times the power of a single-acing single-cylinder engine, with a range of stress on the crank-shaft only one-half as great, needing a flywheel of somewhat less weight to secure the same steadiness of running, and possessing an improved mechanical efficiency. This type of engine is now being built by most makers of large gas engines, and bids fair to become the standard type where a regular turning velocity is essential.

The Nurnberg Gas Engine.—It is impossible in this work to describe every maker's engines, and this engine (fig. 441) has been selected as a good typical example of the tandem double-cylinder, double-acting, four-cycle gas engine of large size. Designed by the Maschinenfabrik Augsburg-Nurnberg, and made in this country by the Lilleshall Company, Ltd., some 250 engines of various sizes, made either by the inventors or their licensees, are now working in various parts of the world.

The cylinder is cast in one piece with its water-jacket, the inner and outer walls separated sufficiently to allow for their different rates of expansion when at work, and to enable scale or mud to be easily got out through the numerous cleaning doors provided for the purpose. Internal pipes are provided to spray the water directly on to the exhaust outlets and other parts requiring to be specially cooled.

The water-cooled boxes containing the inlet valves are bolted on the top of the cylinder, and those for the outlet valves below it, so that any dust entering by the inlet valves has the best possible chance of being blown away through the outlet valves immediately below them. The hollow cast-iron exhaust valves are cooled by water at a pressure of 20 lbs. on the square inch, which enters through the gun-metal valve stalks.

When overhauling, the inlet valves can be drawn upwards, and the outlet, without disturbing the exhaust pipes, downwards into large openings left in the masonry for the purpose. As there are no valves in the cylinder covers, these can be water-cooled boxed castings of strong simple form.

The cylinders do not rest on the foundations, but are carried by the rear guide bar support, the distance pieces, and the engine frame, the first two being bolted down to plates secured to the masonry; on these the castings can slide when the cylinders expand. The distance piece and engine frame are open from the centre line upwards to allow of ready access to the guide shoes, but are strengthened by strong tie-rods near their upper edges.

The hollow ribless pistons are carried by nickel-steel rods, having a tensile strength of 40 tons per square inch, with an extension of 18 per cent. before fracture. The rods are turned with an initial camber, so that when loaded with pistons and supported by the guide shoes at the ends they shall be straight. The whole weight of the pistons and rods is thus carried on the guide shoes outside the cylinders, and only the piston rings are in contact with the cylinder walls. Through the rod a hole is bored, by which water at a pressure of 50 to 60 lbs. per square inch is conveyed to the pistons. It enters by the jointed pipes at the centre guide shoe, and leaves by return pipes fitted within the rods.

Fig. 442 shows the method employed for removing and examining the pistons, and obtaining access to the cylinders for cleaning them out.

The valve gear is worked from a side shaft driven from the crank-shaft by machine-cut gears running in an oil bath. On this shaft are eccentrics operating rolling levers, which control the valves. The governing is by the constant quantity method, the gas valve being tripped by the governor when the requisite supply has entered.

