

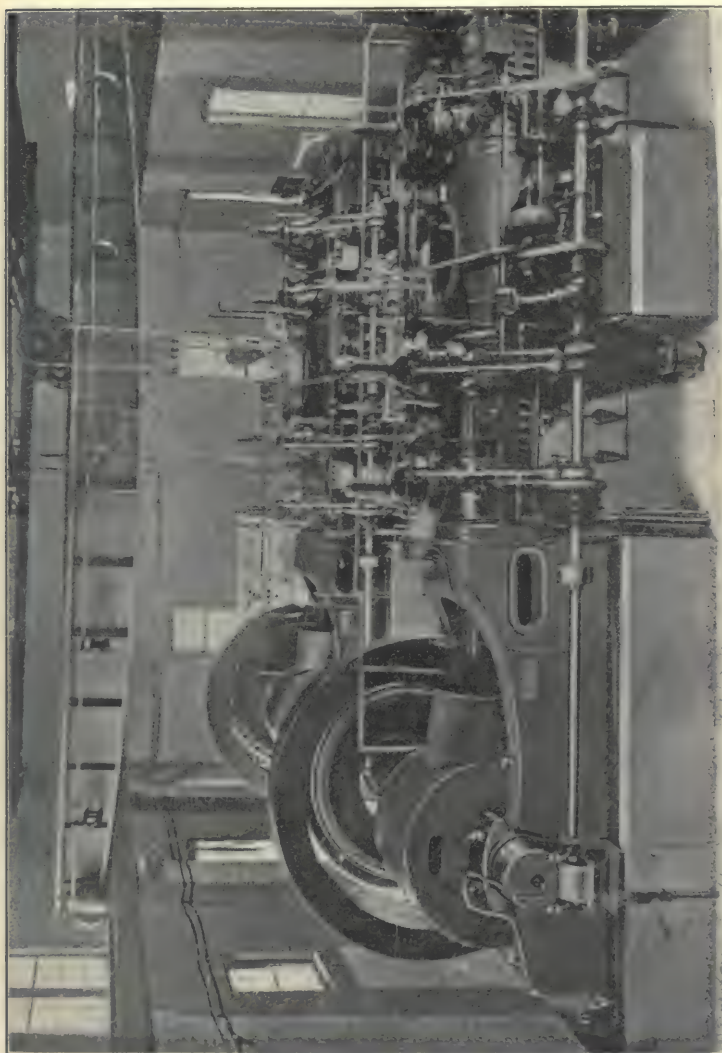


Fig. 12-50. — Westinghouse Double-acting Tandem Gas Engines.

nothing is definitely known to the writer regarding the mechanical details. An interesting development of very recent date is the

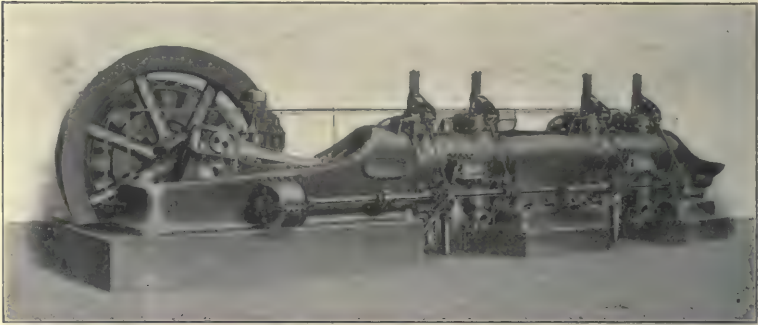


FIG. 12-51. — Westinghouse Double-acting Tandem Engine.

Westinghouse vertical single-acting tandem engine shown in Fig. 12-52. This engine was built by the British Westinghouse Electric and Manufacturing Company.*

The Tod Engine. — The following description of this engine is taken from the *Iron Age* of July 18, 1907:

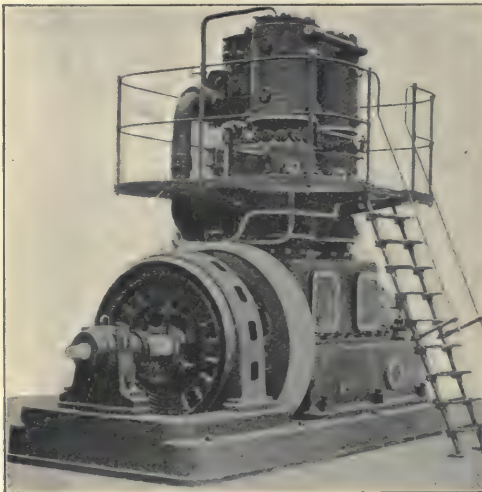


FIG. 12-52. — Westinghouse Vertical Single-acting Tandem Gas Engine.

"The general appearance of the engine is shown in Figs. 12-53 and 12-54. The cylinders are arranged in pairs, two cylinders being connected in tandem to each crank pin. The valve gear, igniter, switchboard and operator's hand wheels are all situated between the cylinders and are easily accessible from an operating platform placed just below the level of the center lines of the cyl-

* W. H. Booth, *Cassier's Magazine*, November, 1907.



FIG. 12-53. — Tod Double-acting Twin Tandem Engine.



Fig. 12-54. — Tod Double-acting Twin Tandem Engine.

inders and shaft. The foundation level under the cylinders being several feet lower than under the frames, leaves ample room below the cylinders to make the exhaust valves, etc., easily accessible, a very desirable but somewhat unusual feature.

"The cylinders and water jackets are integral and cast in halves, secured together with flanged joints at the center. The cylinders are not attached directly to the main bedplates nor to each other, but are supported by the tie pieces in such a way that the barrels themselves are entirely free. All strains are transmitted through four heavy forged steel tie bolts extending the entire length of the cylinders, and attaching directly to heavy lugs on the bedplate. This obviates the transmission of the strains through the cylinder walls, and contributes to accessibility and the easy removing of parts. The pistons are of steel, with cast-iron junk rings, and the pistons and rods are water-jacketed in the usual manner. Adjustable tail-rod supports take the weight of the pistons and rods from the cylinders.

"The valve gear is driven by eccentrics, eliminating entirely the cam drive, which has been an objectionable feature of many of the gas engines heretofore built. There is one eccentric for each end of each cylinder, which drives both the inlet and exhaust valves — an arrangement that reduces the number of parts. The eccentrics are mounted on two lay shafts running parallel to the axes of the cylinders. The latter are driven by a cross shaft, which, in turn, derives its motion from two eccentrics mounted on the main shaft. The inlet valves are on top of the cylinders, and the exhaust valves on the bottom. The inlet valve proper is of the mushroom type, sealing the ports from the pressure in the cylinders. The main valve is operated by a rolling lever and returned to its seat by a spring. The mixing valves and governor valves are of radial gridiron type, and are located in the upper section of the valve bonnet. The mixing valves may be operated individually or collectively by a suitable hand mechanism. The governor valve which controls the admission of gas has constant travel, the time of opening being controlled by the governor by either increasing or decreasing the angle of advance of the crank which operates them, since the engine is of the constant-compression type.

"The governor is of the fly-ball pattern and is in duplicate,

one controlling the operating valves on each side of the engine. The two are driven by Morse chains through a flexible coupling, and are connected by a cross rod which may be removed in case it is desired to operate either side of the engine alone.

"Each end of each cylinder is equipped with two igniters, one operated mechanically and the other by a solenoid. Either may be used independently or the two together. The igniters are under control of the governor, and when the engine is at rest are automatically thrown back to the dead center. The ignition is on the make-and-break system, using direct current at 90 volts, supplied by a motor generator set, which is so designed that either end may be used as a motor or a generator, or both may be used as generators by driving directly from the engine shaft. Connected in series with each igniter is a tell-tale lamp on the switchboard, giving a positive indication as to whether or not the igniters are sparking, short-circuited or burnt out."

