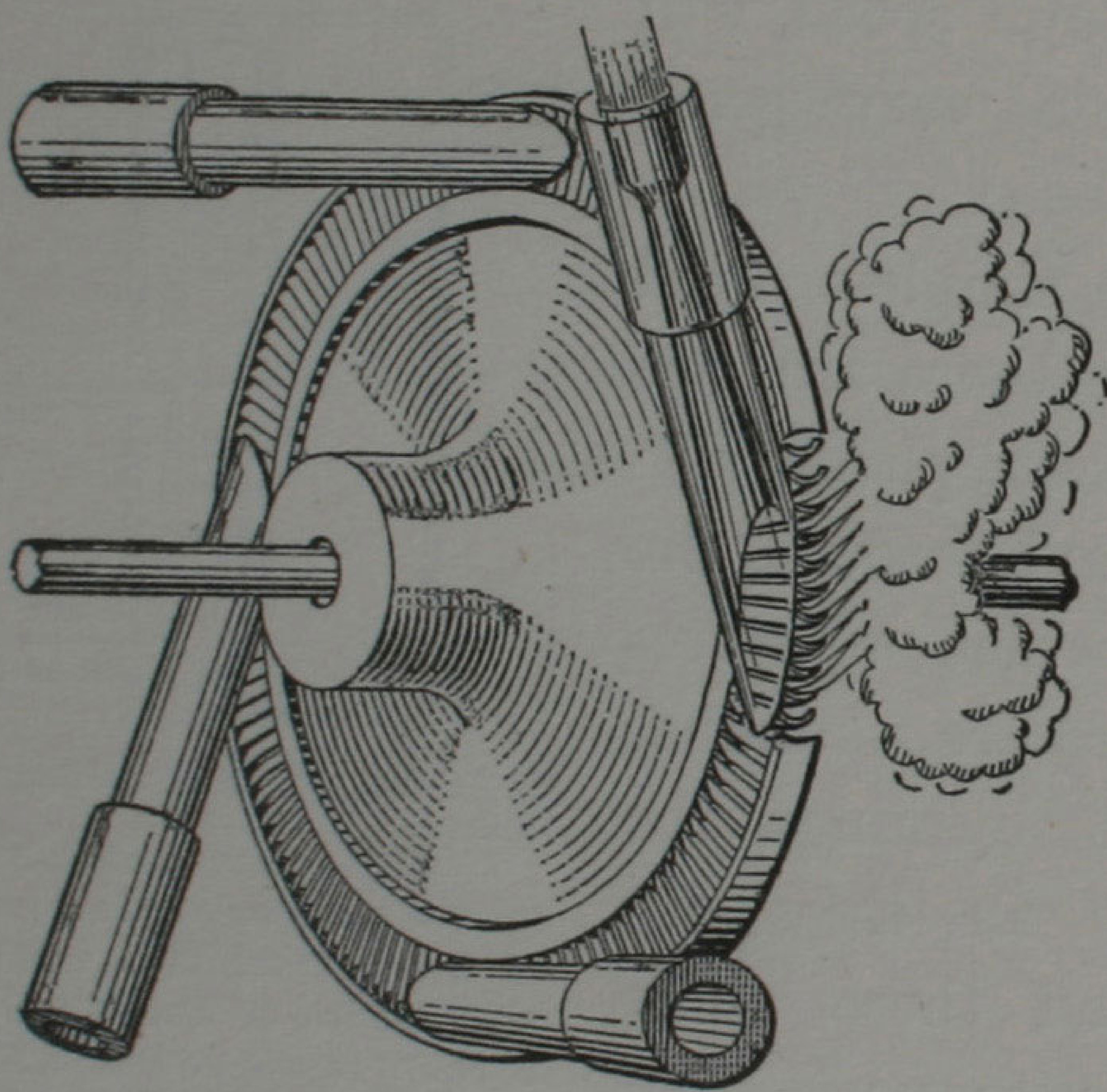
A, High-pressure chamber. B, One of several nozzles. C, Low-pressure chamber in which there is a vacuum. D, Disk, with blades or buckets attached to rim. E, Shaft to which disk is fixed. The path of the steam is indicated by the arrow.

In the simplest kind of turbine there are two circular boxes placed side by side, and through the division which separates them there are a number of small openings, or "nozzles" as they are called, and these allow the steam to pass from the one box to the other. One of the boxes is connected to the boiler, and the other to the condenser. There will therefore be a high pressure in the one and a vacuum in the other.

This great difference between the pressures at the two ends of the openings or nozzles causes the steam to flow through them at a very high speed, and it comes out in the form of small jets. These jets, when they enter the box where the vacuum is, strike a number of curved blades or buckets which are fixed to the rim of a small disk mounted on an axle. This causes the disk to revolve at a very high speed.

In small turbines the speed is sometimes as high as thirty thousand revolutions per minute. Try to think what this means. A watch ticks four or five times in a second. In the very short time between two ticks the disk has made one hundred turns.

The machines which the turbines are required to drive



View of Wheel of De Laval Steam Turbine, showing Action of Steam

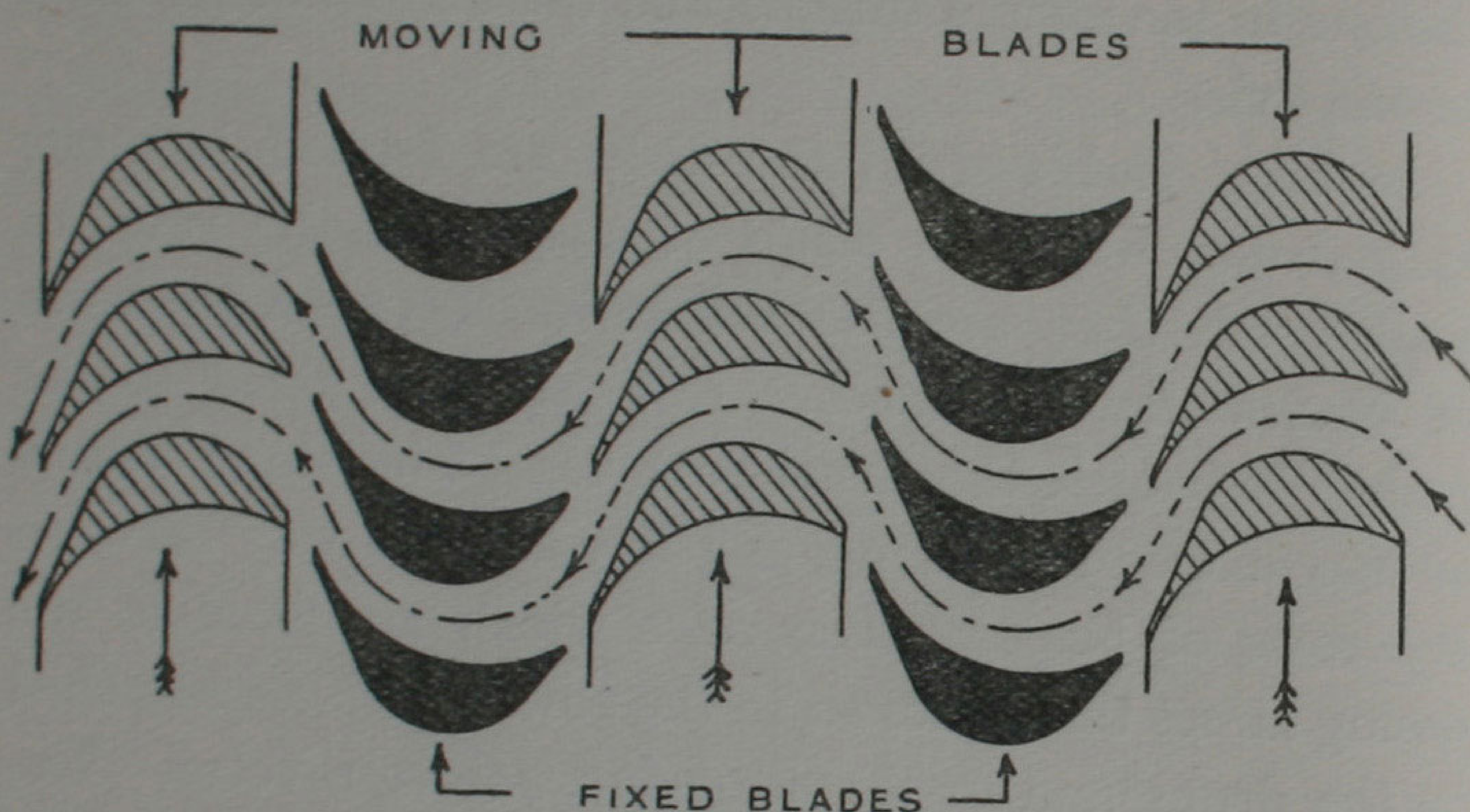
are not generally intended to run at such high speeds as this, so it is necessary to use toothed wheels of different sizes in order that the speed may be reduced. This is a disadvantage, because a good deal of power is lost on account of the friction between the teeth.

The speed of the disk can be reduced if the speed of the steam is made smaller. This can be done by having a large number of boxes placed side by side instead of only two. The first one is connected to the boiler and the last one to the condenser, and each division has a number of nozzles in it. As the steam passes from one end to the other its pressure falls from box to box, but now the fall in pressure from any one compartment to the next is small, and so the speed of the steam is less than it was before. Each box has a disk in it similar to the one in the simple turbine, and these are all connected to one axle.

In large turbines, all the disks are formed into one long drum, which is made of steel, and the rows of blades or buckets are attached to it. Between the rows of blades there is another row which is fixed to the casing in which the drum revolves. The steam enters at one end of the casing, and it winds its way between the rows of blades. The rows which are fixed to the casing direct the steam on to the rows which are attached to the drum, and so the drum is made to revolve. The pressure of the steam gradually falls as it passes from one end of the turbine to the other until it reaches the condenser, in which there is a vacuum.

Although a very simple kind of turbine was made many centuries ago, it was not until about the end of last century that the steam turbine came into use. In the year 1884 Sir Algernon Parsons invented a turbine of the kind we have been reading about, and he used it for driving machinery on land. He then fitted turbines in two ships, and after making many experiments he was able to prove to shipbuilders that his machine had several advantages over the older form of engine (p. 81).

The first passenger vessel to be fitted with these new turbine engines was the small steamer *King Edward*, and this was followed by the *Queen Alexandra.* These two vessels had been running for only a short time when the Cunard Shipping Company decided to build two very large vessels to sail between Great Britain and America. They could not make up their minds whether they ought to venture to use turbines to drive them or



Parsons' Steam Turbine

The moving blades are attached to the drum of the turbine. The fixed blades are attached to the inside of the casing in which the drum revolves. Steam enters on the right, striking the first row of moving blades. It is then guided by the first row of fixed blades on to the second row of moving blades, and so on until it escapes at the end of the turbine. The force of the steam upon the moving blades drives them, and the drum to which they are attached, round. The blades will be seen in the picture opposite p. 81.

to adopt the oldfashioned and well-tried engines. Certainly the turbines of these two small steamers had proved in every way satisfactory, but they were only one-tenth as powerful as those which would be required for one of those great Atlantic liners. No less than seventy thousand horse-power was necessary to give each of these vessels the desired speed.

After considering the matter very carefully the Cunard

Company decided to have turbines, and the *Lusitania* and *Mauretania* were built. Everybody who was interested in shipping or in engineering was impatient to see what the result would be; for those vessels were more powerful than any that had been built up to that time.

The *Lusitania* was launched first, and she broke the record on her journey across the Atlantic. But she did not hold the honour long, for the *Mauretania* completed the voyage in a still shorter time a few weeks afterwards. Then there followed a struggle for the blue ribbon between those two majestic ships. Record after record was broken. This struggle will ever remain one of the greatest events in the history of the steamship.

It is very difficult for us to understand how very large the turbines of these vessels are. A man can walk through the great casing in which the drum revolves with another man standing on his shoulder, and still another on his. Each drum has many thousands of blades fixed to it, and each turbine weighs about one hundred and thirty tons.

The great success which attended these vessels gave shipbuilders confidence in the turbine; and so to-day not only are our largest and swiftest boats and mail steamers driven by them, but our most powerful Dreadnoughts and our smaller men-of-war are also fitted with them. Thousands of turbines are in use on land, too, for driving all kinds of machinery.

23

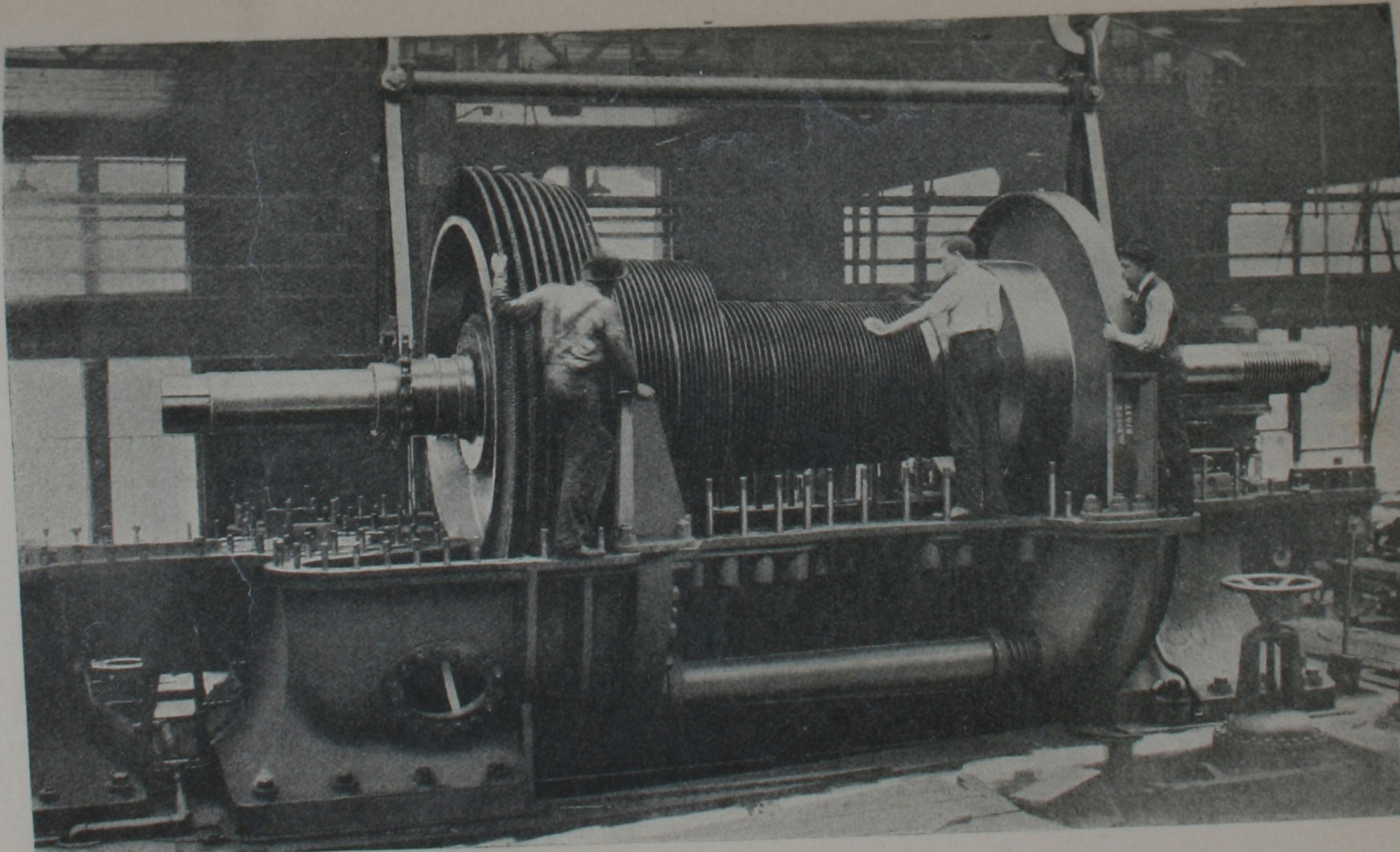
HOW GAS ENGINES WORK

Until about the middle of last century steam was the only substance which was used for working engines. For many years would-be inventors had tried to make an engine which would work with a mixture of gas and air. We are told that in 1680 an engine was made which used gunpowder. The gunpowder was fired in an upright cylinder, and the force of the explosion drove the piston upwards. When this force was spent the piston fell again to the bottom, and another charge of powder was fired, and so on.

It was not until near the end of the eighteenth century that William Murdock discovered that an inflammable gas could be made by heating coal. Very soon after this a man of the name of Barber made a machine very like the turbine we read about in the last chapter; but instead of steam he used the gases which were produced by the explosion of a mixture of gas and air to drive it. But Barber did not succeed in making a satisfactory engine.

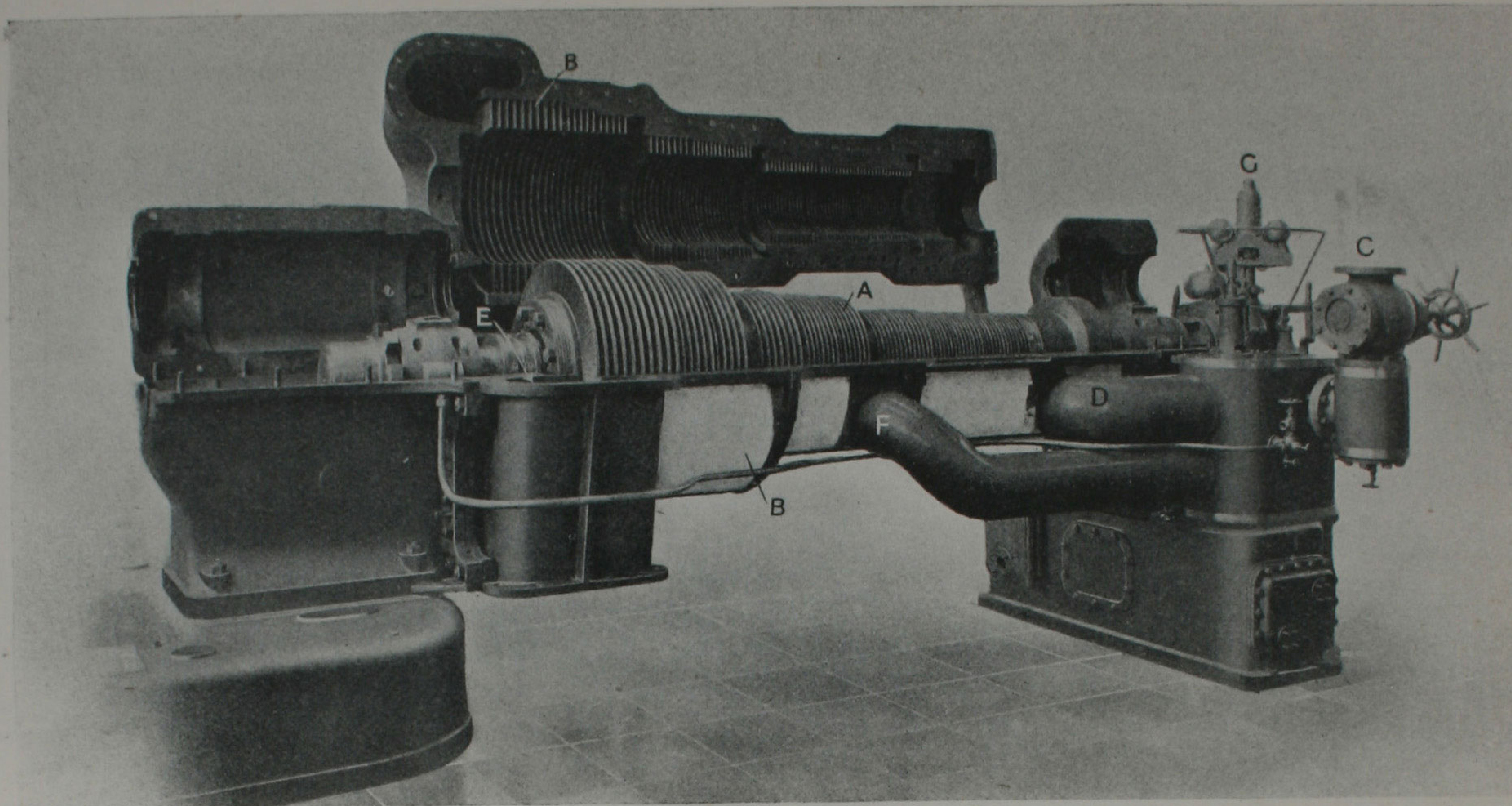
From this time onwards until about the year 1870 many attempts were made to construct a gas engine, but it was not until Dr. Otto made his famous "Otto" engine that success was achieved. To-day nearly all small gas engines are of this kind.