Ignition is by a make-and-break contact worked from an accumulator,

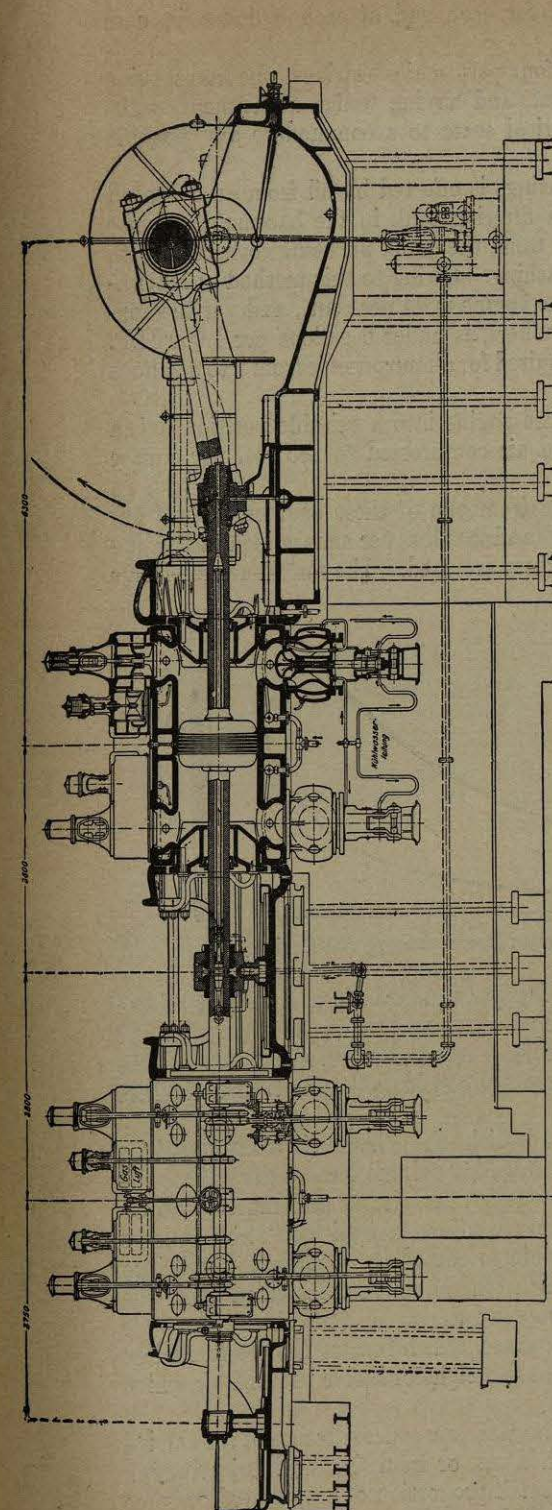

Fig. 441.—Nurnberg Engine.

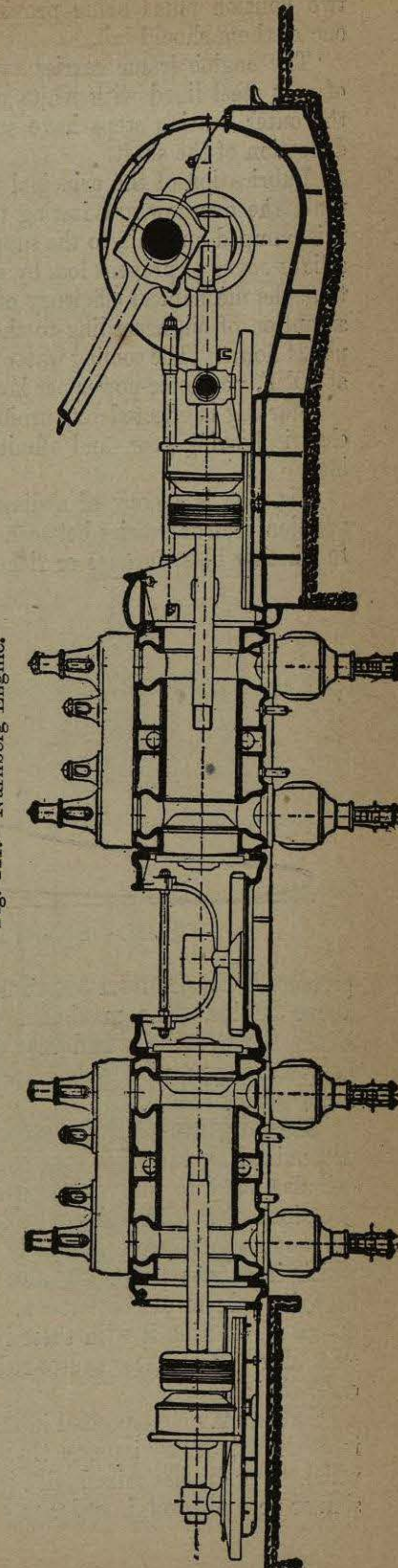

Fig. 442.—Method of Opening up Nurnberg Gas Engine for Examination and Cleaning.

two ignition plugs being provided for each end of each cylinder in case one of them should fail.

The engine frame carries two four-part main bearings, the steps being of cast steel lined with white metal, and having wedge adjustment, while the outer bearing steps have spherical seats to accommodate any possible deflection of the shaft.

Lubrication of the principal bearings is effected by oil from an overhead tank, the overflow gravitating to a filtering tank in the basement, whence it is pumped up again to the supply tank, the crank pit being covered in with a light cover to prevent loss by splashing. Owing to this method of lubrication, the mechanical efficiency of the engine is 85 per cent., and yet the consumption of oil, according to the makers, is under 6 gallons per 1,000 H.P. per 24 hours. The cooling water required for all purposes is from 7 to 8 gallons at 60° F. per horse-power per hour.

Starting is effected by turning the engine into a suitable position by an electric barring gear, and admitting air compressed to 285 lbs. per square inch.

Fig. 443 is a copy of a diagram from one of these engines. The compression pressure varies between 130 and 200 lbs. per square inch, according to whether blast furnace or richer gases are used. The maximum explosive

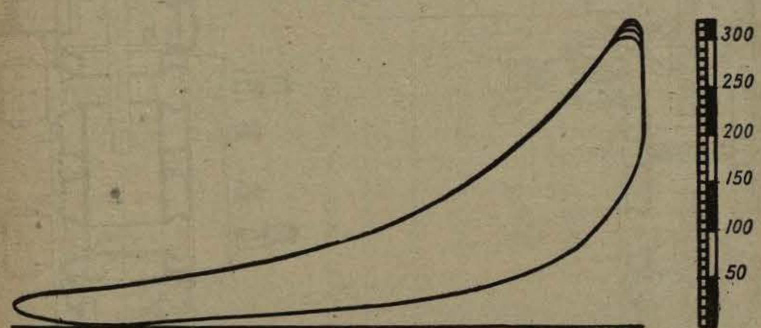

Fig. 443.—Indicator Diagram from Nurnberg Gas Engine.

pressure is usually from 300 to 350 lbs. per square inch, and that at release about 30 lbs. The maximum temperature on ignition is usually about 1,500° C. (2,732° F.), and that at release about 400° C. (752° F.). These figures are approximate only, as there are considerable practical difficulties in measuring them.