The Sargent Engine. — The Sargent complete expansion engine, made by the Wisconsin Engine Company of Corliss, Wis., is shown in general elevation in Fig. 12-55 and in transverse section in Fig. 12-56. As far as the constructive details of this engine are concerned, it has the merit of great simplicity. The engine is built as a double-acting tandem. There is but one valve to control admission and exhaust for each end of each cylinder, and but a single cam to perform these various offices, while a second cam operates the igniter. The lay shaft is driven from the main shaft by a pair of worm gears. The governor is of the inertia type, the Rites, and operates to advance or retard the lay-shaft, thus controlling the time of cutting off the admission of the incoming charge to the cylinder. This construction is decidedly different from that used by other designers.

The combination valve is shown in cross-section in Fig. 12-56. Its operation is described as follows:

"Gas is piped to the chamber *A* in the sub-base and air to the chamber *B*, which pass through the cylinder supports to the chambers *A'* and *B'*, ready to pass into the mixing chamber when the cam depression *M N* passes the roller and the ports *F* in the piston valve register with the ports *E* and *D* in the bushing. When the piston valve goes down to this position, the confined air in the piston valve dash-pot forces open the poppet valve,



Fig. 12-55. — Sargent Complete Expansion Engine.

thus giving free admission to the charge. When the point *N* of the cam reaches the roller, it is forced down, while the other end of the lever goes up, carrying the piston valve which cuts off the admission. The poppet valve seats and both valves remain

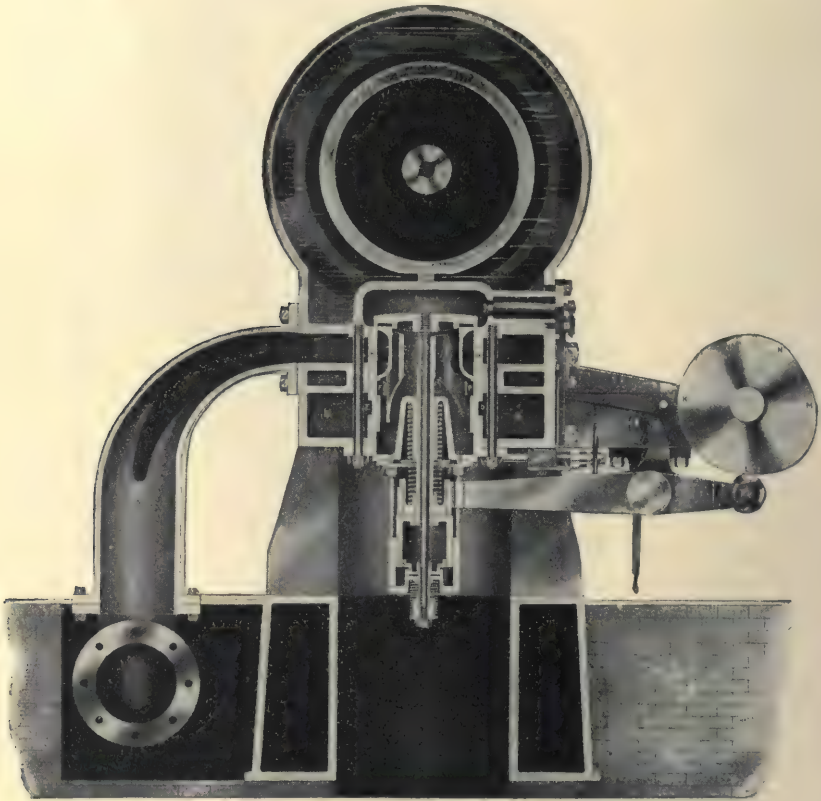


FIG. 12-56. — Transverse Cross-section Sargent Engine.

in normal position during compression, ignition, and expansion, or until the point *L* on the cam pushes the roller down and the piston up, which opens the poppet and the exhaust gases pass out through the ports *K* and the elbow *W* to the exhaust pipe under the floor.

"The poppet valve seals the opening in the combustion chamber during the compression and inflammation, and the piston valve,

holding against no pressure, works loosely in its bushing, cutting off the admission and guiding the exhaust.

"As the poppet valve controls both the inlet and outlet gases, both the valve and seat keep cool and need to be ground not over once or twice a year. The mechanism is simple and, as the roller is always bearing on the cam, the valve motion is practically noiseless."

By revolving the piston valve by the index wheel, the blind port *S* varies the mixture to suit the gas whether it has 100 or 1000 B. T. U. per cubic foot.

The fundamental idea of the Sargent engine is to get complete expansion of the charge in the cylinder. In the ordinary engine, which at full load draws in the charge to the full stroke of the piston, or nearly so, the terminal pressure is anywhere from 25 to 50 pounds, and the final temperature over 1000 degrees Fahrenheit. Sargent claims that his engine, cutting off the stroke at full load at three-quarters of the suction stroke, will show a terminal pressure slightly above atmosphere and a temperature of about 400 degrees Fahrenheit. The system of speed regulation by cutting off at various points along the suction stroke is one used by several makers, but in nearly all cases the engines cut off at nearly full stroke for full load, that is, at full load the ratio of compression is nearly equal to the ratio of expansion. In the Sargent engine the ratio of expansion always exceeds the ratio of compression, and a lowering of the terminal pressure and temperature is of course the result. There is no doubt that this lowering of the temperature has a great deal to do with any success that the use of a combination valve such as described above may have. In the Sargent engine the rated power is developed when the governor cuts the admission off at three-quarter stroke; the rest of the stroke may be considered potential over-capacity. In spite of the fact that ordinary experience shows a gas engine to be most efficient when it is developing its maximum, not the rated, load as long as normal speed is maintained, the claim is made for this engine that its best efficiency is obtained when cutting off at three-quarter stroke.

The Koerting Two-Cycle Engine. — The Koerting engine is of German design, made in this country by the De La Vergne Machine Company of New York. This is one of the two successful large

two-cycle gas engines in Europe, the other being the Oechelhäuser, not made in America. Koerting two-cycle engines are now made by several German firms, whose constructions differ somewhat among themselves and from the parent design, mainly in frame and governor details. The latter seem to have an important bearing upon the amount of work done by the pumps. The type made by the De La Vergne Machine Company is best illustrated from the catalogue of the firm. Fig. 12-57 shows a cross-sectional elevation and a plan of this machine, used in this case as a blowing engine. It is seen that the engine has but a single cylinder which is double-acting. There are thus exactly the same number of power impulses per turn as in a single-cylinder steam engine. The piston is very long, about seven-eighths of the stroke, and is of course water-cooled. This makes it necessary to support its weight at the cross-head and at a tail-bearing to save both cylinder and stuffing-boxes. At the side of the power cylinder there are a gas and an air pump which furnish gas and air by separate passages to the mixture inlet valves at the top of the cylinder. The manner of driving these pumps from a side crank and of operating the piston valves, which control them, by means of rocker arms driven by an eccentric from the main shaft, is clearly shown in Fig. 12-58. Fig. 12-59 illustrates the valve shaft side of a partially constructed machine and shows the manner of operating the inlet valves and igniter gear. The exhaust gases are taken care of by a ring of ports in the middle of the cylinder. These ports are uncovered by the piston alternately on each side (see Fig. 12-57).

The operation of the engine is as follows:

It will be seen from Fig. 12-58 that the pump crank is in the neighborhood of 100 degrees ahead of the main crank, *i.e.*, when the latter is at either dead center the pumps have completed about one-half their stroke. From the beginning of its discharge stroke the air pump B, Fig. 12-60, has forced its charge of air into the passage leading to the main inlet valve and has forced some of this air also partly up to the gas passage, which is the inner concentric passage surrounding the inlet valve stem. In the meantime the piston of the gas pump A, the motion of which has been exactly the same as that of the air pump piston, has been allowed to shove back part of its charge into the gas suction pipe.