The cylinder of this engine is fitted with a long piston which is attached to the axle of the shaft by a connecting rod. The explosion takes place on one side of the



STEAM TURBINE

The rotating part, with its many thousands of blades, is being placed in position in the casing. The upper part of the casing is removed. The blades are clearly seen at the left-hand end. (*See p.* 74)



PARSONS' STEAM TURBINE (with upper half of casing removed)

The disk or rotor A has many rows of blades fixed to it. These revolve between corresponding rows of blades in the casing B. Steam enters by the valve C, and reaches the right-hand end of the rotor by the pipe D. It winds its way between the blades, causing the rotor to rotate, and ultimately escapes by the passage E, to the condenser below. When the load is very heavy, more steam is admitted by pipe F. G is the governor. (See p. 77)

piston only, and the other end of the cylinder is open to the atmosphere.

Let us imagine that the engine has already been started to work. When the piston moves out of the cylinder it sucks in gas and air through two valves. In rushing into the cylinder the gas and air are thoroughly mixed together. The piston then comes back again, and the valves are closed so that the "charge" cannot escape. It is therefore squeezed into a smaller volume and its pressure rises. When the piston has come full back the mixture of gas and air is brought into contact with a heated tube, or an electric spark is made to pass between two metal points inside the cylinder. The mixture immediately explodes and the piston is forced out again. It comes back a second time, and during the time it is returning another valve is held open and the burned gases are sent out of the cylinder into the air. A new charge is now drawn into the cylinder and exploded just as the previous one was, and so the engine is kept going.

For many years gas engines were made only of small size. They were costly to run when compared with steam engines, but they had the advantage that they could be set in motion on a moment's notice, for there was no boiler in which steam had to be raised before the engine could be started.

The expense of coal gas led inventors to experiment with an apparatus which could be attached to the engine in such a way that it manufactured the gas just as it was required. After many efforts they met with success, and the cost of working gas engines was in this way very greatly reduced. Instead of the piston drawing gas from the pipes which come from the gasworks, it sucks air through this "gas producer", as it is called. The air on its way to the producer first passes over hot water, and so it becomes charged with steam. It is then drawn through red-hot coal or coke, and in this way the gas is formed. The gas is now sucked into the cylinder of the engine, along with the air which is necessary to burn it. When in the cylinder it behaves in the same way as ordinary coal gas does (p. 84).

In large engines the air is not sucked through the producer, but it is blown through by a fan which rotates at a very high speed. Some of these producers are very large, for they can turn as many as ten tons of coal into gas every hour. This kind of gas is used in steelworks, not only for driving the engines which work the machinery, but also in the furnaces in which the ingots are heated before they pass to the rolling mill.

24

HOW GAS ENGINES WORK (*Cont.*)

If one were to pass on a dark night through a district where iron is made, he would see great flames shooting up from the tops of the blast furnaces. It will be remembered that coke or coal is burned in these furnaces, and that air is blown in at the bottom. The blast furnace, therefore, acts like a producer, and it is this gas which is to be seen burning at its open top. This is not only a great waste of energy, but when the gas is burned in this way it renders the atmosphere very impure, for a greal deal of dust and tarry matter is carried up from the furnace by it.

For many years this great waste went on, until Mr. Thwaite made up his mind to try to make use of these blast-furnace gases for driving engines. He closed up the top of one of them, and he led the gas to a small engine which he had constructed. At first he was not successful, for this kind of gas is very different from the coal gas which had been used before.

But Mr. Thwaite persevered, and after a time he was able to drive his engine, and he used it to work a machine which produced electricity, with which he lit the works.

Encouraged by this success, Mr. Thwaite suggested a way in which all the gases produced from the hundreds of blast furnaces throughout the country could be made use of to produce the power necessary to drive the rolling mills and other machinery in the works, and so save the cost of the coal required to raise the steam, for steam engines had always been used for this purpose. It is just because coal has been necessary for the working of all kinds of factories that our large manufacturing cities have sprung up beside the coalfields. But coal and iron are generally found together, so the blast furnaces are near to these cities too.

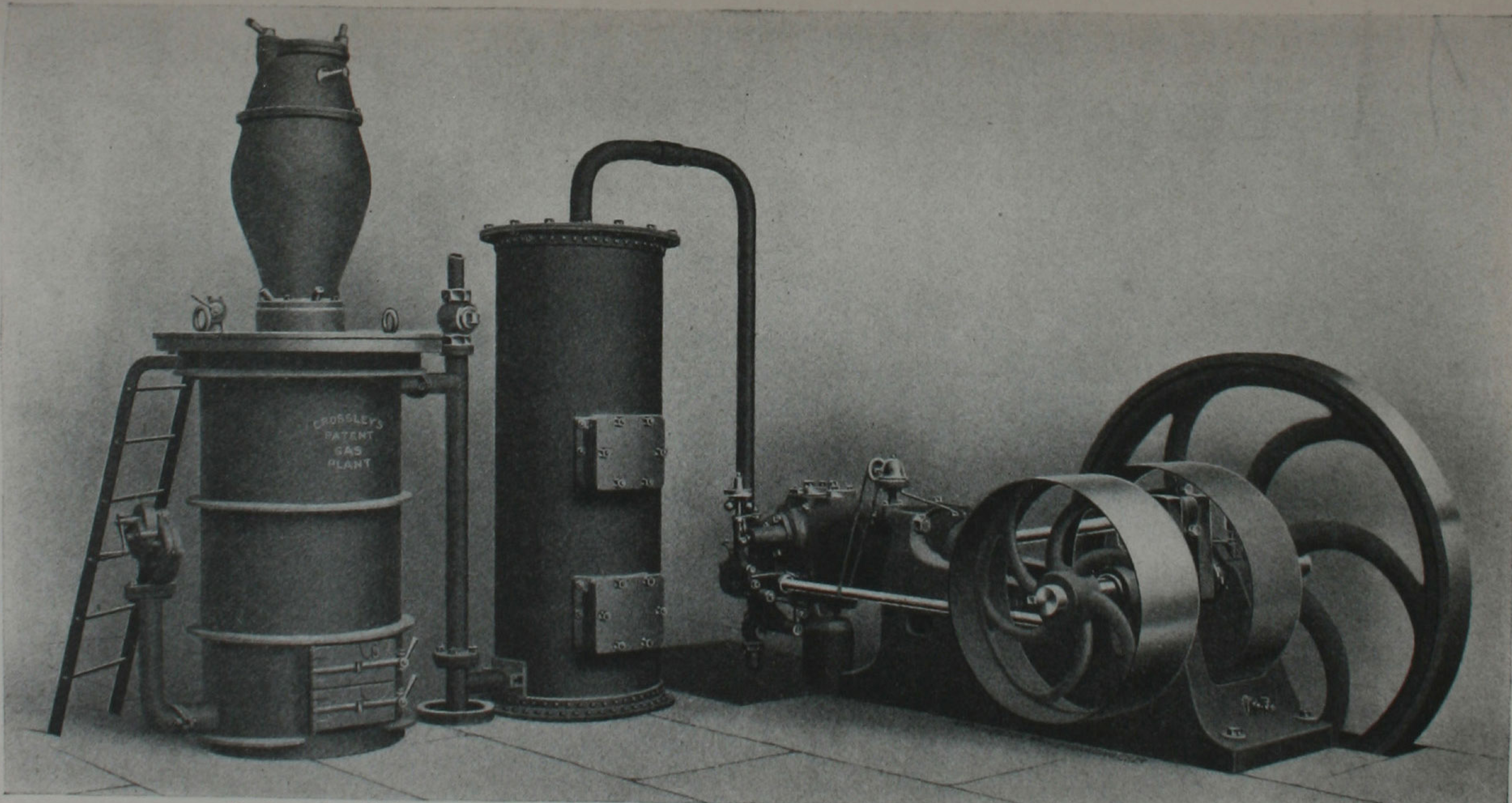
Mr. Thwaite's proposal was that the ironmasters in each district should combine together and send the gases which they had been in the habit of throwing to waste, to a central station, where they would be used to drive gas engines. These engines would then be made to produce electricity, which would be sent back to the works and used not only to light them, but also to drive all the machinery.

But there was something more than this to be gained, for all this could be done by only a portion of the gases. The remainder could then be used to light the towns and villages round about, to run tramcars, and to work the machinery in factories. Surely this would be a great saving.

But it was a long time before Mr. Thwaite succeeded in inducing these ironmasters to try this. They had so long been accustomed to steam engines, which had done their work so surely and caused very little trouble, that they did not care to spend the great amount of money which would be required to build these gas engines, for, after all, they might not be nearly so reliable as the steam engine had been.

It was not until German and American ironmasters had proved that what Mr. Thwaite had suggested was quite right that British manufacturers decided to use gas engines driven by these blast-furnace gases. But to-day the machinery in many ironworks is driven by them, and the surplus energy is sent for many miles in the form of electric currents to towns, where it is used for lighting and for power. And the very fact that power can be had so cheaply has been the means of causing new industries to be started in these districts.

Some of these blast-furnace gas engines are very large, for large engines are more economical than small ones. Some of them give as many as five thousand horse-power.



Producer, in which the gas is made

Scrubber, for cleaning the gas

Engine

GAS PRODUCER AND GAS ENGINE

(*See p.* 82)

Marshall, Sons, & Co., Gainsborough

12-FURROW OIL TRACTOR PLOUGH AT WORK

(See p. 87)

In one steelworks in America there are about seventy engines of this kind, and they are so large that they weigh about one thousand tons each.

25

ABOUT OIL ENGINES

About the same time as the gas engine came into use, the oil engine, which had also engaged the attention of many inventors for years, at last became a reliable machine. This kind of oil engine—for there are now many kinds—works in exactly the same way as Dr. Otto's gas engine does.

Oil is a liquid, but many kinds of oil can be easily changed into gas. It will be remembered that in the chapter on the manufacture of oil we were told that it was purified by being heated until it became a vapour, and that this vapour was again cooled and condensed into pure oil. The very light oils, such as petrol, are very easily turned into vapours. If petrol be placed in the air it will very soon evaporate, and the vapour which it gives off is very inflammable. This is the reason why it is always kept in sealed tins. Many motor cars have been set on fire on account of the petrol leaking out of the tank in which it is carried.

Paraffin oil, which is used for lamps, does not form into vapour very easily. It is called a "safe" oil, because, if it is not allowed to become too hot, it will not give off an inflammable gas. For a long time paraffin was the only oil which was used for driving oil engines, and most of the small engines on land still work with it.

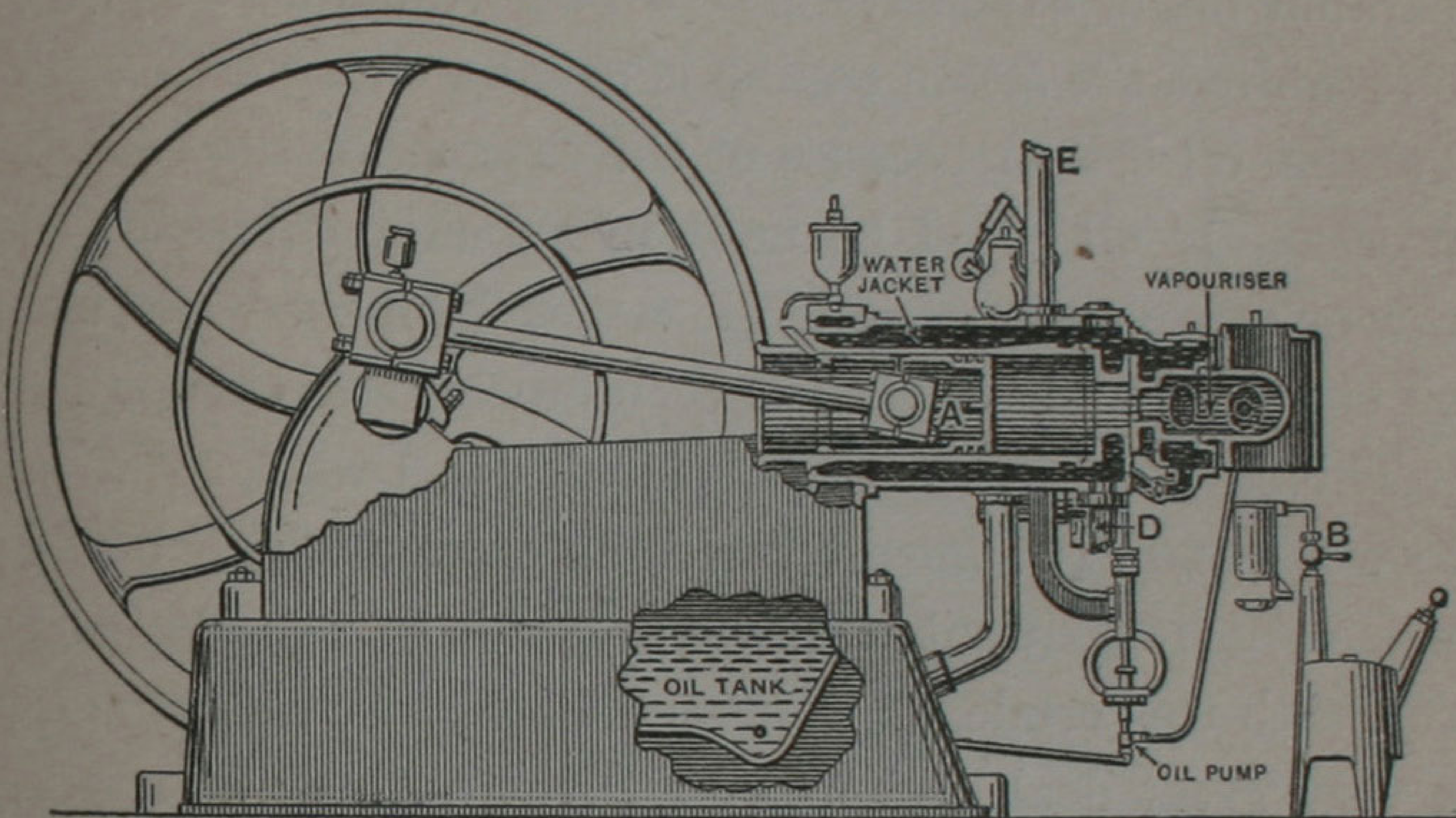
In order to form the vapour, the paraffin is allowed to fall, or is sprayed, into a heated metal box called a "vaporizer". The vaporizer is fixed to the end of the cylinder of the engine, and it is shut off from it by a valve which is opened and closed at the proper times by the engine itself. Air is also drawn into the vaporizer, and it mixes with the vapour.

When the piston moves out of the cylinder it sucks in this mixture and also more air. The valve between the vaporizer and the engine is then closed, and the piston comes back and compresses the charge. This charge is then exploded, and so the piston is driven out again. When the piston reaches its farthest-out position, another valve opens, and the burned gases are forced out of the cylinder when the piston returns.

These oil engines are very useful for many purposes, for they are very easily started to work when required. In many country districts there are no gas-works, and if only a small amount of power is required, as, for instance, for driving a threshing mill or a saw for cutting wood, a steam engine and boiler are not so suitable.

To the farmer the oil engine has proved very useful. In foreign countries, too, it is largely used, especially if oil can be had close at hand. The engine can be mounted on wheels, too, and then it looks very like a traction engine or a steam roller, sometimes to be seen about our streets.

These oil "tractors" are of great use to the farmer. They can move about from farm to farm, and if necessary pull behind them the threshing mill which he uses to thresh his corn. When they arrive at the farm, the tractor is uncoupled and connected to the mill by a leather belt, and in this way the mill is driven and the corn is threshed. Sometimes, too, these oil tractors are



Oil Engine

When the piston A moves to the left, air and oil enter the vapcrizer, which is heated by the lamp B. An explosive vapour is thus formed. This vapour is compressed when the piston returns. It explodes and drives the piston out again, and so the crank is revolved. The piston again returns and forces the burnt gases down the exhaust pipe. The cylinder is kept cool by water which enters by D and leaves at E.

used for ploughing fields. Some of the larger ones draw as many as a dozen ploughs, which are placed side by side, and so each time the tractor goes from one end of the field to the other, it makes twelve furrows (p. 85).

Another use to which the oil engine is now put is for the driving of small fishing boats; and there are many fleets of these little vessels round our coasts and those of foreign countries.

26

ABOUT OIL ENGINES (*Cont.*)

Only small engines of this kind are made, because paraffin oil is expensive. If a large amount of power be required, the steam engine is usually cheaper to work. Paraffin oil is dear because of the expense of the refining process. If oil could be used in an engine just in the raw or crude state in which it comes from the wells, then oil engines could be worked very much more cheaply.

This is the thought which struck Dr. Diesel, so he set to work and experimented with an engine which he had made. After patient work he succeeded in getting it to run with this crude, or unrefined oil, but he had to learn a very great deal, and make a great number of experiments, before he was successful. But in time he overcame the many difficulties, and to-day we enjoy the benefits of his skill.

Dr. Diesel found that he could not change this thick oil into a vapour in the same way as is done with paraffin. He had to adopt another plan. If air is compressed very quickly into a small space, it becomes very hot. This can be proved by working the pump of a bicycle very rapidly, when it will be found that the metal soon becomes very warm. What happens is that a lot of power is expended in pumping the air, and that energy is changed into heat. If the pump be worked slowly, the heat which is produced gets away almost as quickly as it is created, and so the air does not become heated.