Scavenging.—The pressure to which the charge is compressed is determined by the ratio which the clearance volume left at the end of the cylinder bears to the volume swept out by the piston, and must be about one-ninth of it. The piston on its return after the explosion stroke pushes the waste gases before it, but is unable to empty the clearance space, into which it cannot penetrate, and which, therefore, remains filled with the heated products of combustion. Amongst these the next charge must be drawn in, diluting it with these inert gases, which impart heat to it, and so expand it. Both these causes reduce the weight of active gas and air which enter the cylinder.

Carbon may be deposited in the clearance space from traces of tar carried into the cylinder by imperfectly washed gas, or from charred lubricating oil, which generally has mixed with it a small proportion of cotton seed or some similar vegetable oil, in order to ensure the even flow of the mineral oil over

the hot surfaces to be lubricated. Should any glowing particles of Carbon or of dust remain on the surface of the clearance space, preignition at some period of either the suction or of the compression stroke will occur. In either event power is lost, and in the latter case the opposition to the compressing piston causes dangerous stresses in the engine.

To avoid this, in some engines, cool air is drawn or driven through the clearance space in order to displace the hot gases and cool down the cylinder, the operation being known as "scavenging."

One method, now abandoned, was not to draw in a fresh explosive charge on the completion of the exhaust stroke, until a charge of cool air had first been drawn in and expelled. The engine thus became a six-cycle engine, having one explosion in every six strokes. It gave out only two-thirds of the power, and yet the first cost and friction were the same as if it had been operated on four cycles, and its turning was less regular.

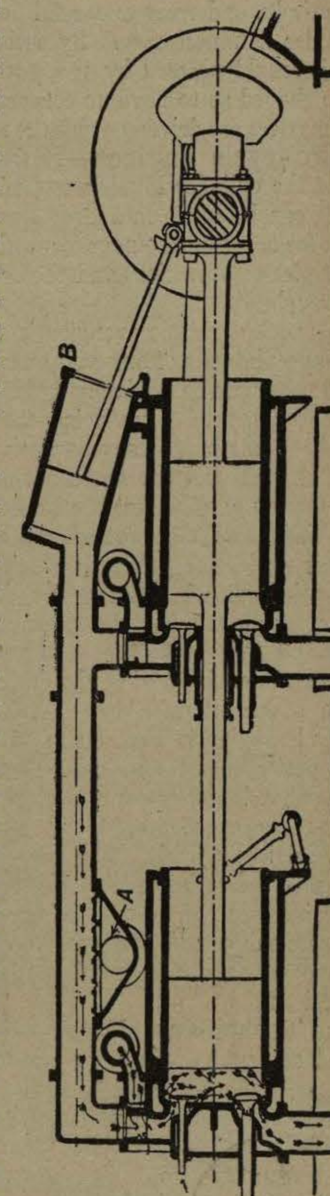

Fig. 444.—Prêmier Gas Engine.

One of the earliest and most successful scavenging engines was the English Premier engine, made at Sandiacre, near Nottingham. Fig. 444 shows the arrangement of this engine in diagrammatic form; it is of the single-acting double-cylinder, tandem, four-cycle type. After each explosion the products of combustion are driven out of the clearance space by cold air drawn in through the valve, A, by the air pump, B, placed on the top of the engine, which compress the air to a pressure of about 3 lbs. on the square inch. This is admitted to the cylinder just before the exhaust stroke is completed, and sweeps the burnt gases before it into the exhaust pipe. The engine was devised to give powers of 100 to 600 H.P. per cylinder when using high compression with rich gases, such as coke-oven gas, which are more subject to preignition than the comparatively poor blast-furnace gas. It has been most successful for this purpose.

Mr. Atkinson devised an ingenious plan for sweeping out the clearance space by an induced draught of air, produced by the momentum of the moving column of gases in a long straight exhaust pipe. By opening the air valve at about one-eighth of the revolution of the crank before it reached the dead centre on the return stroke, and keeping it open for a similar period after the centre was passed, the rush of the gas up the exhaust pipe produced a partial vacuum at its lower end, and cool air entering by the air valve rushed through the clearance space, sweeping the products of combustion before it up the exhaust pipe. This simple device works admirably in the case of small engines, but the action is difficult to induce in the case of large ones, where impulses are less frequent.