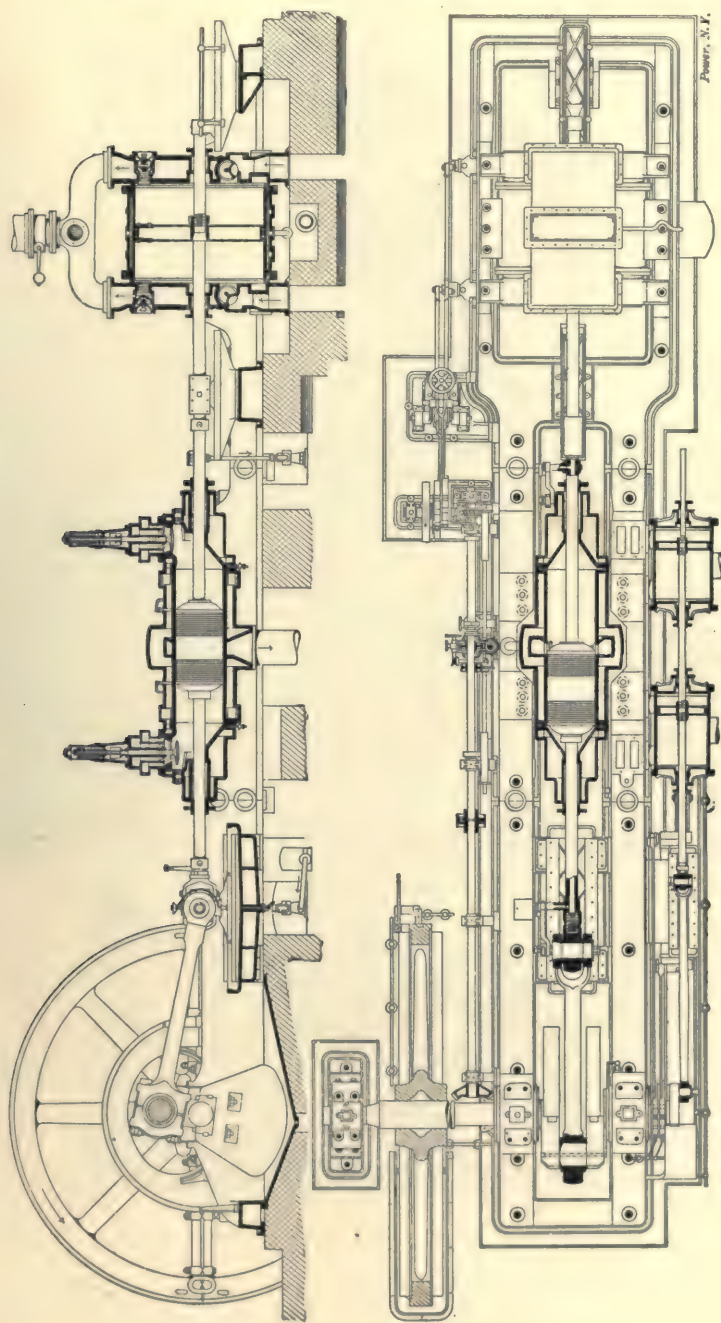


FIG. 12-57. — Koerting Two-cycle Engine, for Blowing Service.

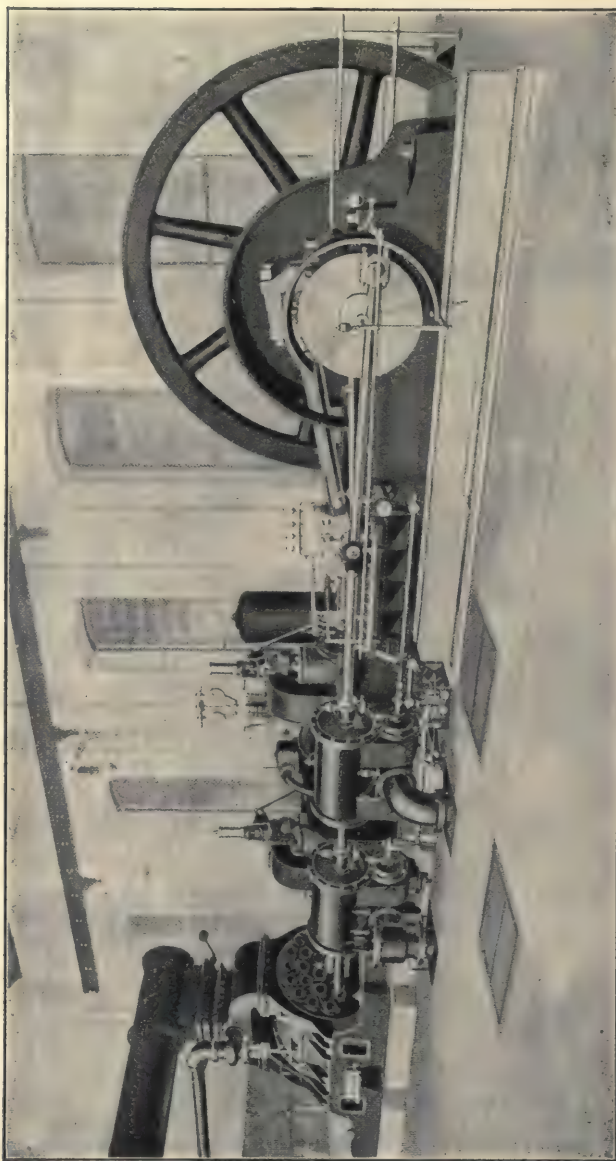


FIG. 12-58. — Pump Side of Koerting Two-cycle Engine.

At the moment, therefore, when the exhaust gases have nearly completely escaped from the main cylinder through the ring of ports, and the main inlet valve is opened, there is at first a rush of air from both the air and gas passages. This serves to drive the remainder of the exhaust gases out of the cylinder. A moment later the gas pump starts to deliver gas and the mixture enters the cylinder. By the time the power piston has covered the exhaust ports on its return stroke, the air and gas pistons

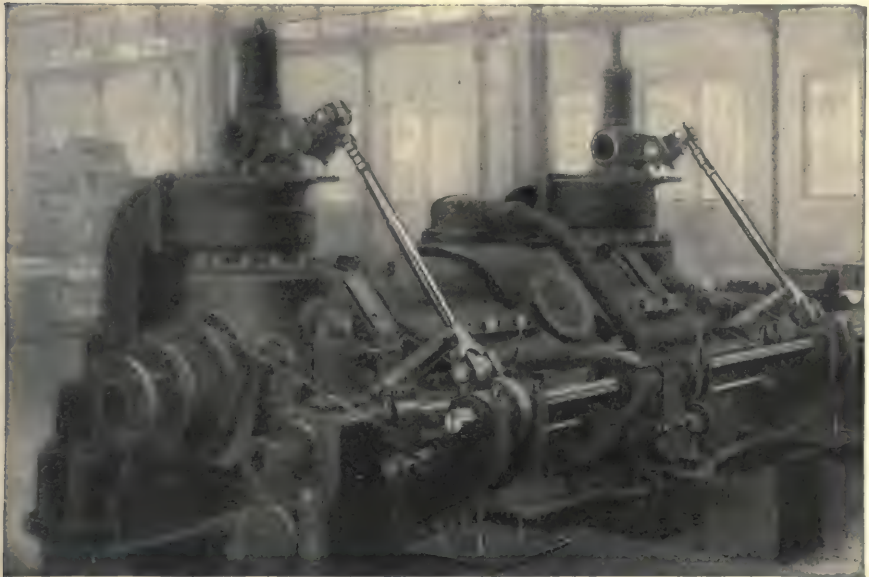


FIG. 12-59. — Valve Gear of Koerting Two-cycle Engine.

have reached the end of their stroke, the inlet valve closes and the mixture is compressed in the power cylinder. Ignition is by electric spark.