In the "Diesel" engine, air only is at first sucked into the cylinder by the piston, and it is compressed to a very high pressure and at a very great rate; it therefore becomes very hot. The crude oil, in the form of a very fine spray, is now forced into this space, which contains the air. The oil is at once heated by the hot air, but does not explode; it burns, and as it does so it expands and forces the piston out. In fact, it behaves very much as the steam in a steam engine does.

To understand the great value of this invention, it must be remembered that all countries are not so well off as our own in having a large supply of coal which can be taken from the mine just as it is required. Russia, America, and some of the Eastern countries are very rich in oil, and until the invention of this engine they had to go to the expense of refining it before they could use it. Not only is this true, but the portion which remains in the still in which the crude oil is heated was of little or no value. Now it has become very valuable, because this new engine can make use of it.

Several years before we in this country began to use Diesel oil engines for driving ships, vessels were moving about on the Caspian Sea by their aid, and many of the smaller Russian war vessels were driven by them. This was quite natural, for oil is to Russia what coal is to Great Britain (p. 92).

Oil engines have several advantages over steam engines at sea. The boiler is no longer necessary. When one thinks of the great weight of one of these large boilers and of the water which it contains, one can understand what this means. Again, the space which used to be occupied by the boiler can now be filled with cargo. Oil, too, is much more easily put on board the ship than coal is, and it is much cleaner.

The oil required for a voyage takes up only about one-fifth of the space which the coal necessary for the same length of journey would occupy. This saving of space makes it possible to carry a still larger cargo, and so the ship is able to earn more money.

One of the first large ocean-going cargo vessels to be driven by oil engines of this kind was the *Selandia.* It was built at Copenhagen, and it put out to sea in 1912, just a century after the *Comet* was launched on the Clyde, and 103 years after the *Phoenix* steamed from New York to Philadelphia. The success which attended the *Selandia* on her first voyage of twenty-two thousand miles, to the far East and back again, proved that the Diesel engine is in every way suitable for use at sea. Although she encountered a violent storm in the Bay of Biscay, her engines gave no trouble. The cost of oil which the vessel used on the journey was not much more than one-half of that of the coal which would have been required for the same distance if steam engines had been used; and as this oil occupied less space, the vessel was able to carry a larger cargo.

Oil engines are now fitted on many of the smaller vessels of our navy, but the steam turbine is used to drive the larger battleships. The funnels which are so familiar on vessels are required to produce the draught which is necessary to keep the coal in the boilers burning, and to carry the smoke away clear of the ship. But when oil engines are used funnels are unnecessary.

27

HOW THE POWER OF THE WIND IS MADE USE OF

Centuries before the steam engine was invented, the farmer used to grind his corn by aid of the wind, or by the help of the water which flowed in the streams near by. Even to-day he often uses the power of the wind for pumping the water which he requires for his fields. It is also used for supplying country houses, and even villages, with water.

The oldest kind of windmill was mounted on a tall post which was kept in an upright position by four wooden stays attached to the top and fixed into the ground, so as to form a sort of trestle. The house in which the grinding was done generally had two stories or floors, and it was mounted on this post in such a way that it could be turned round. A shaft, or axle, passed across the upper story of the mill, and it projected through one side. On this projecting end a number of arms were fixed, and these carried cloth sails, some of which were as long as fifteen yards. The wind blew against those sails, turning the axle which was connected to the rollers inside by which the corn was ground.

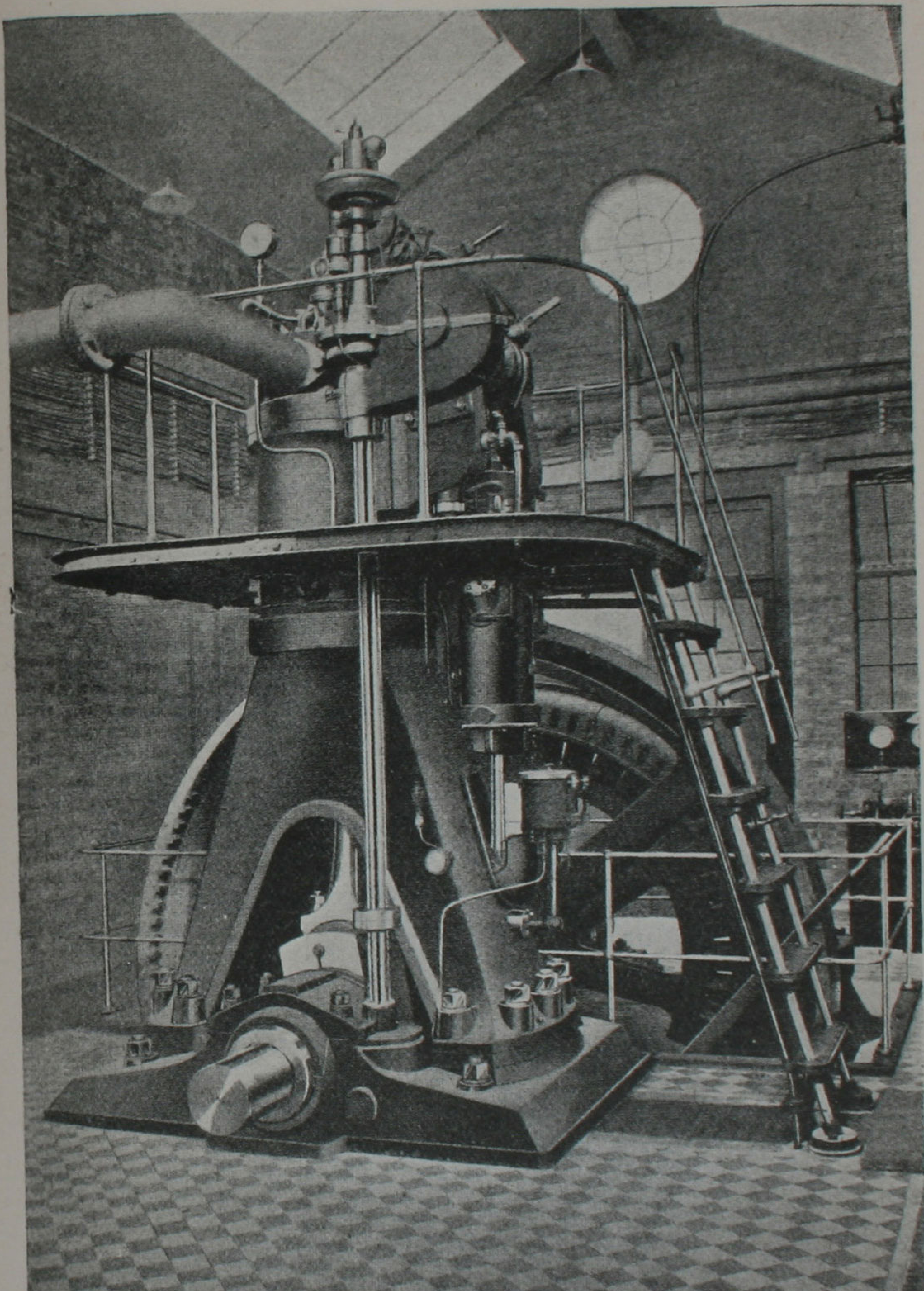
When the wind was very strong the surface of the sails exposed to it had to be reduced just for the same reason as the amount of sail in a fishing boat has to be diminished in a gale; and it was done in much the same way. The sails were reefed by tying parts of them together.

There was a flight of steps by which the farmer was enabled to reach the mill. The top of this ladder was attached to the floor of the mill in such a way that, by lifting the lower end it could be used as a lever with which to turn the mill round, and so the sails were made to face the wind.

In course of time this mill was improved upon. Instead of the whole mill having to be turned round every time the wind changed its direction, it was fixed to the ground—in fact it was built in the form of a tower, and generally of brick. Only the domed roof which carried the axle and the wheel had to be rotated. This was done by hand until Andrew Meikle thought of the idea of placing a sail, or fantail, at the other end of the axle. This fantail resembles the blade or vane of an ordinary weathercock. The wind acts upon it and brings it, and the axle to which it is fixed, into line with its own direction. In this way the main sails are made to face the wind, and so the mill is driven. There are some mills of this kind, which were built about a hundred years ago, still at work.

Although the engineer has been busy making improvements in steam and other modern engines, which are many times more powerful than the wind engine, he has found time to improve it too. Since these old mills were made he has learned how to make steel; and so, in place of the old brick tower and cloth sails, the modern wind engines are supported on steel trestles, and the sails are now replaced by a large number of narrow steel plates.

Many of these wind engines are to be seen in this country; but it is in America that they have found most



DIESEL OIL ENGINE

(*See p.* 89)

Photo. Warner & Co., Essex

WINDMILLS

(See p. 93)

favour. There, thousands of them are put to work every year.

With this new form of engine the mill is no longer placed away up in the air, but it is built upon the ground. The motion of the axle which carries the sails is transmitted to the ground level by another steel axle which passes up through the centre of the tower, and is driven by the sail axle through toothed wheels.

Most of the mills which have been erected in this country are used to pump water for the farm or for country houses. Some of them are made to drive machines which make electricity, and in this way houses, and even village churches, are lit.

One disadvantage of wind power is that it is very variable in amount. One day there may be a gale of such force as to nearly blow the whole mill over, while the next it may be calm, and so the farmer cannot get on with his work of grinding. If the engine is used for pumping water, a reservoir or tank has sometimes to be built of a size large enough to hold a supply of water sufficient to meet the needs during calm weather. If the wind engine be used for making electricity, the electricity can be stored in what are called "accumulators". When the mill is not working, these storage tanks—for that is what they really are—can give back the electricity which has been stored in them; and when the mill is started again they are re-charged.

Modern windmills are generally fitted with a brake which comes into action when the wind is high, and so prevents the speed from becoming too great.

28

THE POWER OF FLOWING WATER

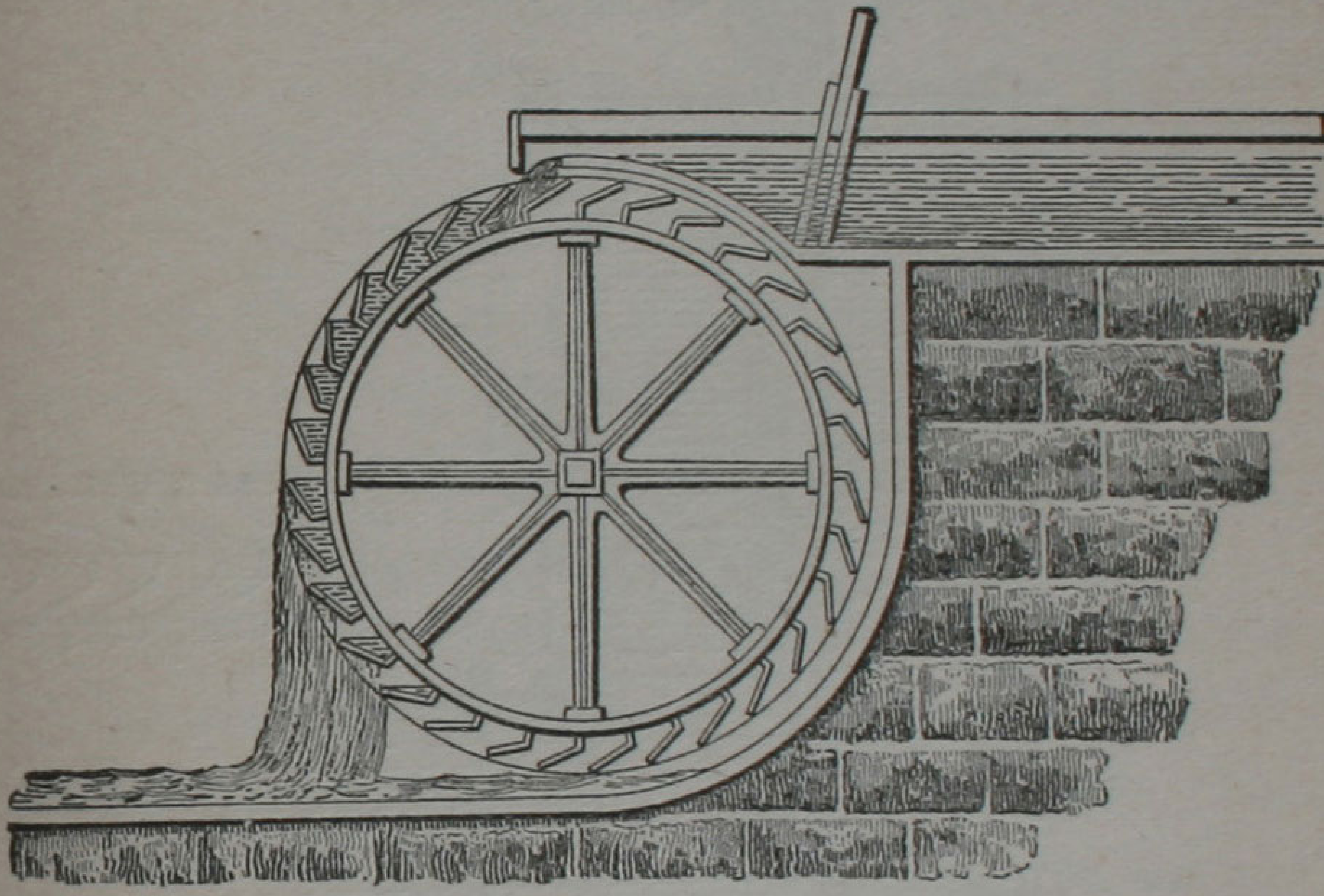
Water power, like wind power, has the great advantage that it is cheap. In this it differs from the power from steam or gas engines, which require coal to drive them. At one time the farmer built his mill beside a stream, so that he might have the power of the flowing water to drive it.

The first water wheel was very simple. It had a number of wooden paddles fixed to its rim, and it was carried by an axle which passed into the house in which the machinery was to be moved. These paddles dipped into the stream, and the flowing water caused them to turn, and so the grinding stones or other machines were revolved.

The supply of water, like the force of the wind, is very variable, and it is generally smallest at the end of the summer, just when the farmer wishes to grind his corn. When the stream is a small one it is sometimes necessary to build a dam farther up the stream, so that there will always be a store of water which can be used when the amount coming from the hills is small.

In this very simple and oldfashioned water wheel, the wheel is turned round because the moving water presses upon the vanes or paddles. The stream generally flows slowly, and so the power of the wheel is not very large. This kind of wheel is called an "undershot" wheel, because the water flows past the bottom of it.

There are other kinds of wheels in which the *weight* of the water can be made use of, but in order to do this, the water must be allowed to fall as it passes through the wheel. This is easily done if there be a waterfall close by, for then the water can be led by a channel from the top of the fall to the wheel, and after it has done its work there, it can be allowed to flow onward again at the lower level. When there is not a sudden

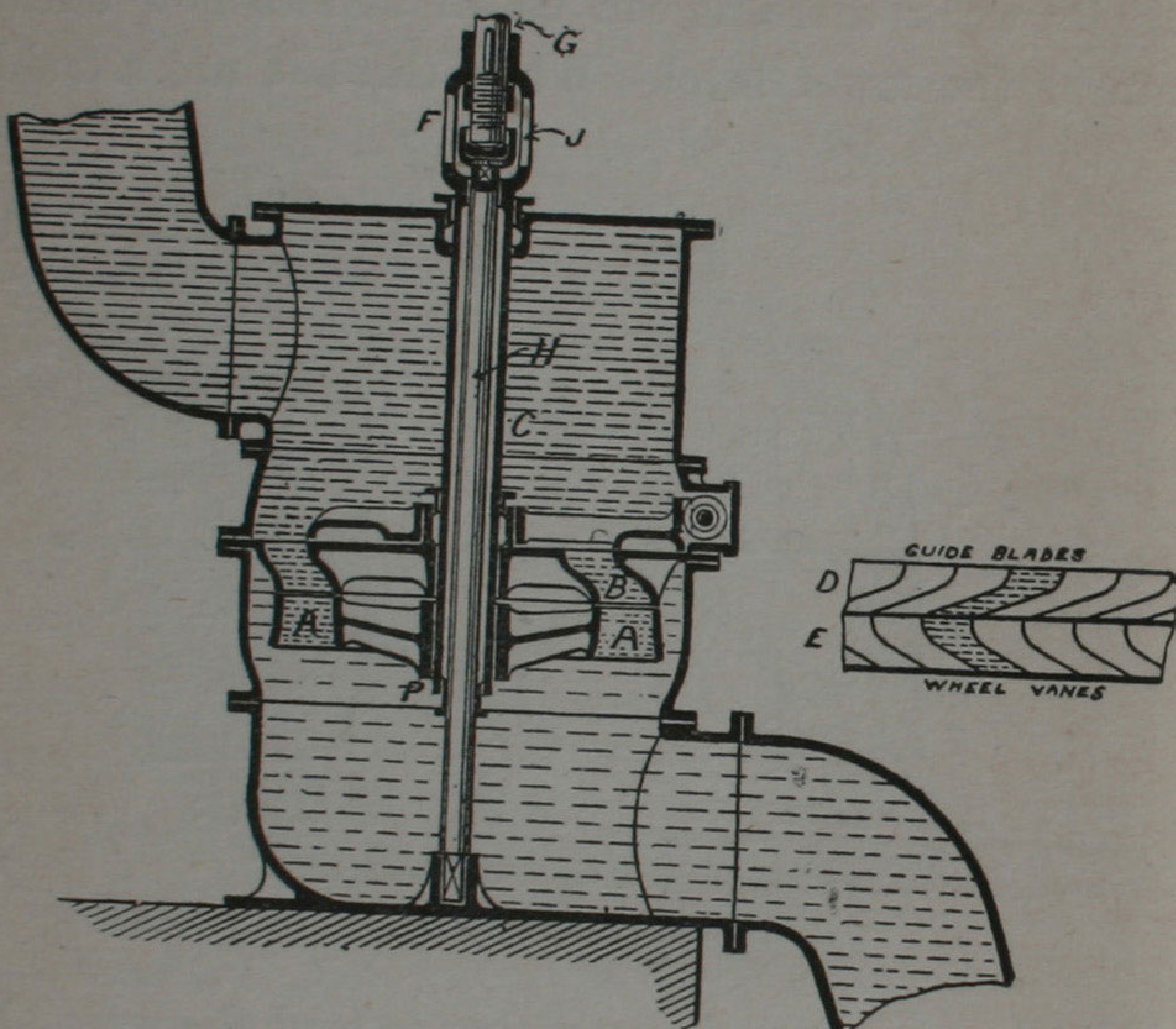


Overshot Water Wheel

fall in the stream, it is necessary to lead the water by a channel from a point some distance above that where the mill is to be placed.

In these wheels, buckets take the place of the vanes of the undershot wheel, and the water, as it flows on to the wheel, fills those buckets, and its weight causes the wheel to revolve.