Most makers of large four-cycle gas engines have now abandoned scavenging entirely, and trust to careful design of the cylinders and clearance space to render it unnecessary. By seeing that there are no internal projections not thoroughly cooled by the water-jacket, and that the clearance spaces are so shaped as to have no corners in which Carbon or dust can collect, all such matters are driven out by the rush of gas when the exhaust valve opens.

Two-cycle Engines.—If the products of combustion can be forced out of the cylinder immediately the explosion stroke is completed, a fresh charge can be taken in and compressed on the return stroke of the piston, ready for firing on the next forward stroke. The engine will then have only two cycles of operation, and the crank-shaft will receive an impulse during each revolution.

For such engines scavenging is an absolute necessity, to ensure the complete sweeping out of any still burning gas remaining in the cylinder, which would otherwise immediately ignite the fresh charge. The time for effecting this cleaning, and introducing the fresh charge into the cylinder, before the piston has moved any appreciable distance on its return journey, is so short, that air and gas would not flow in fast enough at ordinary pressures, and they must, therefore, be forced in by pumps, which deliver them into the cylinder at the instant when they are required.

This cycle was originally devised by Mr. Dugald Clerk in 1880. Its drawback is that in practice the air and gas have to be compressed in the pumps, which requires the expenditure of power, and then are permitted to expand freely into the cylinder without performing work, so that the work expended in driving the pump is lost. Consequently the mechanical friction of such engines varies between 72 and 76 per cent., while that of the four-cycle engine is from 80 to 85 per cent. Yet some managers of steel works prefer them for their other advantages, which they consider outweigh a somewhat larger consumption of gas, obtainable at most blast furnaces for the mere cost of cleaning it.

As originally made, large gas-engine cylinders and cylinder ends were constantly fracturing under the combined influence of high pressures, and the strains set up by the unequal expansion induced by the great heat to which they were subjected. Exhaust valves were a continual source of annoyance and expense, and piston-rod stuffing-boxes were looked upon as almost impracticable.

The Oechelhäuser Engine.—This ingeniously contrived engine was devised to get over the difficulties just mentioned, and was the first really large gas engine to be set to work, one of 600 H.P. being started in 1898. The cylinder is of the simplest possible form, free to expand in any direction, the cylinder and jacket being separate castings, and not cast together, as might be supposed from the diagrammatic drawing, which is intended merely to explain its method of working. There are no cylinder ends to fracture, no valves of any kind exposed to the heated gases, no stuffing-boxes, and the ends of the cylinder are open, so that the tightness of the pistons can be seen at any time.

Fig. 445 shows this engine. It has a long water-cooled cylinder, in which work two pistons, B and C, that nearest the crank-shaft, B, being coupled by a connecting-rod, D, direct to the centre crank, E, and that farthest from it, C, attached to a cross-head, F, to which are secured two side rods, G and H, and to them two connecting-rods, J and K, coupling them to the two outside cranks, which are set at an angle of 180° from the centre one. To

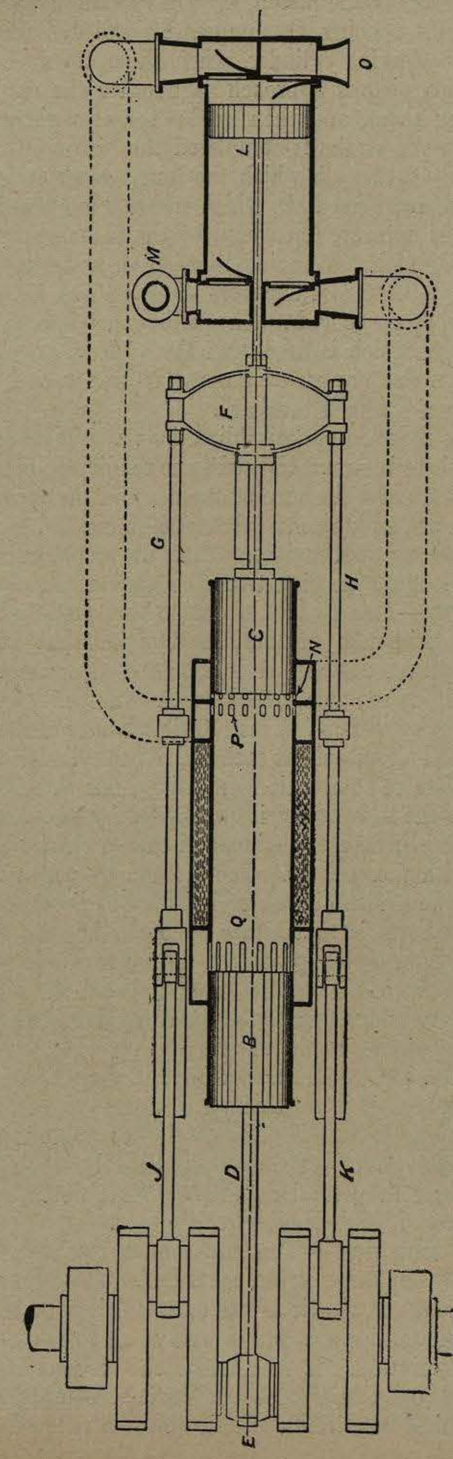

Fig. 445.—The Oechelhäuser Gas Engine.