The speed of Koerting two-cycle engines is controlled by proportioning the amount of gas to the load. In the American type this is accomplished by putting butterfly throttle valves *f-f*, Fig. 12-60, in the discharge passages of the gas pump. The position of these valves is controlled by the governor, which, as some of the other illustrations show, is of the centrifugal type. This method of pump control is open to the objection that if the

gas used is at all dirty, the frictional resistances soon become so great as to render the governor inoperative. Some of the improvements of the later Koerting engines have been devoted to this very point. A modified design of gas pump is that of Klein Bros., Dahlbruch, Fig. 12-61.* In this construction the piston forces the charge back into the suction space through the ports shown at the middle of the cylinder, for one-half the stroke. The amount of gas delivered to the discharge passage during the last

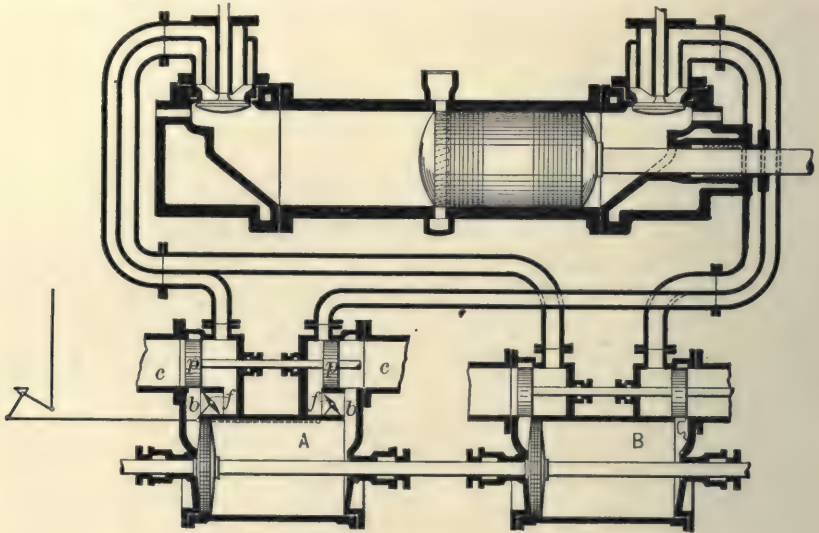


FIG. 12-60.

half depends upon the position of the small overflow piston valves near the bottom. This is controlled by the governor through the linkage shown. Another point that has given some trouble in the first designs of Koerting engines is the fact that the time available for the opening and closing of the inlet valve was but a very small part of the time of one revolution. The inertia actions were very severe and hence the engine speed was somewhat restricted. This difficulty has been overcome in an elegant way in the design of the Siegerner Maschinensban A-G as shown in Fig. 12-62. Here the lay shaft moves only at one-half the speed of

* Hoffman, Zeitschrift d. V. d. I., September 15, 1906.

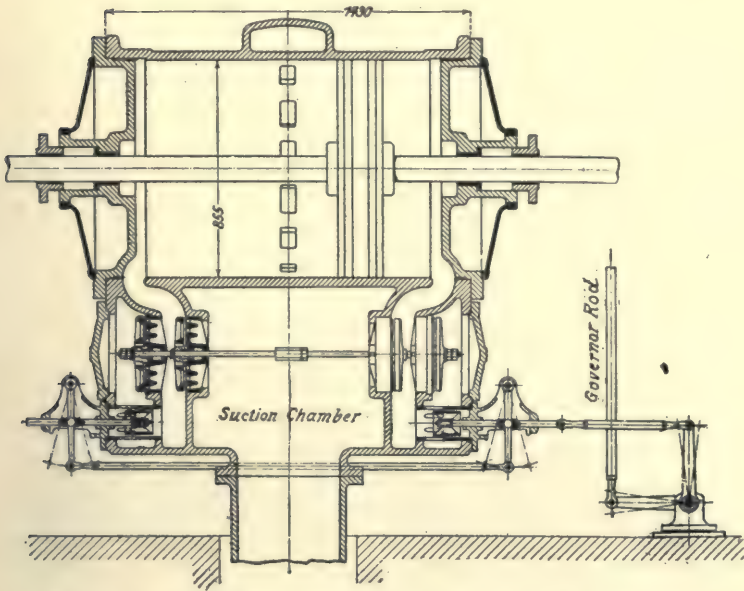


FIG. 12-61. — Gas Pump, Koerting Two-cycle Engine, Klein Bros.

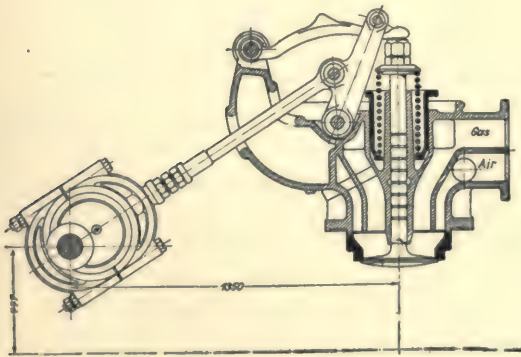


FIG. 12-62. — Modification of Inlet Valve Gear, Koerting Two-cycle Engine.

the main shaft, the same as in four-cycle engines, but the valve is opened twice for every turn of the shaft.

Reinhardt states that the Koerting engine is well adapted to blowing service because it starts easily under load and is certain in its operation through a wide range of speeds.

The Riverside Engine. — This engine is made by the Riverside Engine Company of Oil City, Pa., and embodies in its details several features decidedly different from those of other large engines. Fig. 12-63 shows the heavy duty double-acting tandem type and illustrates the peculiarity of the valve construction very clearly. Besides this type, this firm also builds single-acting,



FIG. 12-63. — Riverside Heavy Duty Double-acting Tandem Gas Engine.

single-cylinder and twin engines, and single-acting tandem engines. One of the single-acting, single-cylinder engines is illustrated in Fig. 12-64. The following is a description of the main features of the double-acting machine. It applies with little modification also to the single-acting type. Fig. 12-65 shows in cross-section the cylinder, valve and piston details of the double-acting engine and will serve as an aid in following the description of these parts.

The main frame or bed is of the heavy duty tangye rolling-mill type with bored guides and main bearings cast in a single piece, and is of great weight and extreme rigidity. The cylinder end of main frame is squared similar to cross-section of cylinder, and has machined holes for receiving the tie bars which attach the cylinder. The design of this frame, with its bored guideway, is such that a large portion of the metal is above the center line, making it exceptionally stiff.

The shaft is of side crank, built-up type and is machined all over.

The cylinders are made in two halves, with heads and valve chest cast integral without joints or packing, and are held rigidly to the main frame by four heavy steel tie bars which take all tension strains. The cylinders are mounted on a heavy cast-iron sole plate, having a machined top surface which keeps cylinders in alignment, permits perfect freedom for expansion and contraction, and by removing distance piece, cylinders can be slid end-wise on sole plate, giving easy access to interior of cylinder, pistons

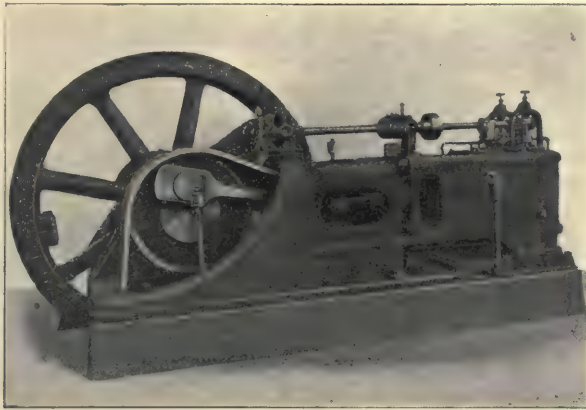


FIG. 12-64. — Riverside Single-acting Single Cylinder Gas Engine.

and piston rings. Rings can be cleaned or changed without disturbing piston or rod. The sole plate makes a drip pan under all the cylinders, keeping oil drip from foundation. The exhaust and inlet piping is attached to the sole plate, hence no piping except the water-jacket piping has to be disturbed when cylinders are moved. There is no overhead piping or wiring to interfere with traveling crane.

Both inlet and exhaust valves are of the semi-balanced water-cooled poppet type, operated in a vertical position. All water passing to the cylinder jacket passes through valves first, giving perfect and positive cooling without any attention whatever.