When the fall is small the water enters the wheel about the level of the axle; but when there is a large drop it is usual to lead the water over the top of the wheel, where it enters the buckets. The first kind of wheel is called a "breast" wheel, and the second an "overshot" wheel. As the wheel turns round, the buckets tilt over, and so the water is emptied out, and it passes away by a channel to the stream again. Sometimes there is a kind of trap-door in the bottom of the



Water Turbine

Water flows from a height into the chamber *C*. It then passes between guide blades fixed in the ring *B*. These blades direct the water on to the vanes in the wheel *A* and so cause it to revolve. *A* is fixed to the shaft *H*, which is connected to the machine to be driven. The shapes of the guide blades and wheel vanes are shown at *D* and *E*.

channel which leads the water to the wheel. When it is desired to stop the wheel this door is opened, and the water drops down clear of the wheel altogether. Sometimes, too, the flow of the water is regulated by means of a gate, or sluice, which can be opened or closed according to the power required.

Now those simple wheels give only a small amount of power; and if the waterfall is a deep one they have to be made very large. They are therefore quite unsuitable when the waterfall is a large one. The modern type of water wheel is called a water turbine, and it is very much smaller than the oldfashioned water wheel of equal power.

In order to understand how this turbine works, let us imagine that a long upright tube is placed by the side of the waterfall, and that it extends from the top to the bottom of the fall. If the bottom end of the tube be closed, and the water be led in at the top, then the pressure of the water upon the bottom will be very great. Therefore, if an opening be made in the bottom the water will flow out at a very great speed.

Now let us cut a number of openings in the bottom of the tube near to the rim, and of such a shape that the water will be made to revolve as it flows out. That is to say, the holes do not point straight down, but are all inclined in the same direction round the circle formed by the tube. Below these openings or channels a disk is placed which has a number of blades projecting from the rim. The water, as it passes out from the tube, is guided so that it strikes these blades, and in this way it makes the wheel revolve at a high speed. The axle of the wheel passes up through the water to the top of the pipe, where the machine which it is required to drive is placed.

The great waterfalls of the world are capable of giving a vast amount of power. A few years ago there were millions of horse-power being carried to waste in these rushing torrents, but the engineer has learned how to harness these great forces of nature, and already hundreds of thousands of horse-power are being continually derived from the world's great waterfalls.

At Niagara great power stations have been erected in which these water turbines are placed. Some of them are so large that they give as many as five thousand horse-power. They are made to drive machines which produce electric currents. It is no longer necessary to place works and factories beside the waterfall, for this electrical energy can be carried along wires for over a hundred miles, and so it can be distributed in all directions and used for all sorts of purposes.

The waters of the Mississippi, too, are now under control, and from them power is derived to drive factories and tramcars, and for the lighting of cities, towns, and villages within a hundred miles of the power station. All this is made possible by electricity. The great rivers and waterfalls in Scandinavia, Switzerland, Italy, and Mexico are also made to give up their power to the service of man.

There are no very large rivers or waterfalls in Britain. We have to depend for our power upon coal; but coal is costly. Water power is made use of in Ireland for the manufacture of a substance called calcium carbide. It is from this substance that acetylene gas, which is used sometimes for lighting villages, and very often for cycle lamps, is made. The gas is produced simply by allowing water to come in contact with this carbide. Acetylene burns with a very brilliant light.

Some years ago a very large power station was erected at Kinlochleven, in Argyllshire. The rainfall at Kinlochleven is very great, and all the rain which falls within an area of about fifty square miles is collected in a large reservoir which has been constructed. This reservoir covers an area of nearly four square miles; it holds about one hundred million tons of water. It is over one thousand feet above sea level. This water is led down the mountain side by four steel pipes, each about one yard in diameter, to the water turbines which give out thirty thousand horse-power. This energy is used to produce electric currents, and these are led to the furnace in which aluminium is extracted from its ore.

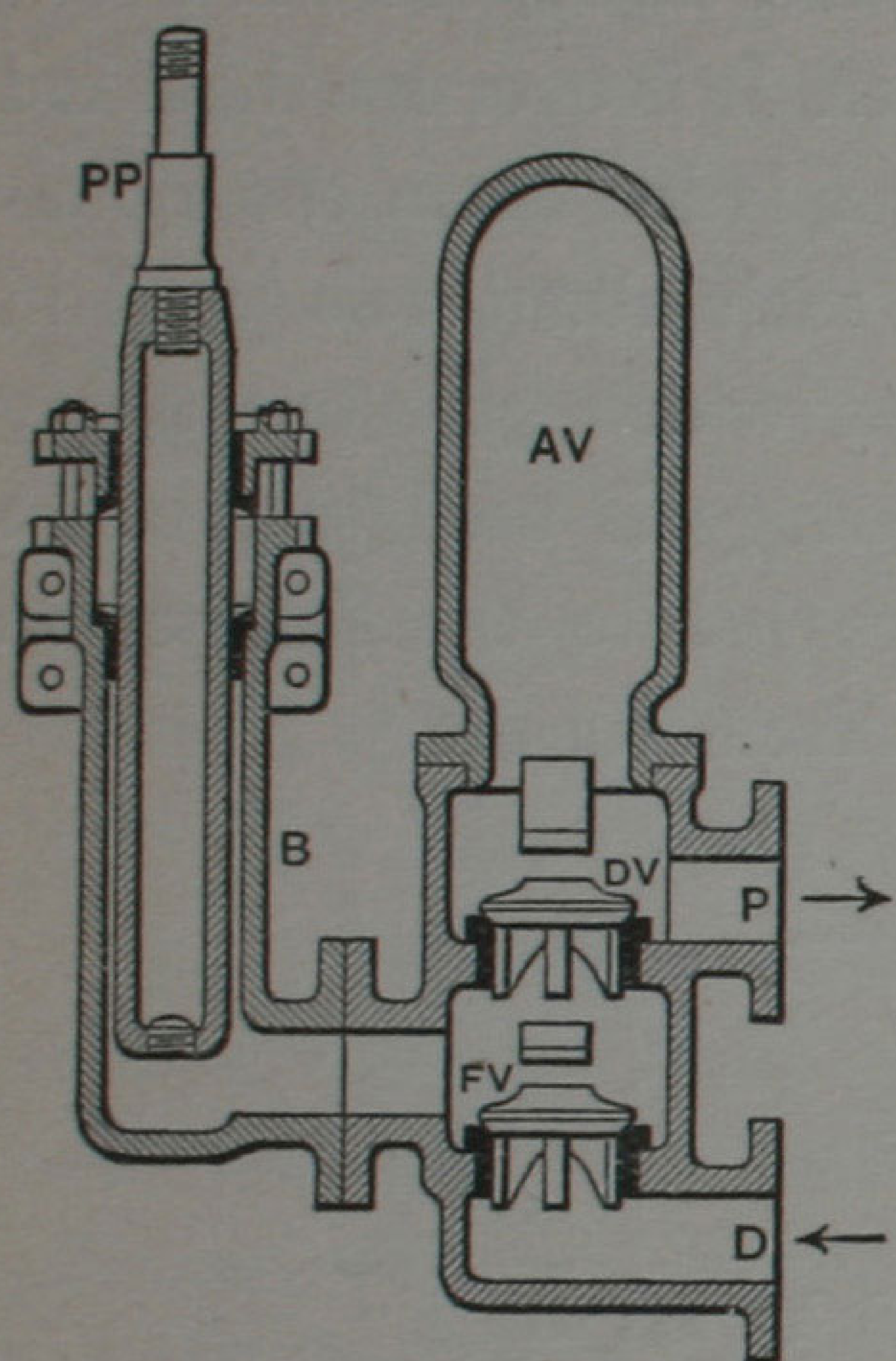
29

HOW WATER IS PUMPED

Water wheels and turbines do their work by the aid of falling water. Even in the simple undershot wheel with its paddles, water is falling gradually as it makes its way along the river bed, for otherwise it could not flow. If the paddles were driven round in the opposite direction by an engine of some kind, the water could be made to flow backwards, and then the wheel would become a pump.

Wheels of this kind have been used in foreign countries to force water along channels made in fields in order to moisten the ground in dry seasons. But this kind of pump can lift water through only very small heights.

Perhaps the syringe was one of the earliest kinds of pumps to be used; and it may have been from it that some of the modern appliances for raising water have been developed, for the simple pump which is to be seen in many country villages works in much the same way.



Force Pump

The piston or plunger P P is moved by an engine. When it rises water is sucked in at D, and it lifts the valve F V. When the plunger comes down again F V is closed, and the water finds its way through the valve D V, and along the pipe connected to P. A V is a vessel in which air is compressed. Its purpose is to make the flow of water steady.

The piston of this pump is moved up and down by the aid of a lever. When it is raised, a vacuum is formed below it and the water is sucked up through a little valve in the bottom of the cylinder or barrel. When the piston is pushed down again the weight of the water closes this valve, and it passes through another valve in the piston itself. On the next upstroke of the piston, this valve is closed just in the same way as the one in the bottom of the barrel was shut, and so the water is lifted up and it flows out at the top of the pump.

In another kind of pump which is used to force water to a great height the valve is not placed in the piston, but in the pipe which conveys the water away. This pipe is connected to the barrel near the bottom, and the valve is kept shut by the weight of the water which has already been forced past it, and is now standing in the

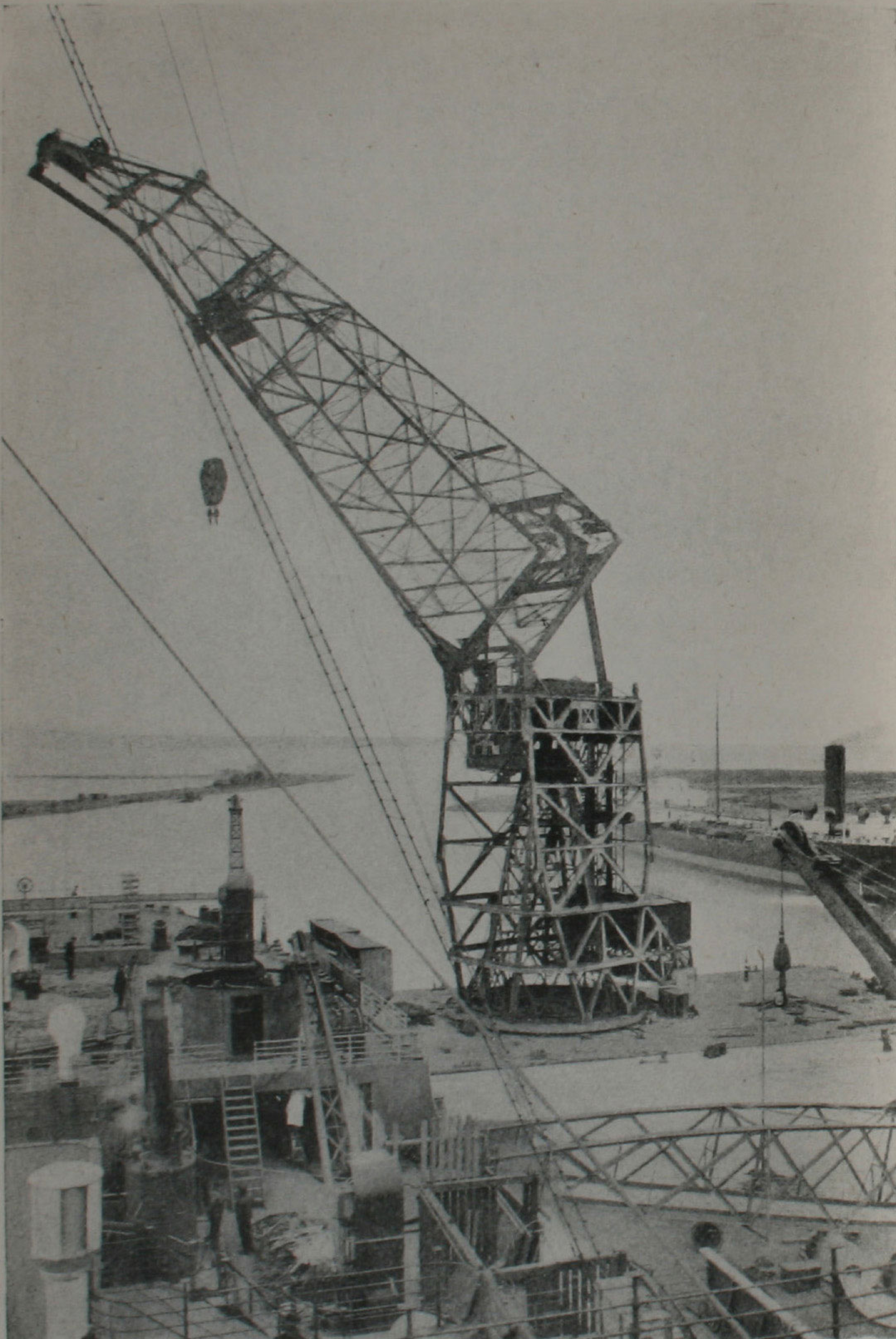


Photo. R. Welch

HYDRAULIC FLOATING CRANE

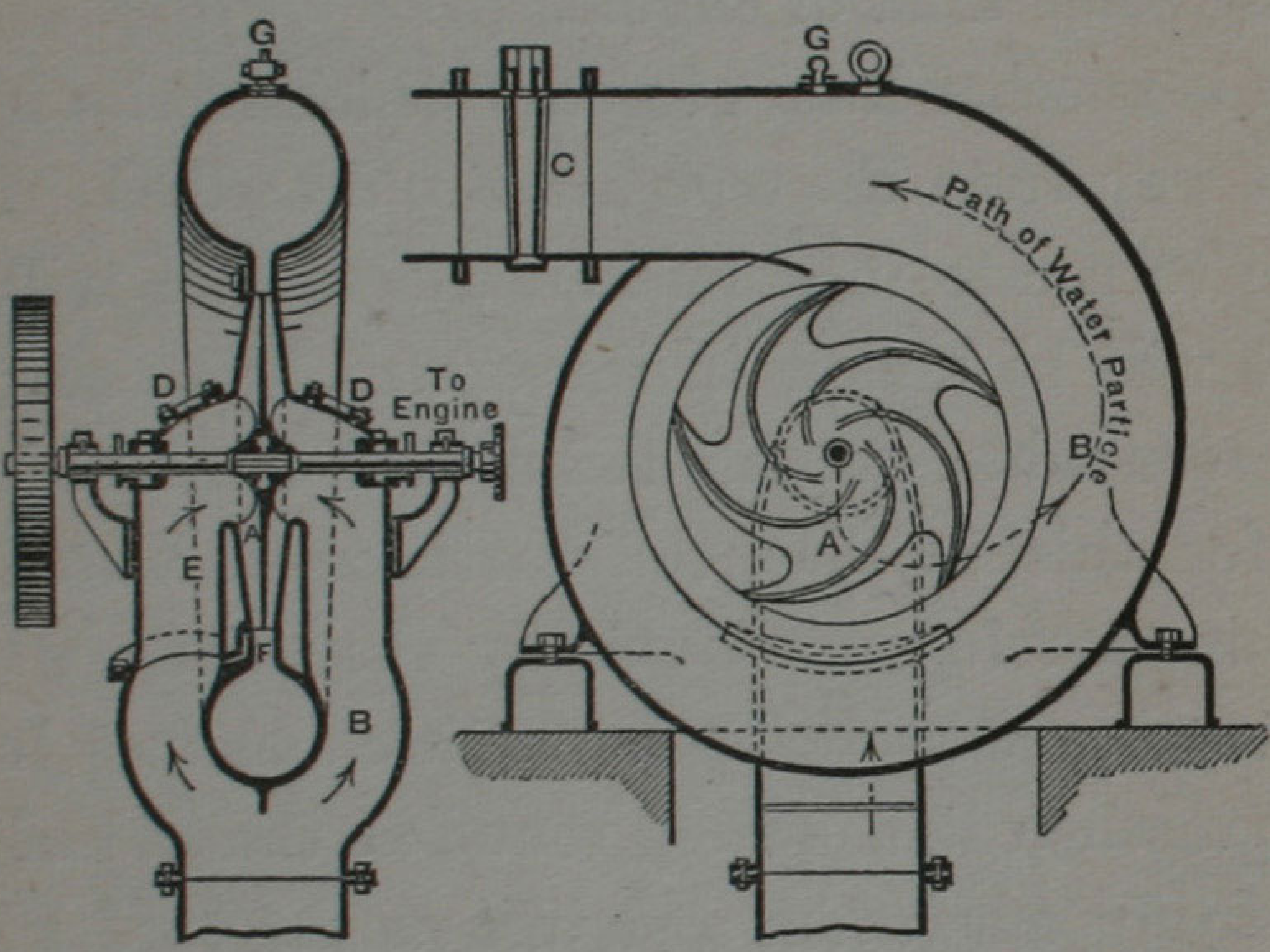
(See p. 106)

upright part of the pipe. Some more water is sucked into the barrel when the piston is raised, just as it was in the simpler form of pump; but when the piston comes down again, it forces the water past the valve in the pipe, and once past this valve it cannot return.

When the quantity of water to be lifted is small the pump can be worked by hand; but large pumps must be driven by some kind of engine.

There is another kind of pump which works in a very different way from the ones already described. If water be made to rotate in a bucket, the surface will not be level; it will be hollow in the centre. The same thing is to be seen when one empties a wash-hand basin. The reason for this is that the particles of water at the outside are moving more quickly than those which are nearer to the centre. Each particle behaves just as a stone does when it is swung round at the end of a cord; it tries to fly outwards; and just as the cord keeps the stone moving in a circle so the side of the bucket prevents the water from escaping. The rotating water in its effort to get away presses upon the inside of the bucket. The force which the water exerts, due to its being whirled round, is called a "centrifugal" force; and a pump which makes use of this force is therefore named a centrifugal pump.

The part of the pump which causes the water to whirl round resembles a water wheel. There is an axle to which a number of curved blades are fixed. This wheel is surrounded by a casing of metal, and there is an opening in the rim to which the pipe which conveys the water away is connected. There is also another opening in the side of this chamber which allows water to flow into the centre of the wheel. The axle which carries the blades projects out through the side of the casing, and it is driven round by an engine or electric motor. The revolving blades make the water spin round, and so it rushes to the rim of the wheel, and it passes away by the delivery pipe. More water is drawn in at the centre,



Centrifugal Pump

The disk A is rotated at a high speed by an engine or electric motor. This causes water to be sucked into the centre of the disk by the passages E. The water is carried round by the disk, and is forced out along the pipe C.

and it, in turn, is caught by the blades and whirled round, and so on. So a continuous flow of water is kept up.

This kind of pump has several advantages over the one in which a piston moves backwards and forwards in a cylinder. The most important of these is that no valves are required. Valves are very apt to get out of order and to become choked if the water is dirty. Another advantage is that the water flows quite steadily, whereas in the older form of pump the delivery is stopped each time the cylinder is being filled.

These centrifugal pumps are very powerful, and they can be made to lift water through many hundreds of feet. When the height to which the water is to be forced is great, sometimes more than one wheel is used—in fact a number of pumps are placed side by side, and the wheels are all mounted on one axle. The water enters the first one, and from there it is forced into the second —from the second to the third, and so on until the several wheels, acting together, have given it sufficient force to enable it to rise to the required height.