the back of the cross-head, F, is attached the piston-rod of a pump. This pump draws in gas on one side of the piston, L, from the supply pipe, M, compresses and delivers it through the ports, N, into the cylinder, whenever these ports are uncovered by the piston, C. On its other side the piston, L, draws in air through the opening, O, compressing and delivering it through the ports, P, into the working cylinder, when these are uncovered by the piston, C. As the two pistons approach each other the explosive charge is compressed between them, and then fired; the two pistons are driven apart, but just before the stroke is completed the piston, B, uncovers the ring of exhaust ports, Q, through which the burnt gases escape, their exit being hastened by the compressed air, which enters a moment later through the ports, P, as they in turn are uncovered by the movement of the piston, C. In this way a thorough scavenging is effected, and when the further movement of the piston, C, at last uncovers the gas ports, N, the gas enters an atmosphere of nearly pure cool air. The pistons then approach each other compressing the charge, which is fired, and the cycle of operations recommences. The details of the pumps, &c., are sometimes varied, but however changed, the principle of action is the same.

As the two pistons move in opposite directions a balance of the moving parts ensues, so that there is no unbalanced force tending to move the engine bodily on its foundations, and the turning moment on the crank-shaft being due to a couple, there are no horizontal forces to be resisted by the bearings and bedplate, as in other types of engines. There are no places in the cylinder where dust or oil can lodge. This is a two-cycle engine.

Koerting Engine.—This two-cycle engine was produced in the year 1890, with the object, primarily, of obtaining two impulses per revolution, as with an ordinary steam engine. It is shown in diagrammatic form in fig. 446. The air and gas are compressed by the pumps, A and B, respectively, which are driven by a crank, C, set 110° in advance of the main crank-pin, D, and are admitted alternately at each end of the cylinder by the valves, E and F. The products of combustion are driven out through the central annular port, G, and the scavenging is performed by the compressed air, as in the case of the Oechelhäuser engine, and then a charge of air and gas is admitted to mix with the cool air. The method by which this sequence of events is secured, although the air and gas pipes are in direct communication and one valve admits both, is that either by throttling the charge of gas as shown in the drawing, or by bye-passing it, a smaller charge of gas is taken in by the gas pump than of air by the air pump, and the air forces back the gas from the valve. Consequently when the valve is opened, the air is first driven into the engine to do the scavenging, followed later by the air and gas mixed together. The arrangement is very simple, and seems to meet the case, although it is maintained by some critics that some gas which is diffused amongst the air is often carried to waste up the exhaust pipe. The details of the pump are varied considerably by some of Messrs. Koerting's licensees, and the actual details are not quite as shown in the diagram, which is merely intended to be explanatory.

Governing Gas Engines.—The hit-or-miss method of governing consists in omitting an explosion stroke on occasion altogether. From the point of view of economy of gas, it is the most efficient of all methods of governing, because it maintains a constant ratio of air to gas, and so ensures the most economical mixture. It also keeps the volume constant, thus securing an economical compression pressure, but it necessitates the following unsatisfactory mechanical conditions. If the load is reduced by one-half, there are in a four-cycle engine seven successive strokes of the piston without any impulse being transmitted to the crank, and if it is reduced by three-fourths, there are no less than fifteen idle strokes between the active ones.