The balancing pistons run in renewable liners and are lubricated positively. These pistons form a large and perfect guide,

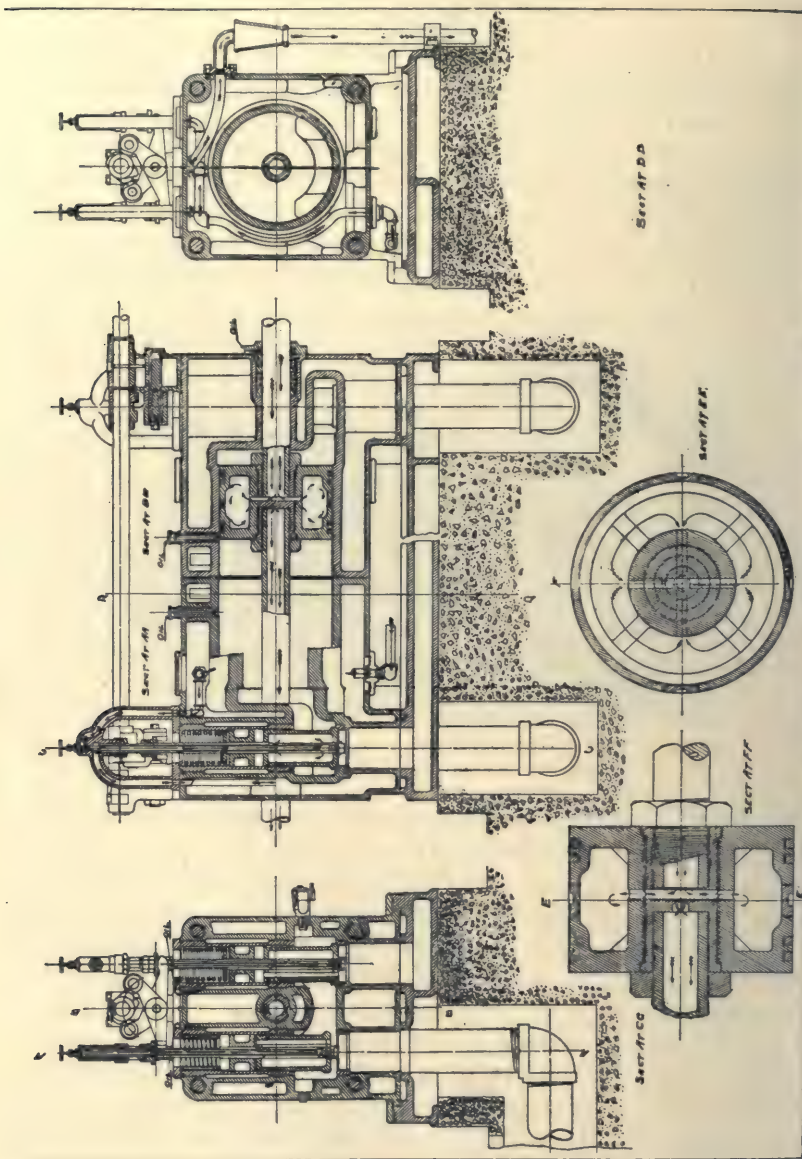


FIG. 12-65. — Details of Riverside Engine.

assuring positive alignment for these valves indefinitely. The valve seats are renewable and are located slightly below bottom of cylinder bore, so that all foreign substances are swept from the cylinder at each exhaust stroke. All valves are readily removed from the top of the cylinder without disturbing cam shaft.

Piston and piston rods are water-cooled, the water entering through a telescopic joint connected to side of cross-head. Circulation through each piston is positive and the overflow is so arranged that pistons are kept full of water. Water passages through piston and rod are large and easy so that not over ten pounds' pressure is required for circulation. The overflow is visible so that water cannot come to a boiling-point without attracting engineer's attention. A heavy tail-rod support and adjustable shoe is provided for carrying weight of pistons and rod. The construction of the piston rod is such that a piston in either cylinder can be removed without disturbing the other cylinder or the connecting rod, cross-head or any part of the valve gear.

The valve gear of the Riverside engine is very simple and consists of a single shaft mounted on top of the engine, running in self-oiling bearings. This shaft runs at one-half the speed of the main shaft and carries the inlet and exhaust cams, cams for operating the oil pumps, and the timers for ignition system. Power is transmitted to the inlet and exhaust valves by an inlet and exhaust lever hung on a single pin. All cams are keyed rigidly to the cam shaft. This construction makes a minimum number of joints subject to wear. Ample adjustments are provided for taking up wear.

Ignition is by an improved method throughout, consisting of two magnetically operated spark plugs in each cylinder. The sparking points being in series with the magnet coils give a positive external indication by the movement of the armature as to whether the spark takes place within the cylinder. The timing is electrical; no gearing or mechanical trips being used, simply a No. 14 stranded wire running through iron armored conduits leads to each plug.

The timer is mounted on the secondary shaft and is built in a heavy, substantial manner. The contacts are of the wipe type and are made of tool steel, and are adjustable for wear. A visible

indicating spindle shows the amount of contact. The entire wearing parts of timer are run in oil, which prevents burning of the contacts and reduces wear to minimum. Wiring from the timer to each spark plug is protected by a five ampere enclosed fuse; thus, should any spark plug become damaged or short-circuited, it would have no effect on the rest of plugs. Any spark plug can be removed and replaced while the engine is in operation.

The time of ignition in all cylinders can be adjusted simultaneously, and by an individual adjustment the time of ignition in any cylinder can be adjusted independently. All of these adjustments can be made when the engine is in operation.

The method of starting the double-acting engine is as follows:

A gas-engine driven air compressor is provided for supplying compressed air for starting this engine, air to be stored in a suitable steel receiver. The pneumatic starting gear on the engine consists of two shifter pistons mounted within the valve lever carrying pin. These pistons are shifted by throwing a small three-way cock which applies compressed air to one side of the piston, which in turn moves the valve levers $\frac{5}{8}$ inch, bringing the cam rollers in line with an auxiliary cam which puts all the valves in both ends of one cylinder into two-cycle action, or, in other words, makes a poppet valve air or steam engine out of this cylinder, which permits the engine being started on any stroke and on either quarter. The operation being entirely automatic, the engine will run as long as compressed air is applied. The other double-acting cylinder continues to operate as a four-cycle gas engine and takes up its explosions after the first revolution. Compressed air is then shut off from the starting cylinder and the three-way cock reversed, which permits the cam levers being returned to their normal position and that cylinder immediately goes into four-cycle action and takes up its explosions on the next revolution. The starting gear adds practically no complication to the engine as the regular inlet and exhaust valves are used for distributing the air. There are no extra shaft or auxiliary valves and no tappings into the cylinders. There is only one compressed air pipe leading to the sole plate, air being delivered into the fuel duct and entering the cylinders via the inlet valves.

The Crossley Engine. — This English engine is made in this

country by the Power and Mining Machinery Company of New York, and known as the American Crossley.

These engines are built as single-cylinder, two cylinder-opposed and double-opposed units, sizes ranging from 50 to 1300 B. H. P. This design differs radically from that of other large engines in that the single-acting cylinder is retained up to the largest sizes, *i.e.*, the design is in a way nothing but an enlargement of the small four-cycle machine. It is fundamentally the same design employed at first by the Deutz Company for their large engines, but has been given up by them some years ago in favor of double-acting engines.

Figures 12-66 and 12-67 show a general elevation and a cross-sectional elevation respectively of the single-opposed type. The cylinder castings are securely bolted to each end of a central frame casting. Both connecting rods work on one crank pin. The pistons are water-cooled. The cylinder proper is a separate liner, resting at the crank end in the jacket casting and held at the head end by the cylinder head. The head carries the gas and inlet valves, while the exhaust valve is placed in a separate casting. The position of inlet and exhaust valve is shown in Fig. 12-68. Both are operated in a horizontal position by means of bell cranks by cams on a lay shaft. In this respect the engine differs from most others in which the valves are nearly always vertical. The objection to the horizontal form is at least partly overcome by giving the exhaust valve a guide at each end. This valve is water-cooled, as is necessary in large machines. The lay shaft *s*, Fig. 12-66, is operated by spiral gears, and actuates the main inlet, the cut-off valve, the gas valve, the exhaust valve, and the igniter gear.