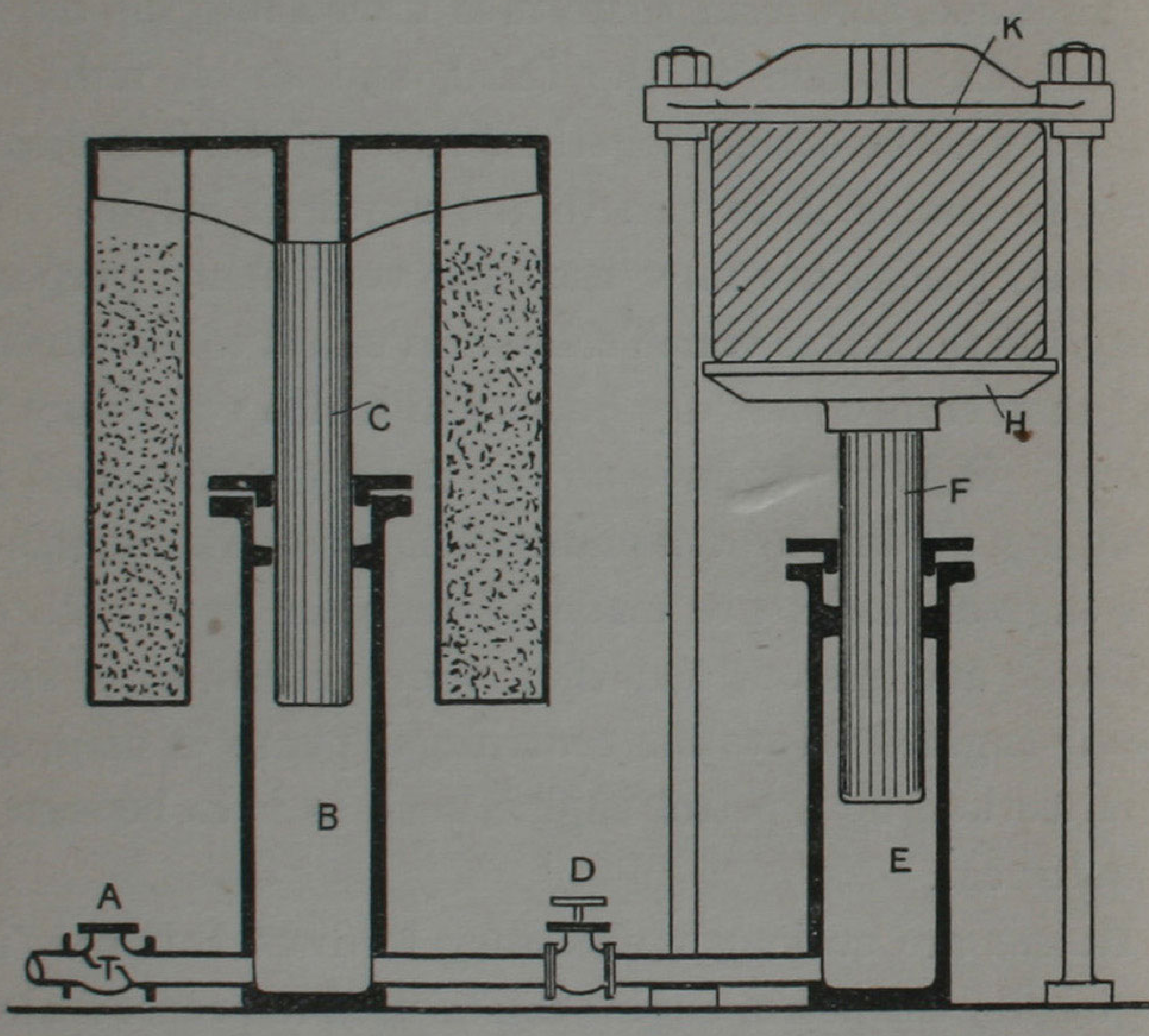
These pumps are now used for very many purposes. They lift the water which collects in mines to the surface, and they empty the "dry" docks in which vessels are repaired. Since they have no valves they can be used for pumping all kinds of liquids. The powerful pumps of fire engines used to be made of the older form with the cylinder and piston, and they were driven by a small steam engine. Now the centrifugal pump is used, and it is worked by a petrol engine, such as is to be seen on a motor car.

Horses are no longer necessary to draw this new fire engine, for the petrol engine can be used to propel it along the road, and when it reaches the site of the fire the engine is disconnected from the road-wheels and attached to the pump. When the pump was driven by a steam engine it was necessary to wait until steam was raised in the boiler; but the pump can be started on a moment's notice when the petrol engine is used.

30

SOME USES OF WATER POWER

Pumps are used not only for raising water, but also for giving it pressure. The water is then conveyed



Hydraulic Press and Accumulator

Water is forced by a pump past the valve A into the cylinder B. This raises the heavily loaded ram C. Meantime valve D is closed. The water cannot escape from B by the valve A, for the pressure upon the top closes it. So water under pressure is stored in the accumulator. When it is desired to work the press the valve D is opened, and the water is forced from cylinder B into E. This raises the ram F, and compresses the bale of cotton, or whatever it may be, between the faces H and K.

through pipes and it is made to work machinery. The water under pressure can be stored in what is called a "hydraulic accumulator". In the accumulator there is a long, upright cylinder in which a piston works. This piston is usually different from the one used in a steam engine, for it is much longer and it projects out of the cylinder; it is more often called a ram. The upper end of this ram is loaded with many tons of stone or pig iron. Water is forced into the cylinder by a powerful pump, and so this great weight is lifted. Once the water is in it cannot escape, for its pressure shuts the valve through which it entered.

The weight on the top of the ram gives the water very great pressure. The pump continues to force in water until, when the ram has risen to a certain height, it moves a lever which shuts off the steam from the engine which drives the pump and so stops it. A great deal of energy has been spent in raising this weight, and this is now stored in the water, and it can be made use of when required for working many kinds of machines.

It was Lord Armstrong who first suggested that water under pressure could be used for working machinery, and especially in connection with the loading and unloading of vessels; and it was he who invented the hydraulic accumulator. But to-day this form of power is made use of in many different ways.

Lord Armstrong first applied his idea to the working of cranes. Instead of winding the lifting rope round a drum, as is so commonly done in small hand-worked cranes, he attached the end of it to the end of a ram which worked in a cylinder in such a way that, when the ram moved outwards, the load suspended from the other end of the rope was lifted. A pipe was led to this crane cylinder from the accumulator, and when a valve in this pipe was opened the weight upon the accumulator ram forced the water into the crane cylinder, and so the ram there was made to move outwards and the load was lifted.

In order to lower the load another valve was opened which allowed the water to flow out slowly, and so the ram came back into the cylinder by its own weight. The rope was made to pass over a number of pulleys which were so arranged that the load was raised faster than the ram moved. These cranes are very powerful, for the pressure of the water is sometimes as great as a thousand pounds on every square inch of the end of the ram.

Cranes of this kind are placed on board ship, and they are used for lifting the cargo on board. They are also to be seen at most docks, and there they are very often mounted upon the top of a large frame which can be run along rails to the place where the load is to be raised. In these large cranes the frame is sometimes so big that it bridges over several lines of railway along which trucks can pass. The water required for the working of the crane is taken from a pipe which is led along by the side of the rails upon which the crane runs (p. 101).

Some cranes are fitted with other cylinders, very similar to the one used for lifting. These are for turning or "slewing" the crane round upon its base.

Another apparatus which one sees at the docks is worked by water. This is the "capstan", and it is used for drawing trucks along the rails and for other similar purposes. The capstan is an upright frame round which the rope which is attached to the truck is wound two or three times, and the loose end is held in the hand. There is an engine underneath this capstan which causes it to rotate. This engine resembles the steam engine, but it is driven by high-pressure water instead of by steam.

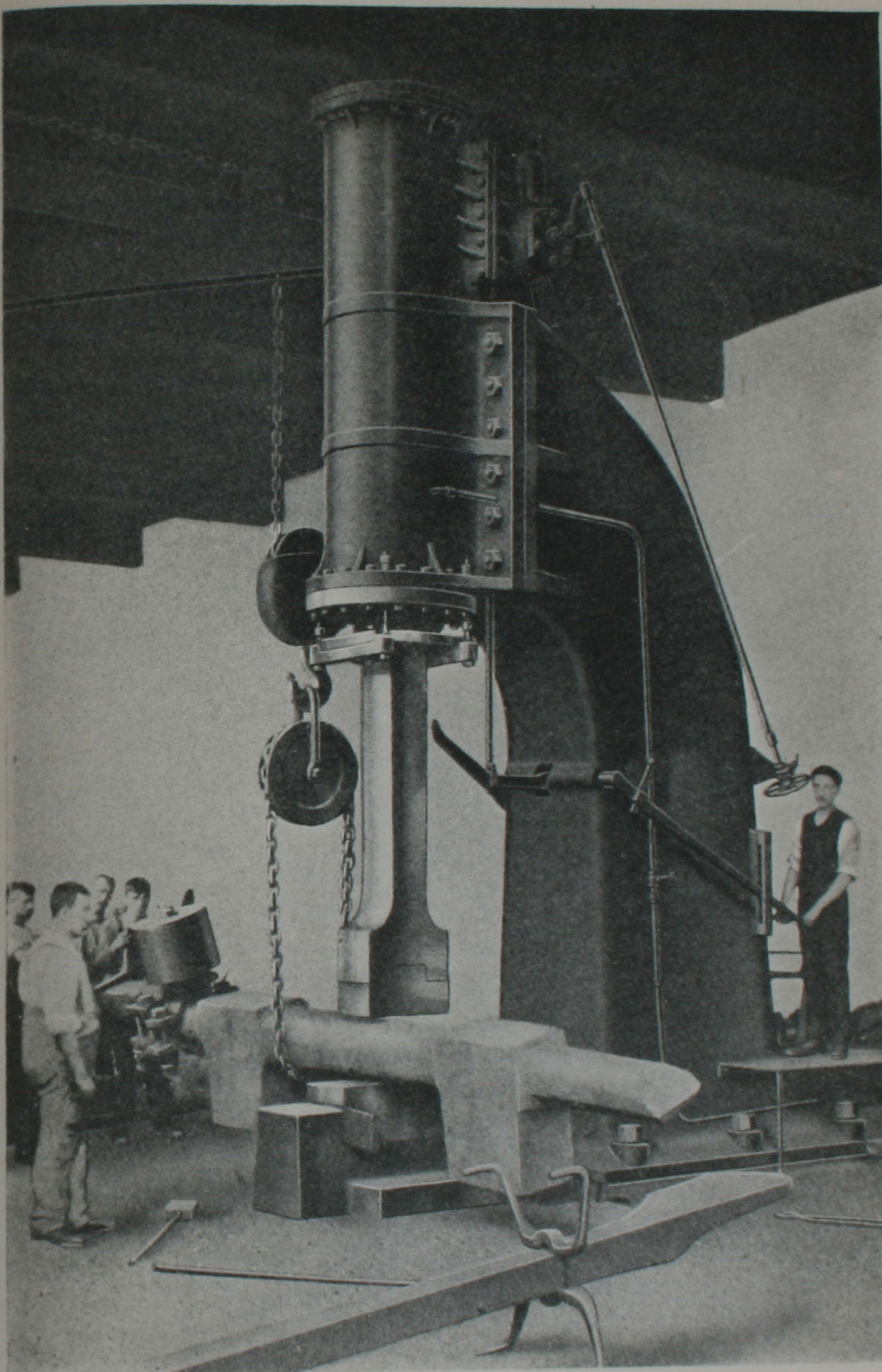
The hoists which are used for loading vessels with coal are very often worked by water power. The trucks of coal, which sometimes weigh thirty tons, are hauled by the aid of a capstan on to a large platform. Wire ropes are attached to the corners of this platform, and after passing over pulleys which are fixed at the top of the high steel tower in which the platform moves, they are fixed to a ram in such a way that when the ram is forced out, the platform and the truck are lifted.

The end of the truck next to the vessel is taken out, and other hydraulic cylinders are then made to lift the other end of the platform. So the truck is tilted up and the coal runs out into a long shoot from which it drops into the hold of the vessel.

Some cargo vessels are fitted with cranes and other lifting machinery which are worked by water power. On warships, too, many examples of the use of water under pressure are to be seen. When a large gun is fired, not only is the shell sent out at a high speed, but the gun is pushed backwards with great force. The gun is allowed to run backwards for some distance and it is brought to rest gradually. There is a ram connected to the gun, and as it moves backward, it forces water out of the cylinder in which it works. But the water has to pass through a small opening, and it takes some time to do this. It therefore resists the backward motion of the gun and gradually brings it to rest. Some railway stations are fitted with buffers which work in this way.

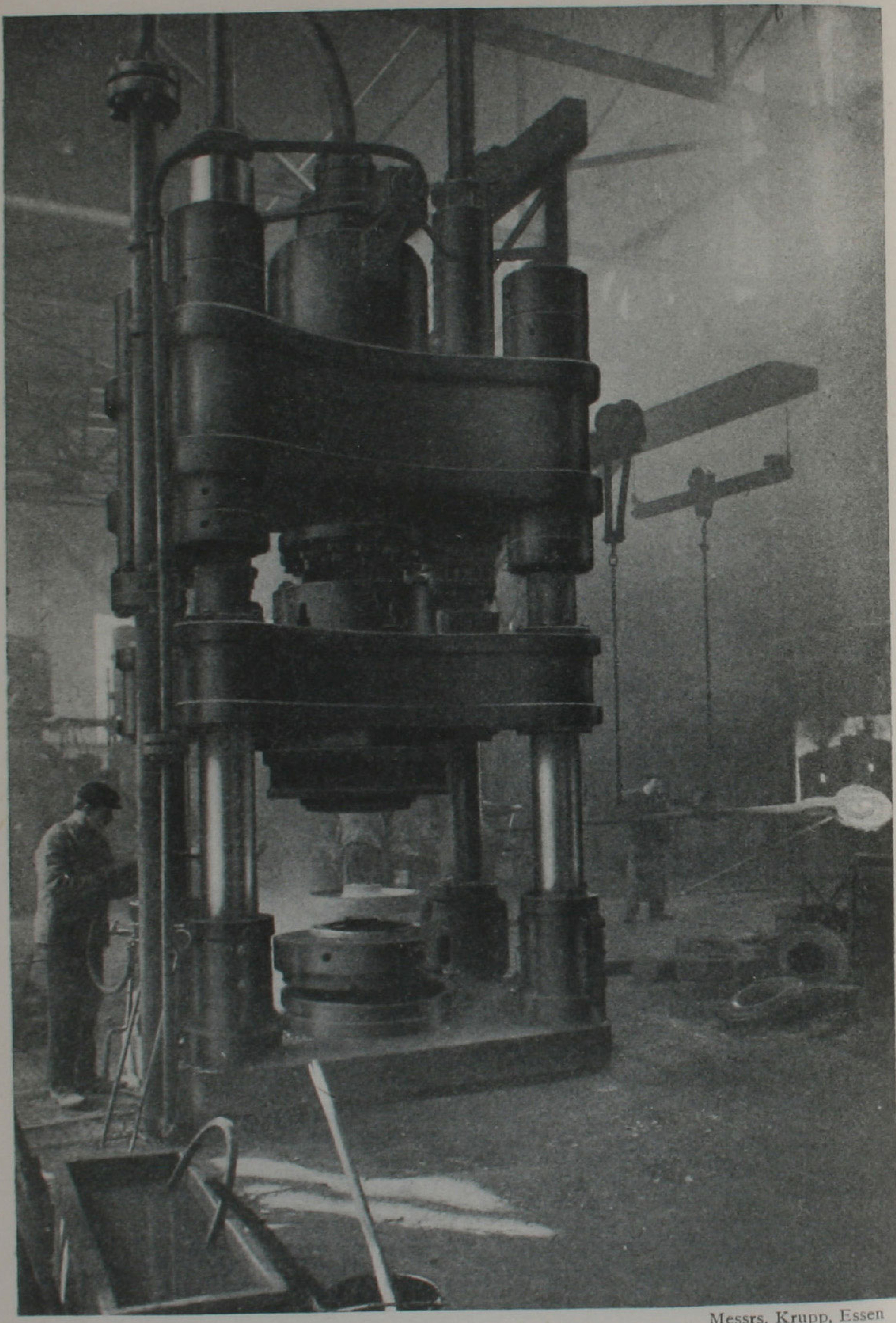
The shells which are to be used in the gun are stored low down in the ship, and, when required, they are lifted to the firing platform by the aid of a hoist worked by water. The back end, or "breech", of many guns is opened and closed by hydraulic power, and the shells, too, are often pushed in by a ram. It must be remembered that these shells are very heavy. Those which are used in the largest guns weigh not very much less than half a ton each.

Hydraulic power is of great service on land, and in some cities water under pressure is conveyed below the ground to factories and works. In London there are nearly two hundred miles of these water pipes, and they convey over ten thousand tons of water every day for working cranes and machinery. Many bridges which span rivers and the entrances to docks have to be moved before ships can pass. Sometimes the bridge is supported on a pier in the centre of the river, and when a ship comes up, the bridge is swung round, so that it lies the lengthway of the river. Or the bridge may be made in halves, each half being mounted on very strong hinges which are fixed to columns of stone on the banks of the river or on the quay walls. The two halves meet at the centre. When the bridge is to be opened, the two parts are turned about the hinges until they are in an upright position and so a clear passage is made for the vessel. These bridges are generally worked by water power.



STEAM HAMMER

(*See p.* 109)



Messrs. Krupp, Essen

HYDRAULIC PRESS

(*See p.* 111)

31

THE SHAPING OF IRON

We have often watched a blacksmith forge a piece of hot iron on his anvil into a horseshoe or some other form. The fashioning of iron in this way has been practised for centuries, but when a large piece of machinery is to be shaped the blacksmith's strength is not sufficient. Sometimes he has to be assisted by a man called a striker, who deals the metal heavy blows with a large forehammer, while the blacksmith holds the work upon the anvil and directs him where to strike. But even then only small articles can be made, for iron is difficult to forge.

About the year 1842 a man of the name of Nasmyth invented a hammer which was worked by steam. This was the first steam hammer, and without it the engineer would be unable to shape the parts of the great engines and machines which he builds.

The steam hammer is just a special kind of steam engine. The cylinder is much the same. It is placed in an upright position and it is mounted on the top of one or more columns. The piston rod comes down through the lower end of the cylinder and it has a heavy hammer fixed to it. Below this is the anvil block upon which rests the metal to be forged (p. 108).

In the early hammers, steam was admitted to the under side of the piston by a sliding valve very like the one which is used on the steam engine. In this way the hammer was raised. The steam was then allowed to escape and the heavy hammer, and the piston rod and piston attached to it, fell upon the metal. Later, hammers were made which were supplied with steam on the upper side of the piston as well as on the bottom. In this way the force of the blow was very greatly increased; for now all the pressure of the steam was added to the weight of the hammer and the parts attached to it.

The valve which distributes the steam is generally moved by hand by means of a lever which is placed at the side. It is interesting to watch a steam hammer at work, and to see the wonderful control which the man has over the force of the blow which it deals. By moving the lever in certain ways he can cause the hammer to give either a sharp blow or a gentle tap; or he can make the hammer head move very slowly and so give the hot metal a great squeeze. A man who knows his hammer well could be trusted to place a watch upon the anvil, and to let the hammer drop upon the glass and crack it without damaging the works. Some of these hammers are very large, and they are able to deliver blows of many tons.