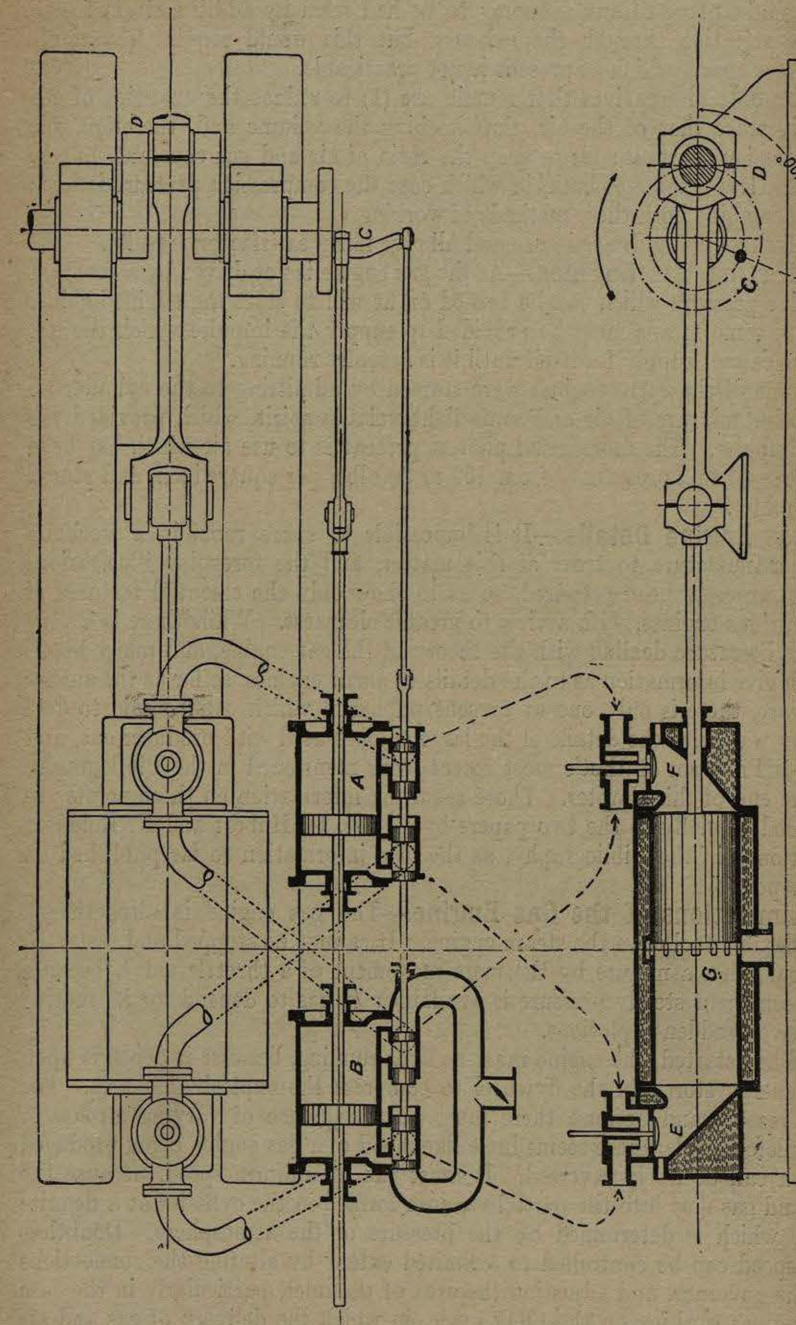

Fig. 446.—Koerting Gas Engine.

This is too crude a means of regulation to be tolerated in the case of large engines, and is no longer used for them. Some method must be found which will enable the number of impulses to remain constant, but their intensity to be varied as required.

Theoretically, the best course would be to keep the quality of the mixture constant, to admit a small quantity, and compress it to the same pressure, taking advantage of any economy to be had from its additional expansion before rejection through the exhaust, but this would require a variable clearance space, which at present is not practicable.

The only alternatives that remain are (1) to reduce the quantity of gas and increase that of the air, thus keeping the volume and, therefore, the compression constant; (2) to keep the ratio of air and gas constant, but to admit a less volume of both, in which case the compression pressure is less; (3) to combine both these methods of working.

All these methods are in use and all give fairly satisfactory results.

Starting Gas Engines.—As the gas engine is not driven by a constant positive pressure which can be turned on at will to start the engine against a load, some means must be provided to supply the impulse which the gas engine cannot supply for itself until it is actually running.

Some of the early engines were started by admitting to the cylinder an explosive mixture of air and some light volatile spirit, which provided the first impulse. The more usual plan at present is to use air which has been compressed to a pressure of from 150 to 300 lbs. per square inch, and stored in a holder.

Gas Engine Details.—It is impossible to spare room in a work on steel manufacture to treat of this matter, and the foregoing illustrations have purposely been prepared, so as to show only the essential features of the various engines, with a view to greater clearness. While there is a very ample literature dealing with the theory of the gas engine, and many books which give information as to the details of small engines, so far as the author is aware, there is only one at present published which can be said to deal in any way with the details of the large engines used with producer gas, and that is Professor Mathot's most recent work mentioned in the Bibliography at the end of this chapter. Those requiring information on these points are referred specially to the two papers by Messrs. H. Hubert and K. Reinhart mentioned in the Bibliography, as the best information so far published on these points.

Limitations of the Gas Engine.—The gas engine is altogether a less flexible tool than the steam engine. It cannot be stopped and restarted several times a minute by the mere movement of a throttle valve, because no permanent steady pressure is available; it has to depend for its motive power on sudden explosions.