Gas and air enter the mixing chamber *M*, Figs. 12-66 and 12-69 through a proportioning valve, the air direct and the gas through a special gas valve. From here the mixture passes a multi-port cut-off valve, which surrounds the valve stem of the inlet valve and is shown in greater detail in Fig. 12-70. This cut-off valve is operated from the lay shaft through the rocker arm *C*, Fig. 12-71. The governor, shown in plan in Fig. 12-69, serves to shift the fulcrum *f* of the rocker arm *c*, Fig. 12-71, thus cutting off the mixture supply to the main inlet valve earlier or later as the load demands. Should the load drop so far that the com-

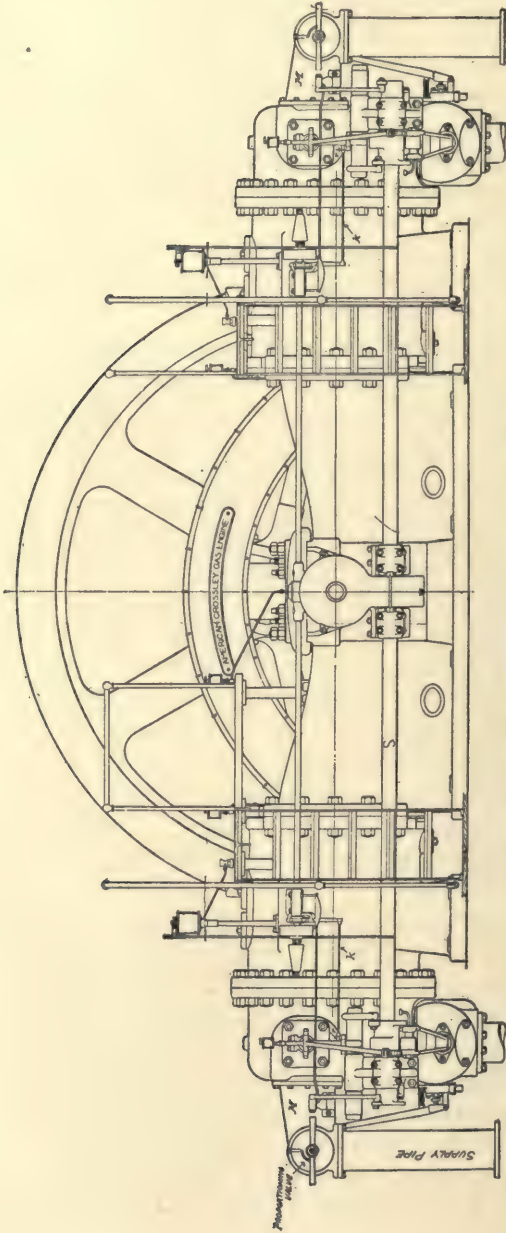


Fig. 12-66. — American Crossley Gas Engine.

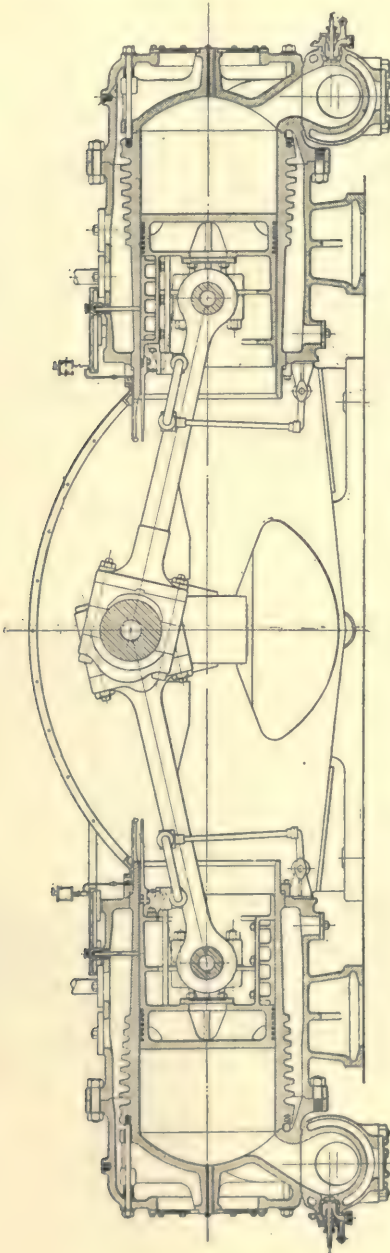


Fig. 12-67. — Cross-section American Crossley Gas Engine.

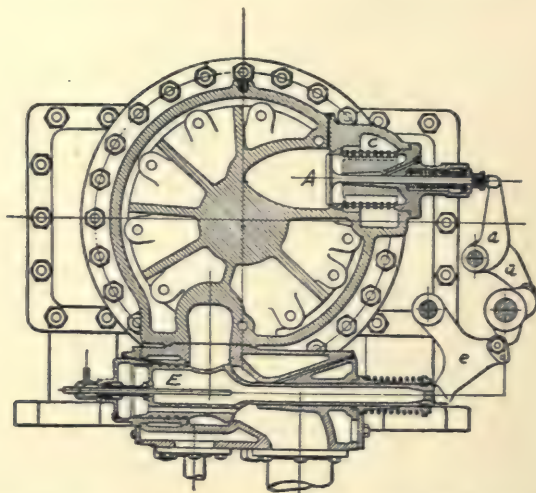


FIG. 12-68. — American Crossley Engine, Inlet Valve at A, Exhaust Valve at E.

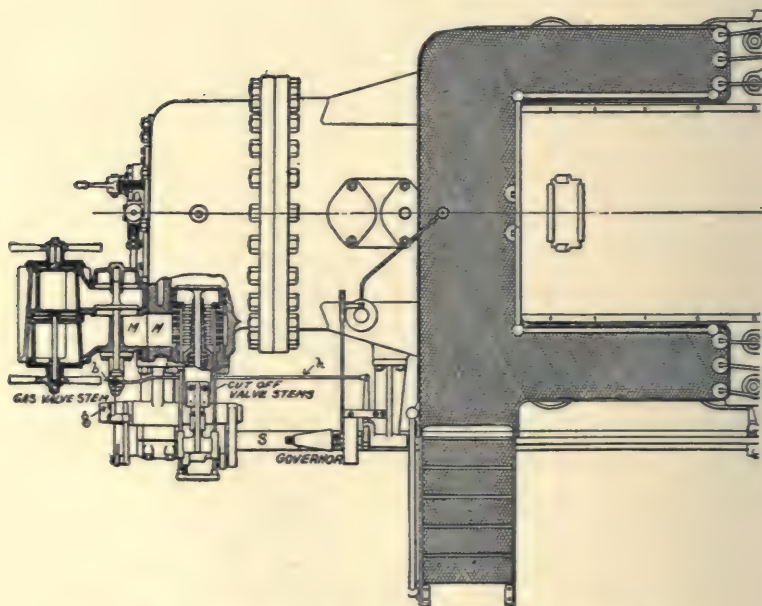


FIG. 12-69. — Details of Valve Gear, American Crossley Engine.

bustion becomes sluggish under very low loads, the engine automatically shifts over to the hit-and-miss governing by the governor withdrawing the block *b*, Fig. 12-69, thus keeping the gas valve closed altogether.

In multi-cylinder engines the point at which this occurs is so adjusted that one cylinder after another changes over to the latter system of regulation and not all of them at the same time.

The American company for some time adhered to hot tube ignition, but some of the later engines were fitted with make-and-break electric ignition.