Sometimes it is required to forge iron into special forms. This can be done by placing a suitably-shaped iron block or "cress" below the bar of iron, and another upon the top. These blocks form a sort of mould and the blows of the hammer force the metal to fill it.

If the block of metal is very thick the effect of the blow may not reach the centre and so an unsound forging will be produced. It is better in such cases to use a machine which gives a steady pressure, or squeeze, rather than a sudden stroke.

The hydraulic press is used for this purpose. The press resembles the accumulator about which we read in the last chapter. The cylinder is mounted on the top of a strong frame and the ram comes out at the bottom. The hot ingot of steel, which may weigh fifty tons, is laid upon the anvil block below, and then water is admitted behind the ram from an accumulator. The ram is forced down upon the metal, and it gives it a great squeeze. In the largest presses of this kind the pressure given by the ram is about two thousand tons.

The hydraulic press is used for many other purposes besides the forging of steel. Esparto grass, which is used for making paper, and other substances, such as cotton, are pressed into bundles by its aid. This is done in order that they may occupy less space in the ship than they would do if they were left in their loose state; and so the cost of transport is reduced (p. 109).

It is this kind of press which is used for forcing lead and other metals through openings in plates in order to form the wires and pipes which we read about in an earlier chapter.

Another purpose to which the hydraulic press can be put is the bending of plates which are too large to be rolled into the desired form. The plates which form the ends of boilers are shaped, while hot, by the aid of this machine.

Small hydraulic presses are also used for forming the heads on rivets which are used to connect plates together. The rivets are heated and inserted in the holes prepared for them, and then they are placed in the press and the water is turned on and the little ram comes down and shapes the head. These small machines can easily be carried about, and so it is unnecessary to shift the heavy plates. Sometimes this could not be done, as, for instance, in building a bridge, for then the plates have to be riveted together in their proper positions. The wheels of railway carriages are forced on to their axles by the aid of hydraulic pressure.

32

COMPRESSED AIR

We have learned that steam, or gas, or water under pressure, can be made to do work. Compressed air, too, can be used for driving machinery. The apparatus used for compressing air is very like a steam engine, but instead of steam entering the cylinder and driving the piston backwards and forwards and so turning the shaft, the shaft is now driven by some other means. It may be revolved by any kind of engine or by an electric machine or a water turbine. In this way the piston is made to move to and fro, and so the machine now acts like a pump. When the piston moves in one direction it sucks in air, and when it comes back again this air is prevented from escaping, and so it is compressed.

When the pressure reaches a certain amount, a valve is opened, and as the piston continues to move, this compressed air is forced into a large storage tank, or receiver. When once in the receiver the air cannot get out by the way it entered, for its own pressure shuts the valve. It will be seen that this air receiver corresponds to the hydraulic accumulator. The piston then moves out again, and draws in a new supply of air, which it compresses just as it did the previous one.

There is now locked up in the receiver a supply of compressed air which may be drawn off as required. If the compressor were to continue running it would force more air into the receiver, and if none were being taken out the pressure would increase until something burst. To prevent this, a safety valve is fitted upon the receiver. But even then, if the compressor did not stop, it would simply waste its energy in forcing the air past the safety valve into the atmosphere again. There is therefore an apparatus which regulates the supply of power to the machine which drives it. When the pressure rises to the highest value which it is considered safe to allow, the power is shut off, and the compressor is stopped and does not begin to work again until some of the air has been drawn off.

Compressed air is largely used in mining. Instead of the oldfashioned pick, the miner has machines which can bore holes and cut slots in the bed of coal. There are many varieties of these machines—one is the "pick" machine. It is mounted on wheels, so that it can be readily moved from place to place in the mine (p. 116).

If we think of the cylinder and piston of a steam engine, we will be better able to understand how this machine works. Instead of steam, compressed air is used. It is supplied through flexible pipes from a compressor which is situated at some convenient position in the mine. There is a little valve on the top of the cylinder which moves very rapidly to and fro, and so admits the air to the cylinder, first on the one side of the piston and then on the other, time about.

The machine is wheeled into position and a tool is fixed to the end of the piston rod. The compressed air is then turned on and the tool is driven against the material to be cut. The valve shuts off the supply to that side of the piston and admits it to the other, and so the tool is brought back. But it is immediately forced forward again by a fresh supply of air. In this way the tool is made to give a series of blows similar to those which a hammer would give. These machines work very rapidly. The tool can be made to give as many as two hundred and fifty blows in a minute, and the force of the blow can be regulated to suit the nature of the coal or stone which is being cut.

A machine of this kind can be made to undercut the bed of coal for a distance of five or six feet from the surface. This done, the coal above is loosened, and it tumbles down and is removed in trucks to the bottom of the shaft, and then raised to the surface in the cage. Sometimes it is necessary to blast the coal or stone in order to get it out. To do this a hole is drilled into the bed, and a charge of explosives inserted and fired. These holes can be drilled by small machines which are worked by compressed air in much the same way as the coal cutter is. They can cut a hole about six feet deep in two or three minutes. This is very much quicker than a man could do it.

33

COMPRESSED AIR (*Cont.*)

Compressed air is also used for driving the pumps which raise water out of the mine. In some mines the trucks of coal are pulled along by ponies, and in others by a wire rope driven by an engine. In many American mines they are drawn by locomotives very like the steam locomotives we see on our railways, but driven by compressed air which is stored in a tank or receiver carried by the engine itself. Just as a railway locomotive gets its supply of water from a water-tank, so the air locomotive is supplied, when required, with compressed air from a large reservoir placed at the side of the track in the mine.

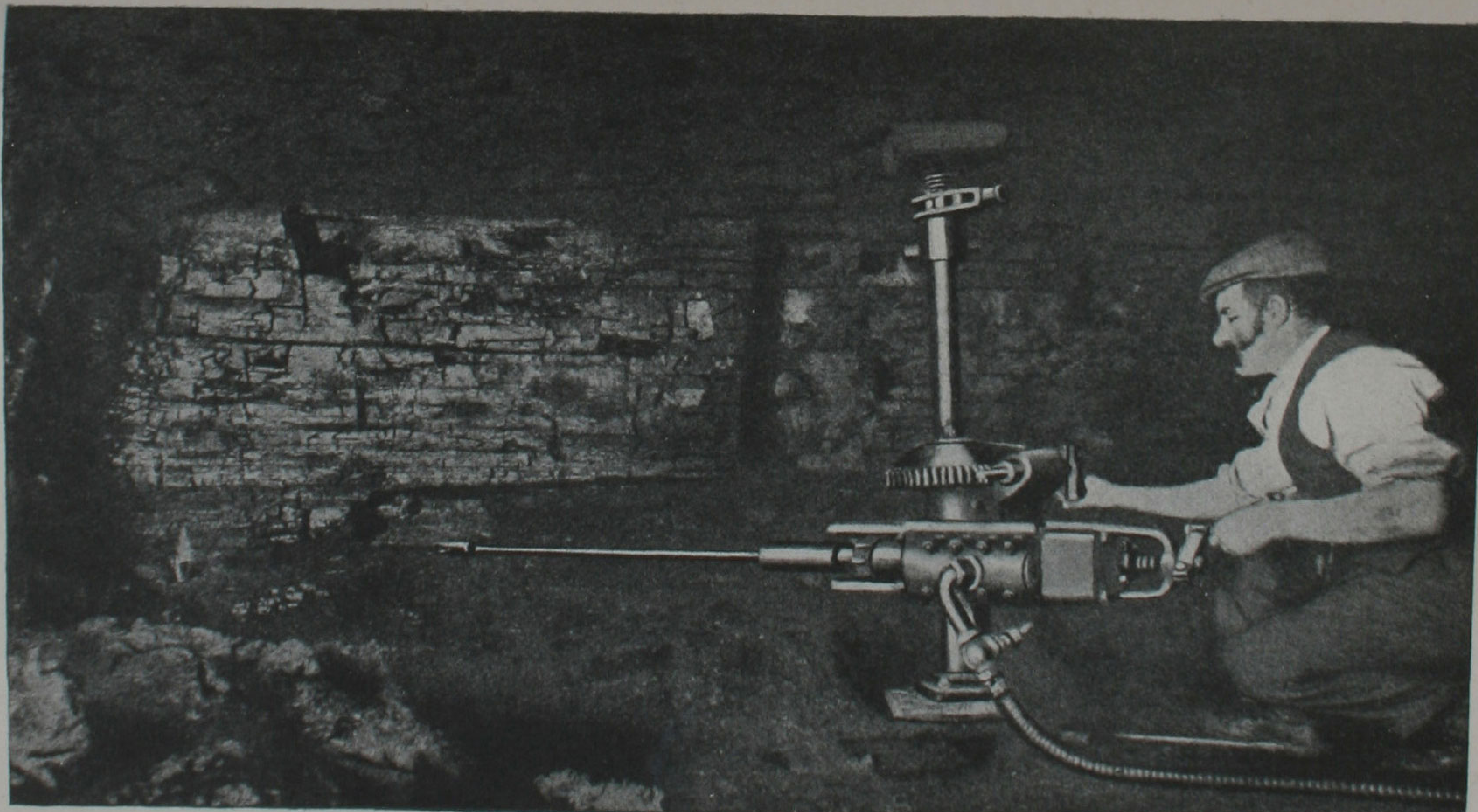
The engineer makes many uses of compressed air in the manufacture of machinery. By means of tools operated by it he can cut through steel plates with very little trouble. The machine he uses for this purpose works in the same way as the coal-cutter, but it is very much lighter. The tool, too, is of a different shape; in fact it is just a chisel. The machine is held against the plate, and the little valve which regulates the supply of air is opened. The chisel strikes the plate, just as it would do if hit with a hammer, only the blows are stronger. They follow one another, too, very much more rapidly. The chisel pares off a thick shaving in much less time than a man could do in the oldfashioned way.

Little machines can be carried about by hand for drilling holes. It is much easier to carry a small machine, and the air pipe which connects it to the reservoir, to the work than to lift a heavy boiler or other structure to a stationary drilling machine. Not only so, but those little machines can get into out-of-the-way corners which could not be reached by the ordinary form of machine. Hammers very like those for cutting steel are also used for dressing and carving stone.

Compressed air has also been used for driving tramway cars. There are many miles of pipes under the streets of Paris which convey air which has been compressed in a central station to the manufacturers' works, there to be used for driving all kinds of machinery. In America, too, one finds air power distributed in the same way.

When a dock is to be built, great cylinders made of steel have to be sunk far down into the bed of the sea in order that the walls may have a strong foundation. These "caissons", as they are called, have strong steel shoes fixed to their lower ends. These shoes are sharp, and the weight of the metal above forces them into the clay. Compressed air is very often used to force out the water from the insides of those cylinders as they gradually sink down into the bed of the sea.

Within the last few years compressed air has been used in the larger post offices for conveying telegrams from one department to another, and even for sending them to other offices some distance away. The tubes are generally made of lead. The carrier in which the telegram is placed really forms the piston, and the long tubes, the cylinder, of an engine.



COAL-CUTTING MACHINE

(*See p.* 113)


Sulzer Bros.

DRYING AND DRESSING ROOM, LA NEGRA REFRIGERATED-MEAT PLANT, BUENOS AIRES

(See p. 123)

When the telegram is received at the office it is placed in one of these carriers which is then inserted in the tube. The opening in the pipe is then closed, and the compressed air is turned on, and the carrier is shot along the tube to the room where the telegraphic instruments are placed. The empty carrier is then sent back again and is ready to receive another message.

Under the streets of London there are many miles of tubing through which telegrams are continually passing from one office to another. In some American cities parcels are handled in much the same way.

Air under pressure has been used in place of explosives in guns, but it has not yet proved successful. It is, however, applied to the firing of torpedoes.

34

MACHINES WHICH MAKE ICE

We are all familiar with a great many ways of producing heat. We heat our houses by burning coal, and our schools and other buildings by hot water or steam. But we probably never think of how cold can be produced, perhaps because it has never occurred to us that cold is required.

We have often heard of the frozen meat which comes in shiploads from the Argentine Republic, Australia, New Zealand, and other parts of the world, and we have noticed the blocks of ice which enable the fishmonger to keep his fish fresh on a hot day. We may have heard, too, of skating rinks and curling ponds of artificial ice. It is to machinery that we owe all these.

It is well known that all articles of food which readily decay when exposed to even ordinary temperatures can be preserved for very long periods if they are kept sufficiently cold. Grouse, &c., according to law, must not be shot before the twelfth of August. Yet in London, which is many miles from the nearest shootings, ample supplies of grouse are to be had in the early morning of that day, and long before they could be conveyed thence. But these are birds which have been shot at the end of the previous season and preserved in "cold storage", or the "refrigerator" as it is called, until they can be sold without infringing the law; for it is illegal to sell, as well as to kill, game during the close season.

There are several ways in which cold can be produced, all depending upon well-known physical laws. It will be well first to consider one or two simple examples of these laws.

The first law tells us how the pressure and the temperature of a gas are connected with one another. If water be boiled in an open vessel the temperature of the water, and of the steam which is formed from it, is what is commonly called the "boiling-point". This boiling-point is 212 degrees on the thermometer which we generally use in this country.

Different liquids boil at different temperatures. But if water be formed into steam inside a boiler in which the pressure is very high, the temperature will now be much greater than 212; in fact, the higher the pressure, the higher will be the boiling-point.

This fact is made use of in order to find the height of a mountain. The higher we ascend from the level of the sea, the lower does the pressure of the atmosphere become, for there is not so much air above the top of the mountain as there is above the sea. If water be boiled at those two levels, then the boiling-point at the sea level will be higher than the boiling-point at the mountain top, and from the difference between these boiling-points, the man of science can tell the height of the mountain above the sea.

It is well known that it is impossible to cook an egg at the top of a high mountain. The reason for this is that the egg requires to be heated to a certain temperature to be properly cooked. The boiling-point of water at the sea level, or not very far above it, is quite high enough to do this, but it is not so at the top of the mountain.

If a quantity of water be placed in a closed vessel and the air be extracted from above it, our law tells us that it will boil at a low temperature, for the pressure is now lower than that of the atmosphere. In fact, if there is a very good vacuum above the water it will boil at what we are accustomed to call "freezing-point", or the temperature at which water, when exposed to the air, becomes ice.

Then the second law comes into play. When a liquid is changed into a gas or vapour it absorbs heat. For example, the steam which is formed when water boils takes up a great amount of heat from the burning coal. In the same way, when the water in the vacuum is changed into a vapour, the vapour absorbs heat. But where does it get this heat, for there is now no burning coal to supply it? The truth is that when a little of the water boils, the vapour takes the heat from the remainder and so cools it, and it is formed into ice. Blocks of ice can be made in this way.

There is another familiar example of this cooling effect of boiling liquids. If a little methylated spirits be dropped upon the hand a sensation of cold will be felt. The reason is that the spirits evaporate, or boil, when exposed to the air, and the vapour in forming takes heat from the hand, and so it is cooled.

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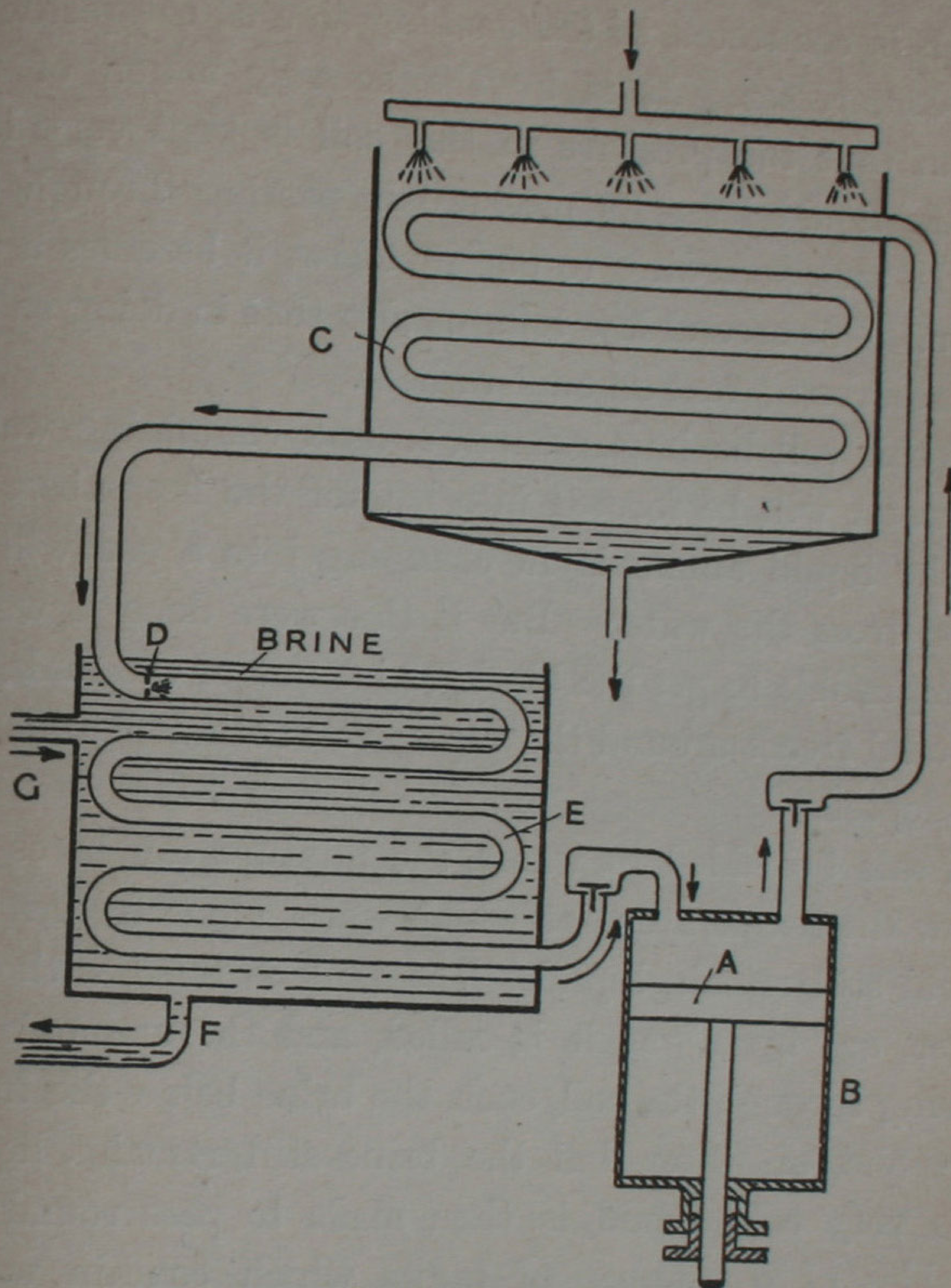
MACHINES WHICH MAKE ICE (*Cont.*)

It is by changing vapours or gases into liquids, and back again, that most ice-making machines work. One of several substances may be used. Ammonia is one of the most important.