When started, the engine must be kept running, because it depends upon the energy stored in the flywheel to compress the explosive charges. For this reason, and because there must be a sequence of varying strokes to complete a cycle, there seems little likelihood of a gas engine being produced which can be freely reversed. It must run at uniform speed, because the air and gas flow into the partial vacuum formed in the cylinder at a definite rate, which is determined by the pressure of the atmosphere. Doubtless the speed can be controlled to a limited extent by altering the connections to the governor, and adjusting the area of the inlet, particularly in the case of engines working on the Clerk cycle, in which the delivery of gas and air is effected by the positive displacement of pumps. Such changes of speed, however, are strictly limited, and take time to effect. From the very nature of the case, a sudden explosion of an intensely hot gas, which loses heat rapidly to the cold water-jacket which confines it, must be utilised promptly, for such energy is very evanescent, differing entirely from the steady permanent pressure of steam from a boiler, utilisable at practically any desired rate. If an explosive engine is coupled to a mill by any mechanical means, it cannot be employed to grip the piece to be rolled slowly, then increase the speed during the run, and reduce it towards the end, so as to avoid shooting the piece out of the mill at a dangerous speed.

The gas engine gives its maximum economy at a maximum load. Reducing by one-half the net power delivered by it increases the consumption of gas per unit of power from 25 to 35 per cent. If rated at its full load it may take an overload, provided it lasts for one or two revolutions only, by drawing on the energy stored in the flywheel, but to do so must slow down considerably. The slightest permanent overload stops it entirely.

If a gas engine has been put down too small for the work to be done by it, it cannot be altered to give appreciably more power, and must be replaced by a larger engine; and if a piece sticks in the rolls, the engine cannot be reversed to wind it out again.

Omission to appreciate these facts, and to recognise that the power which a gas engine is sold to give out is its maximum power, has caused the total failure of gas engines of a nominal power equal to the average power exerted by the steam engines they were put in to replace.

The cost of repairs and of oil is much more than in the case of a steam engine, though much improvement in this respect has been made in the case of the most recent engines.

Finally, gas engines must be laid off for cleaning at intervals of about two or three months, the operation in the case of a large engine occupying two or three days, during which time the whole mill, if coupled to an individual engine, must also remain idle, and if the mill is a reversing one, a gas engine cannot in any case be coupled to it. Nevertheless several large mills on the Continent are driven by gas engines, and also at the Moss Bay Works, in Scotland, where a 30-inch three-high Lauth Plate Mill is directly coupled to a 1,850 H.P. Oechelhäuser gas engine. Messrs. Monks, Hall & Co., Ltd., of Warrington, also drive their small mills by gas engines.

In all these respects the gas engine is at a great disadvantage compared with a steam engine, which can be started and stopped, run fast or slowly, and in either direction at will. Can be so proportioned that the consumption per unit of power varies within much smaller limits from half or even a quarter load right up to 50 or 100 per cent. overload; and if overloaded the steam engine will continue running though at reduced speed. If it is found that more power is required than the steam engine was originally designed to give out, the setting of the valves, or the pressure of steam, are easily altered, and many engines to-day are working under loads more than twice as great as they were originally designed to meet, and without very serious increase in their consumption per horse-power. A steam engine will run for years with only such repairs as can be effected during the week-end.

The reversal of the mill may no doubt be effected by a reversing gear similar to that to be described on p. 775, but for powerful mills needing to be reversed quickly the only really satisfactory method of transmitting the power between the engines and the mill is by the electric current.

The Humphrey Gas Pump.—A novel apparatus for directly utilising the explosive power of gases has been recently invented by Mr. Herbert A. Humphrey, and as this may be used to pump water, to blow air for blast-furnace use, to generate electricity, and for other purposes, a considerable development may be expected in the future if the inventor's expectations are fulfilled.

To see the apparatus in its simplest form, imagine a long pipe bent into the form of the letter U nearly filled with water, and with the ends turned upwards, one end being closed, while the other is open. Admission and exhaust valves are fitted at the top of the closed branch of the pipe, which serve respectively to admit the explosive mixture, and to allow the escape of the burnt gases. Lower down in this U tube are fitted water admission valves. When an explosive mixture of air and gas is admitted and fired on the top of the water in one leg, the water is depressed in this leg, and correspondingly raised in the other leg, overflowing the top of the tube into the delivery tank; owing to the momentum imparted to the column of moving water, the gases expand below atmospheric pressure, thereby sucking open the water admission valves, so that an additional quantity of water flows in. When the momentum imparted to the column of water is expended, the head of water in the leg causes it to flow back again, driving out the bulk of the burnt gases, until the water strikes and closes the exhaust valve. The remainder of the burnt gas is compressed, cushioning the water, and thus giving it a second return impulse, somewhat less than the previous one, which draws in a fresh charge of explosive mixture; this is compressed by the return of the oscillating column of water, the charge is then fired, and the cycle of operations is complete.

This cycle of operations is the theoretically perfect cycle proposed by Beau de Rochas in 1860, having a long outward explosion stroke followed by a long inward expulsion stroke; these being succeeded by a short outward suction stroke and a short inward compression stroke. It is the cycle which Atkinson succeeded in obtaining in his gas engines, which proved to be the most economical in gas of their day, but were discontinued in practice because the saving in gas effected by them did not compensate for the increased cost of lubrication and upkeep due to the greater number of their moving parts.