The Snow Engine. — The Snow Steam Pump Company build

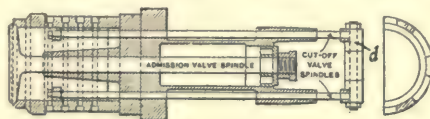


FIG. 12-70. — Inlet Valve, American Crossley Engine.

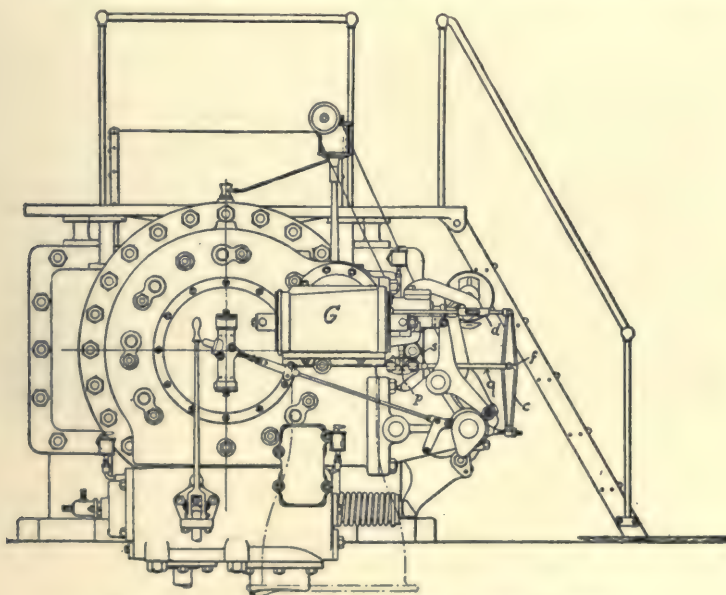


FIG. 12-71. — End View, American Crossley Engine.

two types of horizontal double-acting four-cycle machines, called respectively Type "A" and Type "B." Both of these designs differ radically from the construction of other large gas engines

in that the valves are placed in chambers at the side of the cylinders. There are reasons for and against this construction, the main disadvantage being perhaps the cut-up form of the combustion chamber. Some of the many advantages are outlined below.

Type B engines are built in single-cylinder units from 20 to 125 horse-power, and in tandem units from 80 to 500 horse-power. The general features of the design are shown in elevation in Fig. 12-72 and in cross-section in Fig. 12-73.



FIG. 12-72. — Snow Type B Gas Engine.

The most notable installations of Type A engines is found in the Martin station of the San Mateo Power Company in California. This station at present contains three of the twin-tandem units, a fourth is in course of erection, and the foundation is laid for a fifth. Fig. 12-74 shows a general view of the station, and also serves to give a general idea of the appearance of the engines. The engines of the Martin station were described in great detail by C. P. Poole in an article in *Power*, January 14 and

21, 1908, to which the writer is indebted for the following information:

Figure 12-75 shows in cross-section the main features of the design, while Fig. 12-76 is a transverse cross-section through one of the valve chambers to show the valve construction. Each cylinder of the twin tandem unit is 42 inches in diameter by 60-inch stroke. The engines are direct connected to Crocker-Wheeler generators rated at 4000 K.W. each. They are capable, however, of carrying momentarily an overload of 33 per cent, and have demonstrated their ability to carry 15 per cent overload continuously. These figures make these units the largest gas power

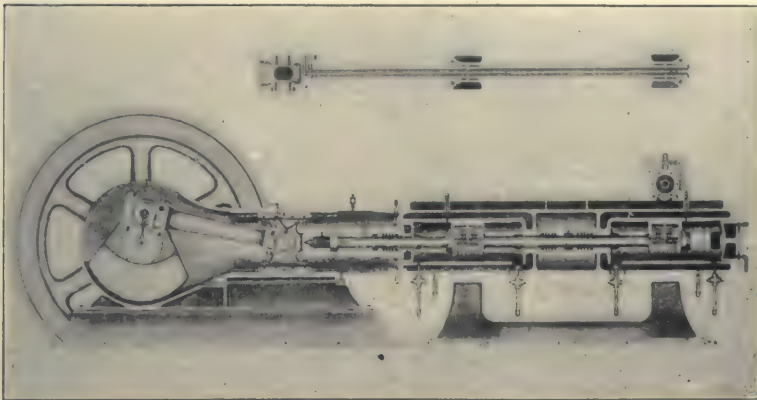


FIG. 12-73. — Cross-section of Snow Type B Gas Engine.

engines in the world. The fuel used is an oil-water gas made by the Lowe process.

The main frame is of the side crank type. The cylinders are cast in two parts, fastened together by flanges at the center, as shown in detail in Fig. 12-77. This construction makes the outer wall independent of the cylinder wall proper, and avoids temperature stresses. The valve chambers are cast integral with the cylinder casting. The cylinder heads are plain jacketed covers containing nothing but the stuffing-boxes. For the purpose of safety against leakage, however, each head has a double seat. The front and rear cylinders are connected by a distance piece of box-section, which has large openings in the side through which heads and pistons may be removed if required. The pistons are



Fig. 12 74. — Snow Type A Engines, Martin Station, San Mateo Power Co., Cal.

made in two parts bolted together. These pistons, together with their rods, are of course water-cooled, the water entering at the front cross-head and leaving at the tail cross-head.

The distinguishing feature of these engines, however, is the valve construction, shown in detail in Fig. 12-76. Mr. Poole, in the article mentioned, describes the gear as follows:

"The cam shafts which drive the valve gear are driven by steel gears, bevel gears being used on the main shaft, driving back through spur wheels to secure the proper reduction in speed of two to one. The igniters and lubricators are also driven from the cam shafts, as are also the starting valves, which admit compressed air on the cylinders for starting. The inlet and exhaust

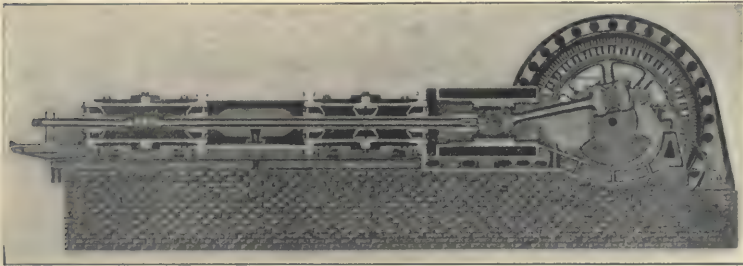


FIG. 12-75.

valves are driven by cams made of chilled cast iron, located on the cam shafts, which run in bearings bolted to the side of the valve chambers.

"The inlet and exhaust valves are of the unbalanced mushroom type, working in cages secured to the top and bottom of the valve chamber. Both valves and their cages are water-jacketed, in order to prevent back-firing or pre-ignitions on account of the treacherous nature of the gas used. Each inlet valve is combined with a combination mixing and throttling valve, of piston form, so designed that when the inlet valve opens gas and air ports in proper proportion are open for the passage of gas and air in the ratio desired, the amount of the opening of both being fixed by the governor. From this it will be evident that the engines operate with variable compression and constant mixture, the supply of air and gas to each end of each cylinder being throttled directly at each inlet valve for its end of its cylinder.