The chief part of the apparatus is the compressor. It is very like the air compressor which was explained in the last chapter, only it is ammonia gas that is compressed instead of air. As the piston moves along the cylinder it sucks in the gas on one side, and it also compresses the charge which has previously been drawn in on the other.

This compressed gas is forced into a coil of pipe over which cold water is allowed to flow. The water takes heat from the ammonia gas and so changes it into liquid



The "Refrigerator"

When the piston A of the compressor B is moved upwards by the engine (not shown), ammonia gas is forced into the coil C, which is kept cool by means of flowing water. Here the gas becomes liquid. It then passes through the small opening D, and becomes a gas again as it enters the coil E. It absorbs a large amount of heat from the brine surrounding the coil, and so cools it. The cold brine is then pumped out at F and forced through pipes placed in the cooling rooms. Or the brine may be made to pass round the outsides of tanks containing fresh water which is to be converted into ice. It returns to the brine tank at G. The ammonia gas is sucked from coil E when the piston A moves downwards, and is compressed as before when the piston ascends.

ammonia. From this coil of pipes the liquid ammonia is forced through a small hole, or nozzle, into another coil which is connected to the sucking side of the piston of the compressor. It is by the sucking action of the piston that the pressure in this coil is kept very low. So the liquid loses its pressure in passing through the nozzle, and, according to our first law, it becomes a gas again. Our second law tells us also that in doing so the gas absorbs a great amount of heat.

If this coil be immersed in a tank containing water, the water will be formed into ice, for the heat absorbed by the liquid ammonia in changing into a gas will be taken from the water. But if this were done it would be impossible to get the block of ice out of the tank, for it would freeze around the pipes; so another plan has to be adopted.

If salt be added to water, the mixture can be cooled below the temperature at which water alone freezes and it will still remain liquid. The tank is filled with salt water, or "brine" as it is called, and the ammonia, in passing through the coil, cools the brine below the freezing-point of water, but the brine still remains liquid. This very cold liquid is then made to pass round the outsides of a number of tanks which contain water. The water is cooled in this way, and blocks of ice are formed. The ammonia gas is then sucked into the compressor again, and there its pressure is raised. It is then cooled and expanded through the nozzle just as it was before; so the same ammonia is used over and over again.

The cold brine, instead of being used to make ice, is often circulated in pipes which surround rooms just in the same way as hot-water pipes are used for heating buildings. The articles of food, such as carcasses of animals, game, vegetables, fruit, and fish, are hung or stored in these rooms. The cold brine cools the air in the room below freezing-point, and so the contents are preserved until required (p. 117).

The walls of these cooling rooms are double, and the space between is filled with materials which are very bad conductors of heat. This is necessary, for otherwise the heat of the outside air would pass through the walls, and it would be impossible to keep a low temperature inside.

The carcasses which come from abroad are frozen in a room of this kind before they leave. The freezing must not be carried out too rapidly, for then only the outsides would be frozen and the inner portions would decay. The ships which carry these carcasses are fitted with cooling chambers, and so they are prevented from thawing. When they arrive they are placed in the cold storage, which is generally situated near the docks.

The first cargo of frozen meat was brought to this country in 1881. Now, thousands of carcasses, shiploads of fruit, and millions of gallons of frozen milk and cream arrive every year.

All our large passenger ships are provided with cooling rooms, so that the passengers can enjoy fresh food instead of the tinned articles which would have to be used if these cold chambers were not there.

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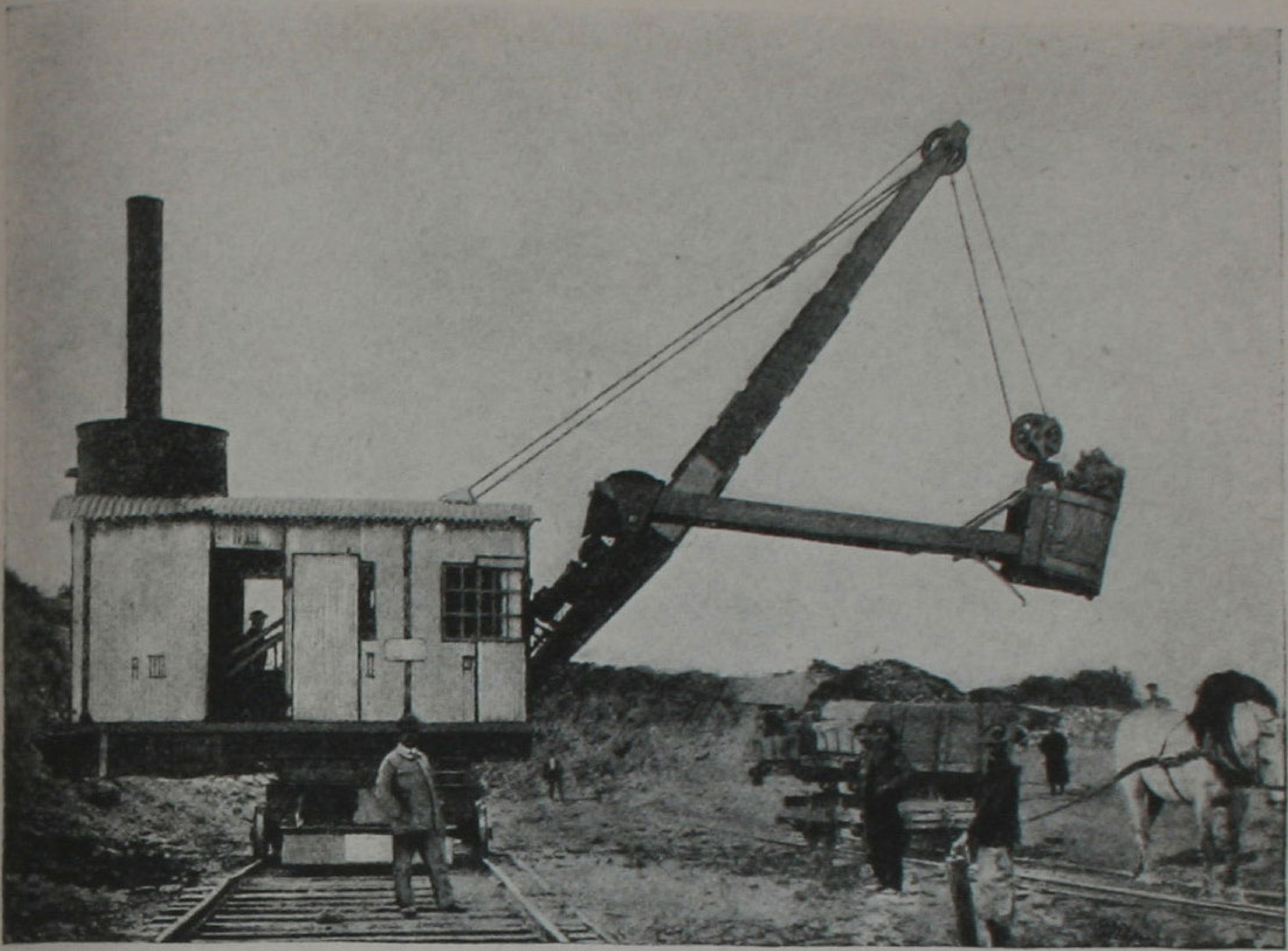
DIGGING BY MACHINERY

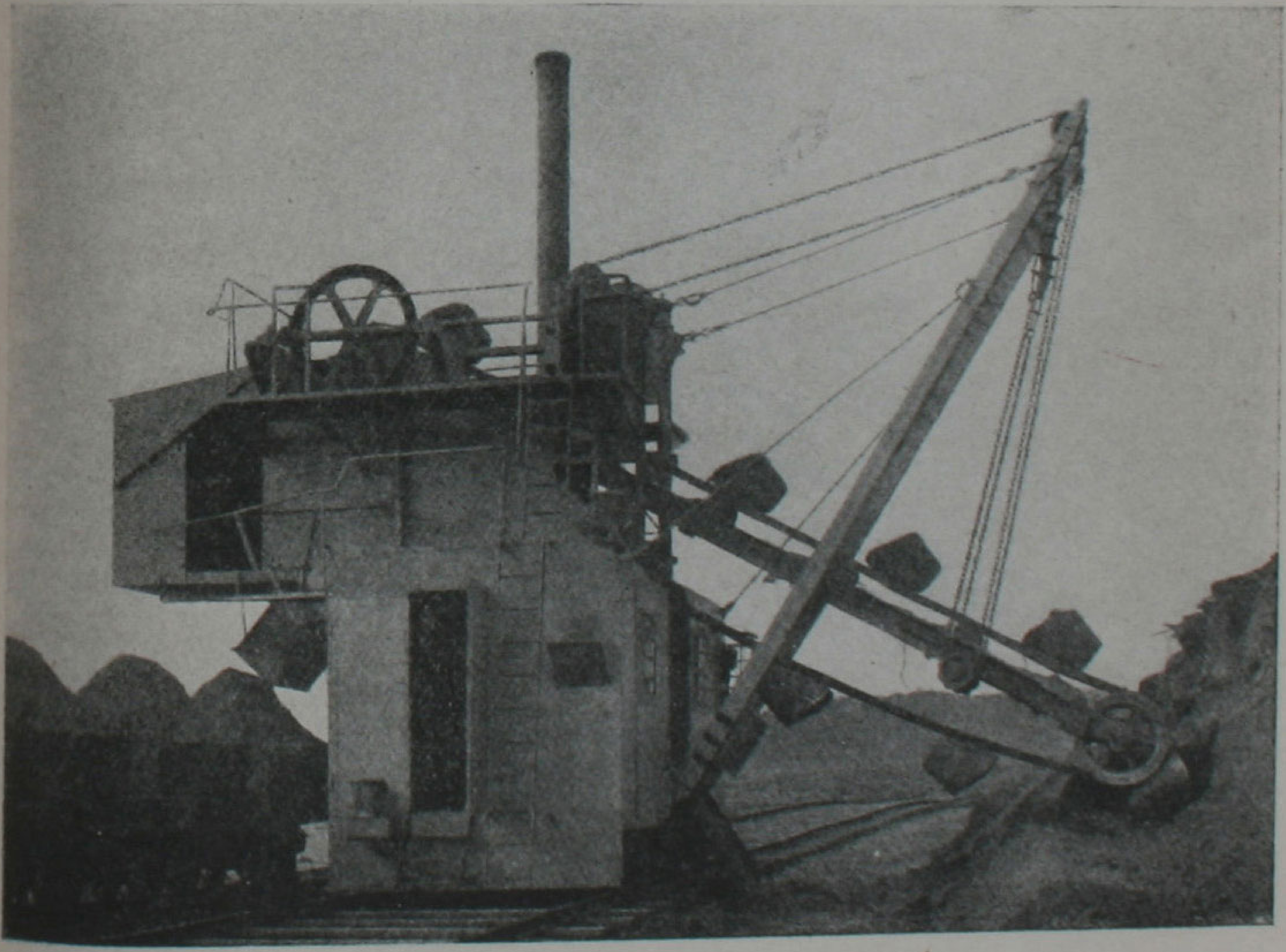
When a railway is being made it is usually necessary in places to cut away large parts of the ground in order that the track may be as level as possible. This means a great deal of work, especially if there is much rock to be cut. Sometimes a rock has to be blasted with gunpowder. But even if the ground is soft a large amount of shovelling must be done.

The same thing happens in the making of canals and docks. Great walls of timber and clay, called "coffer-dams", are built to keep out the water, and then the channel which is to form the canal, or the space which is ultimately to become the dock, is cut out on dry land. If man had to do this by hand and wheel the earth away in barrows the work would occupy a very long time, and it would be very expensive. But the engineer has made for himself diggers which are driven by steam or electricity. Some of them are so large that they can do the work of fifty, or even one hundred, men.

The digger is like a strong crane mounted upon wheels, so that it can run along rails. It resembles the cranes which one sometimes sees on dock quays. It is arranged so that the jib or pole over which the wire rope or chain passes can be raised or lowered and also turned round just as it can in most cranes. There is a large bucket made of steel plates of the same shape as the common form of coal scuttle with the sloping lid, but there is no lid upon the bucket. The back of the bucket is pivoted

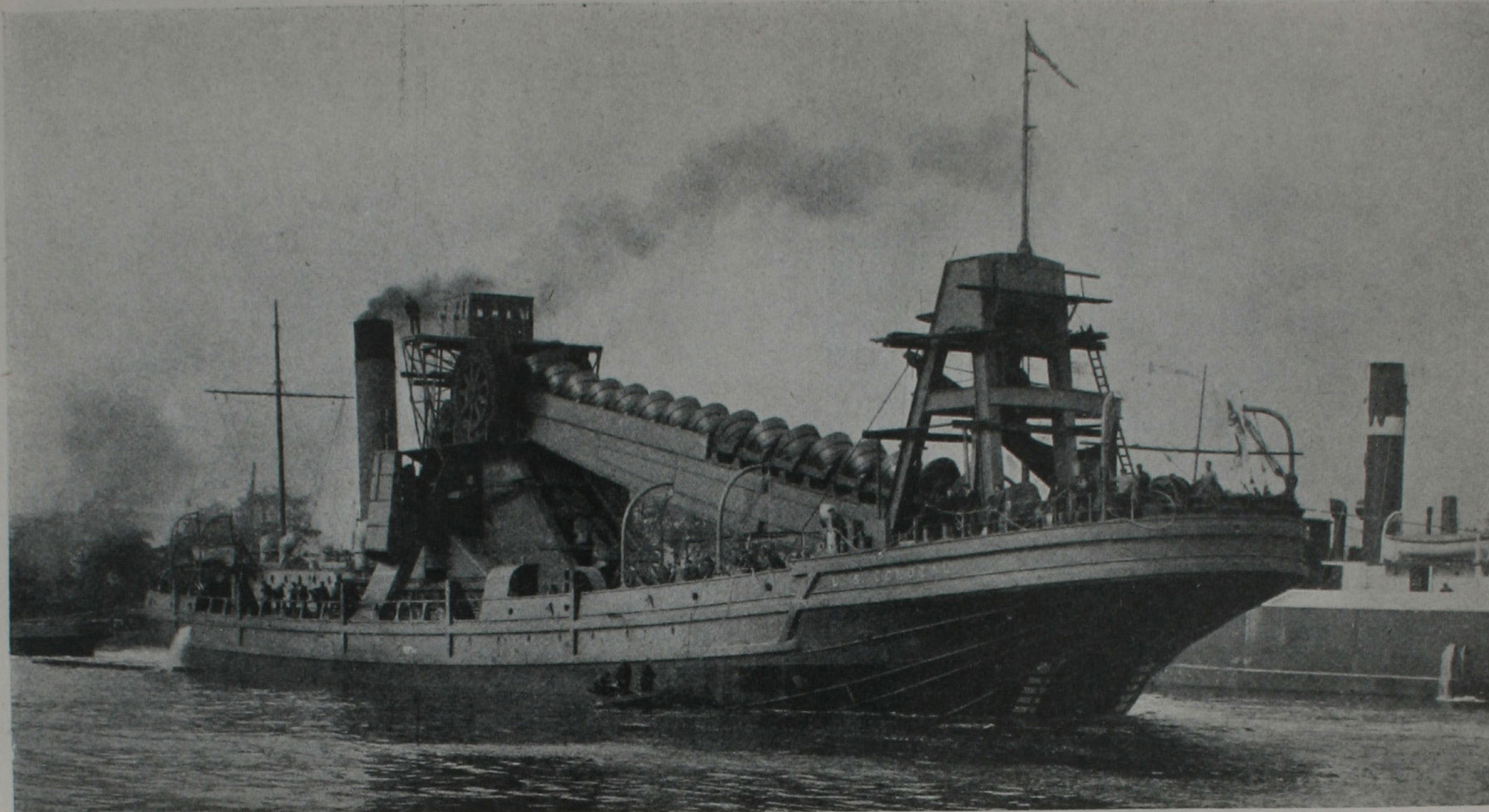


A STEAM "NAVVY" OR BUCKET DREDGER LOADING A TRUCK



A BUCKET DREDGER

(See p. 125)



Simons & Co., Ltd , Renfrew

BUCKET DREDGER "COROZAL", CONSTRUCTED FOR USE ON THE PANAMA CANAL

(*See p.* 127)

to a point some distance up the jib, and the front of it is suspended by the chain which passes over the point of the jib and down to the winding barrel. When the barrel is turned, the front of the bucket is raised or lowered (p. 124).

The front has a number of sharp, strong teeth which enable it to cut its way. The whole crane is run forward on rails which are laid on the ground where the earth has already been removed. When the edge of the bucket has got a bite of the earth, the chain or rope from which it hangs is pulled up, and a great shaving is pared off. The depth of the cut is usually about six inches, and the bucket holds about half a ton of earth.

After the bucket is filled the crane is swung round and the door is opened in the bottom, so that the contents fall into a truck and are taken away (p. 124). In railway construction the material which is taken out of a cutting can be used to fill up hollows and to make embankments at places where the ground is too low.

But it is not only on land that large volumes of earth and other materials have to be removed. Inland waterways have sometimes to be made deeper in order to allow of larger ships to pass. Again, most of our large seaports are some distance from the mouths of the rivers upon which they stand. These rivers are continually bringing down sand and small stones, and the sea never ceases washing up the sand from the great bed of the ocean. Unless these deposits are continually removed out to sea again in course of time the mouth of the river would become so shallow that only small ships could reach the docks.

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DIGGING BY MACHINERY (*Cont.*)

All this digging below the sea is done by dredgers, of which there are several kinds. A dredger is a ship which is fitted up with some kind of digging apparatus. The kind of digger used depends upon the conditions under which it has to work. A simple, but oldfashioned, form of dredger had a scoop made of iron, and of much the same shape as the article which a grocer uses for lifting tea or sugar. Of course it was very much larger, and instead of the inner end being of metal, it was a stout leather bag. This scoop was fixed on the end of a pole, and as the ship moved forward it was dragged along the bottom.

The digging part of another kind of dredger may be compared to two hands. If you wished to lift as much sand as possible from a heap you would probably do it by placing your wrists together, with the palms of your hands facing one another, then you would push your hands down into the sand and bring them together, locking the fingers of one hand between those of the other. The hands of the dredger are made of iron, and they are hinged together at the top. The fingers are so shaped that they fit into one another when the hands are closed. The digger is held open, and it is let down from the ship by a chain. Its weight is sufficient to make it penetrate into the bed of the sea or river. It is then pulled up, and the hands come together and so grip the material. The contents are then discharged into the hold of the ship or into a barge alongside and carried out to sea. Diggers of a similar kind are frequently used on land when the ground is very soft.

The "bucket" dredger is a favourite one. The ship has a long narrow well formed in the centre, which is open to the sea at the bottom. The water cannot enter the ship by this well, because its sides extend above the level of the sea. Through this opening there passes a strong, ladder-shaped structure of steel. The top end is pivoted in brackets which are placed at a considerable height above the deck. The lower end of this ladder has a chain attached to it, and this chain is wound round a drum, which is placed on deck. The drum is turned by an engine, and in this way the bottom of the ladder can be raised or lowered to suit the depth of the bed from the surface (p. 125).