But in the Humphrey pump there are no moving parts except the valves, which may be washed at each stroke by the water; there are no reciprocating parts except the oscillating column of water which serves the purpose both of a piston and a flywheel, no pistons or piston-rod packings to wear, leak, or require lubrication, so that the cost of attendance and upkeep should be exceedingly small.

Moreover, the pump cycle can carry the expansion of the gases below atmospheric pressure, which should make this appliance more economical in the consumption of gas than any existing gas engine, and another possible source of economy is that probably the gas will require little or no cleaning, thus saving the power now consumed by the costly gas-cleaning plants.

Obviously the moving column of water is easily adaptable for compressing air for blowing blast furnaces or Bessemer converters, and a 1,350 H.P. plant is under construction for delivering water under pressure to an hydraulic turbine coupled direct to an electric generator for the supply of electric power. The saving in gas is expected to more than compensate for the loss in conversion in the turbine, which can be made very compact. It is also quite possible that in some cases the turbines could be coupled to the work direct without requiring the intervention of the electric plant to transmit the power.

One of these pumps was exhibited at the Brussels Exhibition of 1910,* where it attracted much attention, and if the expectations of the inventor

* *Engineering*, vol. xc., 22nd July, 1910.

are fulfilled (he has shown much ingenuity in overcoming what seemed at first sight conditions almost impossible of fulfilment) the apparatus should play an important part in future iron and steel works.

Gas Engines in England and on the Continent.—The employment of gas engines has made much greater advance in Germany than elsewhere—far more than in England. There are various reasons to account for this state of affairs. In Germany fuel has usually to be carried such long distances that it costs much more than it does here, and there is consequently much more inducement to try to save it. Fritz Sellge, describing one of the best instances of the saving of fuel secured by employing gas engines, shows that at Differdingen the installation paid 15·56 per cent. on the outlay, and that more work was accomplished. But this saving is based on coal costing 18 marks (17s. 7d.) per ton. With coal at usual English prices the saving would be about half this amount, and unless some other advantages were incidentally obtained would not provide for interest and sinking fund, and would not be a sound commercial transaction in this country.

Moreover, German steel works are largely owned by banking houses, which pay much lower rates of interest on money deposited with them than would be paid by English works having to raise money by loan in the ordinary way, and these owners of the German works might find it suit their other trading interests to encourage expenditure on plant, even if not directly remunerative to the steel works. So that it does not follow that what pays in Germany need necessarily pay in Great Britain where conditions differ.

Most English blast furnaces have no steel works connected with them, and were they to instal gas engines in place of their existing steam engines would have great difficulty in using or disposing of the surplus power so gained. This difficulty has been removed in the Middlesbrough district,* where the Cleveland and Durham Electric Power Company purchase waste heat in the form of coke-oven or blast-furnace gas, or exhaust steam, wherewith they generate electric current, and in some instances even sell it to the very firms from whom they have purchased the heat wherewith to generate it. For these works the effective "pooling" of their fluctuating surplus heat is an economical operation, while the electric company, on their part, find that the fluctuation of supply and demand in the individual plants "cancel out," so that on the whole both are remarkably constant.

No doubt, too, theoretical perfection, which appeals so strongly to the highly trained mind of the German, that he is not dismayed at any complexity needed to attain it, has little attraction for the English manager, who values much more a low repair bill, and the simplicity and fewness of parts which conduce to steady running. When he possesses boilers and engines of good modern construction, he naturally hesitates to scrap them for gas engines, which even now have scarcely got over the diseases incidental to infancy, while the length of their useful life is at present unknown, though Professor Threlfall's estimate that a new cylinder is required every three or four years must be based on experience with engines of far from modern design.†

Mr. F. Limburg gives figures to show that a steel works could actually be run by the gas from the blast furnaces alone without the use of any fuel except the coke used in the blast furnaces. This is doubted by most people, but it could certainly be approached.

* "Power Supply and its Effect upon the Industries of the North-East Coast." Chas. H. Merz. *Iron and Steel Inst. Journ.*, 1908, vol. iii., p. 81.

† *Journ. Inst. Electrical Engineers*, No. 196, Aug., 1909, p. 61.

There can be no doubt that the advent of gas engines of large power, worked by blast-furnace gas, and the facilities for distributing such power, electrically, must hasten the time when blast furnaces and steel works are merely two departments of one large plant, of which all portions are mutually dependent on each other, a condition which obtains largely even now when both Bessemer vessels and open hearth furnaces rely for their economical operation upon the supply of molten pig from the blast furnaces.

The possibility of employing the coke-oven gases also for power and heating in the steel works must further increase the marked modern tendency to combine various branches of industry in one large aggregate of interests.

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