At each end of the ladder there is a large sprocket wheel very like those on a bicycle. A strong endless chain made of steel links passes over those wheels, and to each link a steel bucket is attached. The upper wheel is driven round by an engine on board the ship, and the bottom end of the ladder is adjusted so that the buckets, as they come round, scoop up the sand or silt. The buckets then travel upwards, and on passing over the upper wheel they are turned upside down, and so empty their contents into a shoot which leads either into a barge or into a hold in the ship itself.

When the latter plan is adopted, the bottom of the hold is fitted with doors, which are kept shut by means of chains. When the hold is full, the ship steams to the place where the material is to be deposited and the doors are let down. The ship is held in position by mooring chains, and as the dredging proceeds the chains on the one side of the ship are slowly tightened and those on the other side are slackened, and so it is made to travel sidewise. In this way a broad cutting is made. This done, the ship is moved forward by drawing in a mooring chain at the bow and another cut is taken, and so on.

When the material to be removed is small and loose, such as sand, it can be sucked up by means of a powerful pump. The pump which is used is of the centrifugal kind. Since it has no valves it is not liable to become choked with sand or stones.

A flexible pipe is connected to the pump and let down to the bottom of the sea. In order to prevent large stones, which would damage the pump, from being lifted, the lower end of the pipe is covered by a rose similar to that used on a watering pan. The pump delivers the material into the hold of the ship. Of course a great deal of water is pumped up. The sand settles to the bottom of the hold, and the water is then allowed to flow out from openings in the side of the ship, and the sand is left behind.

38

THE LOCOMOTIVE

Of the many kinds of machines which have been invented, few have done more to change the conditions under which we live than the locomotive. The ease and safety with which we can get from place to place to-day when compared with the difficulty and inconvenience which existed a century ago is truly wonderful. Had it not been for the locomotive the great progress which has been made in commerce would have been impossible.

The name of James Watt is inseparable from the steam engine of whatever kind, either on land or on board ship. We are told that he, along with his friend Murdock, to whom we are indebted for coal gas and for the idea of using compressed air, patented a locomotive about one hundred and thirty years ago. A model of this engine is to be seen in the South Kensington Museum.

One hundred years before this the great Sir Isaac Newton, the story of whose discovery of the force of gravity is so well known, proposed to use steam for propelling vehicles, in a novel way. He suggested that the vehicle be fitted with a steam boiler, and that the steam as it was formed be allowed to escape through an opening which pointed in a direction opposite to that in which it was desired to go. You may have observed that when water issues from a garden hose at a high speed the hose itself is forced backwards. It was this force which Newton proposed to make use of; but instead of water he used steam. But Newton's locomotive, if it was ever constructed, was not a success. Lifeboats have been built which work in this way. Water is sucked in from the sides of the vessel by a pump, and is discharged in the form of jets at the stern.

Although one or two steam locomotives were in use at collieries in the early years of last century, it was not until 1825 that George Stephenson's engine was used to draw a passenger train on the Stockton and Darlington Railway. This interesting old locomotive resembled the traction engines which are now to be seen on our roads. It is very interesting to read the notice which was sent out to intimate this first railway trip. The train was a long one. First came the locomotive, and behind it its tender for carrying coals and water, then six trucks laden with all kinds of merchandise. Behind these there was a coach which was reserved for the members of the Company and any of the nobility and gentry who cared to risk the journey. Then followed other six open wagons for the use of strangers; and, last of all, other fourteen wagons intended to carry the workmen.

It was stated in the notice that any person found riding on horseback by the side of the railway would be punished in accordance with Act of Parliament. But the journey was quite successful, and for thirty-three years this engine continued to run. It now stands upon a pedestal at Darlington station.

But it was not until three years after this memorable trip that Stephenson built the engine by which he is best known. This was the "Rocket", and it is astonishing to find how very like the present-day locomotives it was. Of course it was much smaller, and it was not so perfectly made as engines are nowadays; nor was it able to run at such high speeds. Since these days locomotives have been increased in size and speed. Some of them are so large that there is scarcely any room for the funnel. It has to be made very short in order that it may not come in contact with the roofs of the tunnels. When many of these tunnels were built, the engineers did not think that the size of locomotives would increase so greatly or they would have made them larger. Perhaps, too, they would have placed the rails farther apart.

The locomotive differs from a stationary engine and boiler only in arrangement. The principles upon which it works are just the same. The boiler is mounted upon a steel framework which is carried on wheels, and the engine is placed underneath. At the cabin end of the boiler where the driver and stoker stand is the firebox, which is square, and it has a rounded top. The gases from the fire pass along a great many tubes, generally made of steel, to the front of the engine and then up the chimney. The tubes do not go quite to the front. Behind the circular door, which is to be seen on the front of any engine, is the smokebox, and here the small cinders which are carried from the fire by the gases are collected and removed from time to time. The tubes are enclosed in a circular steel shell which forms such a prominent part of the engine, and they are surrounded with water. The engine generally has two, but sometimes four, steam cylinders. In some engines the cylinders are outside the frames, and then the connecting rods are attached to pins on the wheels. In others they are placed between the frames, and the rods are then coupled to cranks formed upon one of the axles. The exhaust steam from the engine passes up through a pipe called a blast pipe, which is placed in the centre of the smokebox and directly below the funnel. The rush of steam up this pipe produces the draught which is required to keep the fire going. This is the reason why a mixture of steam and smoke issues from the funnel when the engine is running.

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THE LOCOMOTIVE (*Cont.*)

There are several differences between engines which are used for passenger trains and those intended for goods traffic, because the conditions of working are very different. The passenger train has often to go long distances without a stop. Even when it does stop at intermediate stations there is no time for it to take in a fresh supply of water or coal; so it must carry sufficient quantities of these very necessary things with it. This is the purpose of the tender which follows immediately behind the engine. The lower part of the tender is just a large water tank mounted on wheels, and the sides are continued upwards in order to form a storage space for the coal.

On the other hand, many goods trains are not required to travel long distances. Even if they should be, it is not inconvenient for them to stop to take in a supply of water from one of the tanks which are to be seen built upon a tower at the side of the line. Coals, too, can be easily obtained when required.

If the journey be a very long one, the tender attached to the passenger engine may not contain sufficient water to last. To meet this difficulty on some lines a long trough is made between the rails at a level part of the track, and this is kept filled with water. When the engine arrives at the beginning of this trough the driver lowers a scoop into it. This scoop is connected by a pipe to the tender. The rapid forward motion of the scoop forces the water up the pipe, and so a supply is obtained without stopping the train.

There is another difference between the passenger engine and the goods engine, and that is the size and arrangement of the wheels. The front wheels of a passenger locomotive are generally small. They are fixed to two axles mounted in a frame quite separate from the main frame of the engine. On the top of this frame there is a large pin upon which the front of the engine rests. This allows the "bogie", as the frame which carries these front wheels is called, to turn, and so the engine can pass round a sharp curve safely and quickly. Bogies are not usually provided on goods engines, because goods engines go much more slowly.

Again, some of the wheels of the passenger locomotive are large. This, too, is because the speed is high. If the wheels were made small then they would revolve more quickly, and so would the cranks. This would make the pistons move at a very high speed, which would be very objectionable.

The wheels of goods engines can be made smaller than those of the passenger engine, because the speeds are not so great. A locomotive has a number of pairs of wheels, and so only a portion of the weight of the engine comes on each pair. Now it is the pressure between the wheels and the rails which prevents slipping, and if only one pair of wheels be driven round by the connecting rods, this pressure may not be sufficient to make them grip the rails.

To get over this difficulty, two or more wheels on each side of the engine are coupled together by rods which are attached to pins fixed in the wheels, and at some distance from the centres of the axles. In this way advantage is taken of the pressure between more than one pair of wheels and the rails. Since goods engines have to draw very heavy loads, sometimes as many as five wheels on each side are coupled in this way. In passenger engines, on the other hand, it is usually found sufficient to connect only two pairs of wheels.

Improvements are continually being made on locomotives in order to make them more economical. Instead of burning coal some are fitted to use oil. Naturally this is most often done in countries where oil is more plentiful than coal.

The steam, when it enters the cylinder of an engine, is partly condensed to water by coming in contact with the cold walls. This is bad for two reasons. It is wasteful and it is dangerous. If water be allowed to accumulate in the cylinder, it is apt to burst it, for water is almost incompressible, and so, when the piston moves along the cylinder, and strikes the water, a very great strain is put upon the metal.

To avoid this, many engines are now fitted with an apparatus called a superheater. This is a coil of pipes which is generally placed in the smokebox. The steam passes through this coil on its way from the boiler to the engine, and it is heated by the gases as they pass to the chimney. When this is done the steam is less liable to condense to water in the cylinders. These "superheaters" are fitted to many land boilers.

The time may come when the oil engine will be used for locomotives. Already a number of engines are driven by petrol motors, and experiments have been made to discover whether the Diesel oil engine can be applied to trains. The great success which has attended the application of oil engines to ships and to motor cars gives us reason to expect that in time equal success will be achieved in railway oil engines.

Electricity, too, is used to a very large extent for driving trains, especially in suburban districts where the distances between stations are short and a rapid service is required.

In London there are already many miles of electric railway in the much-heard-of "tubes" below the city.

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HOW RAILWAY SIGNALS ARE WORKED

The greater speed at which railway trains travel nowadays as compared with the speed they travelled at fifty years ago, would be expected to have greatly increased the risk of accident. But the greater care with which railways are now constructed, the almost perfect systems of signalling in use, and the reliable and powerful brakes which are fitted to all passenger trains have counteracted the dangers which would otherwise accompany speeds of sixty, or even seventy, miles an hour.

It is true that disasters occur now and again; but when it is remembered that, on an average, four million people travel by train every day in the United Kingdom alone, one cannot but wonder at the small number of fatal accidents which befall the passengers. The men who look after the shunting of goods trains seem to run greater risks than the travelling public do. This may be because they become less conscious of the danger of their occupation the longer they are engaged in it.

There are now many ways of working railway signals. We are all familiar with the rows of long levers which are to be seen in the little cabins by the side of the railway, and in the larger ones at the more important stations. No doubt we have often watched the signalman pulling over these levers in order to lower or raise his signals.

Some of the signals are a long way from the cabin, and it is sometimes as much as a man can do to move the many links and rods which connect them to the levers in his cabin.

But electricity and compressed air have come to the assistance of the signalman just as they have done to many other classes of workmen. So, instead of having to move heavy levers, he has only to turn little handles or press buttons and the electricity or the air does the rest.

When the line has no side branches off it, the train itself can, by the aid of electricity, be made to work its own signals.

Railway signalling is a little difficult to understand unless one were to examine all the apparatus for oneself and have it explained by someone who knows all about it. So we can hope to learn only a little about signals by reading. But much can be learned at a railway station if one is interested.

Let us imagine that we are standing on one of the platforms of a railway station where there are two sets of rails—one for the up-going trains and the other for the down-coming ones. We shall think only of the set of rails next to our platform; for the arrangements for both sides are the same. Looking first in the direction in which the train approaches our station, we see a signal not very far away. This is called the "home" signal. Away beyond this, and generally a little over half a mile from the station, is the "distant" signal. It is distinguished from the others by having a "V"-shaped notch cut in the end of it. Turning now to face the way in which the train goes out from our station, we see, quite close to us, the "starting" signal. These three signals are worked from the cabin close by.

Away beyond the starting signal is another one, but it is under the control of the signalman farther up the line. Let us call the man in the cabin near to us "our" man, and so save confusion.

Above the row of levers in each cabin there are two pairs of instruments which have to do with the line on our side. There are other two pairs for the other sets of rails, but we do not wish to think of them. The instruments in our cabin are connected to similar ones in the cabins on either side, one pair to each, so that a message can be sent from one cabin to another right along the line. The two instruments which form a pair are different from one another. One has a bell, and the sounding of it is familiar to us all. The other has an indicator, and it has a little diamond-shaped needle pivoted behind the glass front. This needle can be made to swing to one side or the other.

Our man has been warned from the cabin farther along the line that a train is approaching. Before he puts his signals down, however, he must make sure that the line is clear ahead. To do this he moves a handle which hangs below his bell, and this rings the bell in the next cabin. The man there understands by this that our man wishes to send a train on, so he looks at his needle instrument. If the needle is upright then he knows that the line is clear. He then moves a handle below his instrument to one side, and the needles in his and our cabins immediately move over and point to "line clear". Our man then puts his signals down, or, as he says, "he accepts the train", and very soon it enters the station.

When the train has passed the starting signal, our man again rings the bell in the next cabin and moves the handle below the needle instrument to the other side. Immediately the two needles, one in each cabin, move over the other way, and now point to "train on line". So long as his needle is in this position our man knows that he must not accept another train.

Very soon the train passes the next box, and then the signalman there rings back to attract our man's attention. After doing this he again moves the handle below his needle instrument into an upright position, and immediately the needles stand erect and point to "line blocked". Our man then raises his signals.

Now this term "line blocked" appears to be a strange one, for the line has just been cleared of a train. But this is done for safety. It is quite possible that the signalman farther up the line, after he has sent his train on, proceeds to carry out some shunting operations near to his box upon the main line. But he can do this safely, for our man, when he sees his needle at "line blocked", knows not to send on another train without first asking if the line is clear, just as he did before.

Then again, if our man simply depended upon the message that the train had passed the next box, an accident might take place, for, just after the next signalman has sent his train on, and before he has put his signals up again, he may have become ill. In that case, if our man sent on another train it would pass the next box and probably run into a train standing in the section beyond.

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HOW RAILWAY SIGNALS ARE WORKED (*Cont.*)

Now one might ask: "What is the good of having three signals? Would not one be sufficient for each cabin? In many cases it would, but not always. Each signal has a purpose and a message for the driver or it would not be there.

The distant signal, for one thing, warns the driver that he is approaching a station. He does not require to stop although it points to danger, but if it does it tells him that the home signal is at danger also, and he must not pass it. So he slows down in readiness to stop, but in the hope that the home signal will drop before he reaches it. If it does not, he must bring his train to a standstill.

The Board of Trade, which controls the working of railways in this country, has made a rule that there must be a complete section of railway between two trains. A section is the part under the control of one signalman. But an exception is made to this rule. This first train may have moved out of our station, but it may still be in the next section. Yet there would be no harm in admitting a second train into our station so long as it was not allowed to go beyond it. This would save time, because very likely by the time this second train has discharged its passengers and is ready to start again, the first train would have passed out of the next section. Here, then, we see the real use of the three signals. Our man keeps up his distant signal and so makes the driver slow down. When the train is near to the home signal the driver sees it drop. He knows that he may proceed into the station slowly, but the starting signal is still against him, and so he dare not pass the station. Then, if by the time the passengers have got out and the new ones gone aboard, the starting signal has gone down, indicating that the next section is now clear, the train may proceed whenever the guard blows his whistle.

When there are a number of crossings or branch lines, the "points" have to be shifted in order that the train may be made to run on the proper set of rails. Then the number of levers in the cabin must be increased, for the points, as well as the signals, are controlled by levers.

In shunting yards and sidings the points are sometimes shifted by means of a lever which is placed close beside them. These levers, with the heavy weights at their ends to prevent them from shifting, are very frequently seen objects on a railway.

In a single-line railway the method of signalling is often different from that used on a double line. You may have seen the signalman and the engine driver exchanging two things which look like small bags with a brass ring attached. This is sometimes done while the train is moving, each man putting his arm through the ring of the "tablet" as it is called, held by the other.

The line is divided into sections in much the same way as was explained for the double-line railway. If the line is a long one there must be loops, so that trains going in opposite directions can pass. These are usually placed at the stations. The driver cannot enter a section until he gets the tablet or passport from the signalman. When he gets it he proceeds, and when he passes out of that section he exchanges it with the next signalman for another, which allows him to enter the next section, and so on. But what is to prevent two engine drivers, going in opposite directions, from receiving tablets from the signalmen at the two ends of the section at the same time? If they did so then a collision would occur; but again electricity comes to our help.

The tablets in the signal cabins are mounted on frames which are connected to one another by electricity in such a way that immediately one of the signalmen removes a tablet, neither he nor the one at the other end of the section can get another one out. So the line is protected until the driver has handed up the tablet at the other end of the section and the signalman there has replaced it in its frame.

It has been said that signals are worked by electricity or by compressed air; sometimes both are used. At the bottom of each signal post, and at each set of points, there is either a small engine worked by compressed air or an electric motor. These are controlled either by compressed air, which is led to them from the signal cabin through small pipes, or by an electric current conveyed by wires. When a signal is to be raised or lowered, or a set of points to be shifted, the signalman simply moves a little handle, and the engine or motor is set in motion. This relieves the signalman of much hard work, for the moving of the little lever is as simple as playing on a piano. The mechanism is arranged in such a way that the lever cannot be moved through its full distance unless the signal or points, as the case may be, has actually moved into its desired position, so that if the engine or motor fails to work this is at once detected by the signalman.

One advantage of these systems over the oldfashioned one in which long levers are used is that the cabin can be made much smaller, and it can be worked by fewer men. Some signal cabins have four or five hundred of these little levers.

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RAILWAY BRAKES

The open wagons of the first passenger train had very simple brakes indeed. A block of wood was fixed to a long lever which was pivoted near its lower end, and the upper end could be reached from the inside of the wagon. The brake was applied by simply pulling the lever and so forcing the block against the wheel.

The early forms of railway brake resembled the one which is usually seen upon a horse carriage, but it was of much rougher construction. As speeds increased, more brake power was required, and so the brake blocks were moved by means of screws which were turned by hand-wheels. There were a number of levers between the end of the screw and the block, and these were so arranged as to increase the pressure of the block upon the wheel.

Stephenson used a little steam cylinder to work his brakes. The piston-rod was connected to the brake block, and when the steam was admitted to the cylinder the brake was forced against the rim of the wheel.

Then it became usual to have one or more brake vans on the train. These were simply wagons fitted with powerful brakes which were all applied at the same time when it was desired to stop the train or to reduce its speed.

Another arrangement was tried. Each carriage was fitted with a brake, and the levers of all the carriages were connected to a chain which was worked by the engine-driver.

Although this arrangement has been given up in favour of much better ones, it is interesting, because it was the first continuous brake. By the word "continuous" we mean that all the brakes are put on or off by a single mechanism. This mechanism is under the control of the driver or the guard.

Nowadays all passenger trains which are drawn by steam locomotives are fitted with continuous brakes, but there are now no long levers nor chains, for the brakes are worked either by compressed air or by the pressure of the atmosphere. One of these brakes is known to everybody by name. It is the "Westinghouse" brake, and it is controlled by air under pressure.

On the side of the engine there are two little cylinders, one above the other, and each is fitted with a piston. The two pistons are connected together by a piston-rod. The one cylinder is really a little steam engine, and the other is a little air compressor.

Underneath the engine there is a large tank or receiver which is filled with compressed air by this engine. It is this store of compressed air which puts on the brakes on all the carriages when required.

Below each carriage there is a cylinder and piston. The piston-rod passes out through the bottom of the cylinder, and it is connected to the brakes in such a way that when the piston is forced out they are pressed against the wheels. These cylinders are called the brake cylinders.

The cylinders are connected to one another, and to the air vessel under the engine, by a long pipe called the