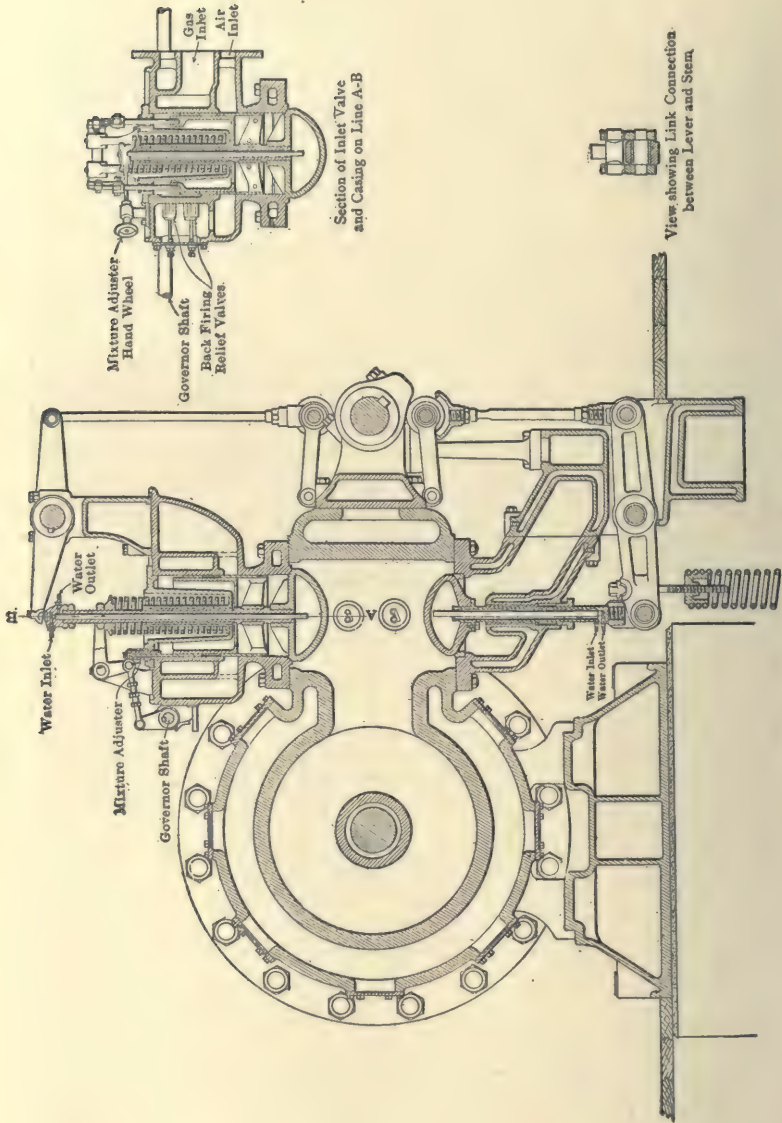


Fig. 12-76. — Transverse Section, Snow Type A Engine.

"The exhaust valves are of cast iron with nickel-steel stems and are thoroughly water-jacketed, the water being fed to and carried from the valve by positive circulation. The connection of the exhaust valve cages with the exhaust pipe is so made that the cages can be readily removed without disconnecting any other part of the engine."

In discussing the reasons for locating the valves at the side, Mr. Poole quotes the builders as follows:

"It permits of the use of an absolutely continuous bedplate under all cylinders, which is considered essential on engines as long as these for maintaining absolute alignment and permitting unrestricted movement to compensate for variations in temperature in cylinder walls and connecting parts.

"A solid, unbroken foundation from one end of the engine to the other is thus secured, and the builders consider that a solid, unbroken foundation is more essential for a gas engine than for any other prime mover on account of the enormous weight of the reciprocating parts and the inability to fully counterbalance.

"It enables all working parts of the engine, without exception, to be located above the engine-room floor and therefore to be in full view of the attendants at all times.

"Inlet- and exhaust-valve driving motions from the cam shaft are short and direct.

"Exhaust valves are much more accessible for removal when located in a valve chamber on the side, since the crane can be used throughout the entire operation and all work in connection with the removal and displacement of the exhaust valves is done from the engine-room floor.

"With valves located in a side valve chamber, broken inlet and exhaust valves cannot get into the interior of the cylinder and lodge between the piston and the cylinder-head, causing wrecks.

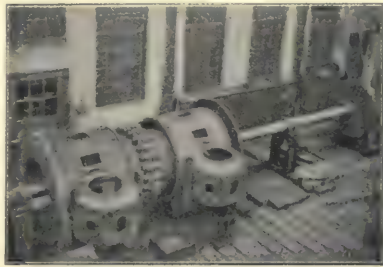


FIG. 12-77. — Cylinder Construction, Snow Type A Gas Engine.

"It has been very generally the opinion of gas-engine designers that the location of the valves in a side valve chamber of the kind used on the California engines entailed the certain disadvantage that foreign material entering the cylinder with the air and gas would deposit on the bottom of the cylinder counterbore, while if the exhaust valve be located on the bottom, such deposits will be carried out through that valve; furthermore, that lubricating oil collects in the bottom of the counterbore and is carbonized, causing back-firing and pre-ignitions. Experience with these engines thus far indicates that if lubrication is properly effected no carbonized oil is found in the cylinder, and that when oil is supplied excessively the resulting deposit of carbon is located not on the surface of the clearance space, but on the top of the piston barrel directly under the oil-inlet holes, on the piston rod where it wipes in from metallic packing, and on the face of the cylinder head directly under and close to the piston-rod hole in the head."

The Cockerill Engine. — This machine is built by the Soc. Anon. John Cockerill in Seraing, Belgium. This firm builds several types of engines, differing among themselves mainly in their valve constructions. Fig. 12-78 * shows a 1200 horsepower tandem gas engine, in which the inlet valve is on top, the exhaust valve on the bottom of the cylinder. Both are operated apparently from the same cam on the lay shaft. This type of machine is built either for quality or quantity governing, in which case the construction of the inlet valve differs. Fig. 12 79 shows another form, a single-cylinder double-acting engine direct connected to a blowing cylinder. The details of the valve gear of this machine are quite clearly shown in Fig. 12-80.† Both inlet and outlet valves are side by side at the bottom of the cylinder.

Figure 12-81 shows the latest form of the double-acting tandem Cockerill engine.‡ The distinctive features of this machine are that all valves are placed below the cylinder and that eccentrics only are used for operating these valves. The valve gear proper represents one of the most complicated constructions used

* H. Dubbel, Z. d. V. d. I., Sept., 1905.

† Güldner, p. 479.

‡ Güldner, p. 481.

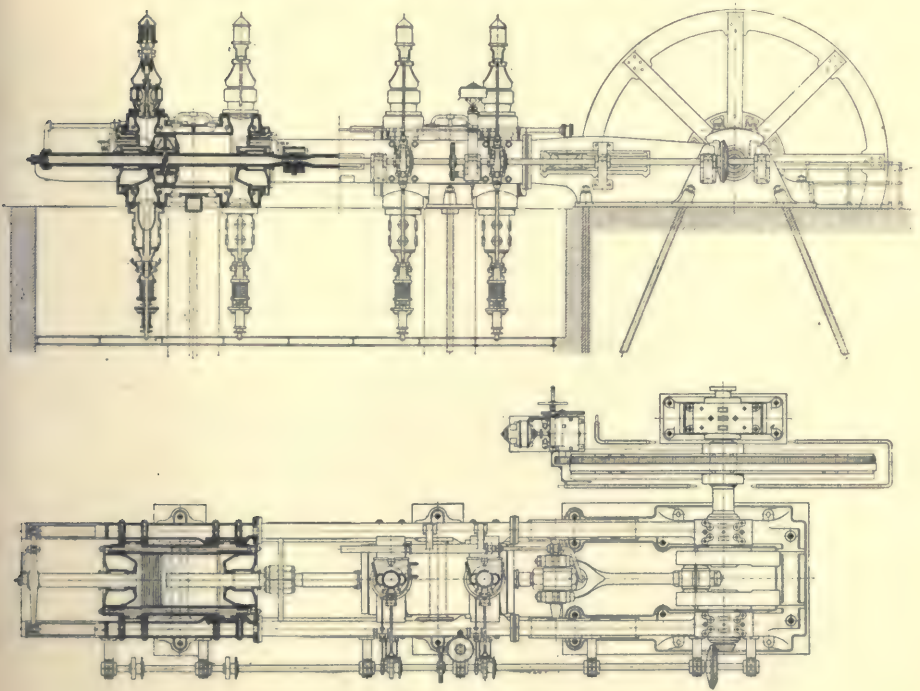


FIG. 12-78.



FIG. 12-79.

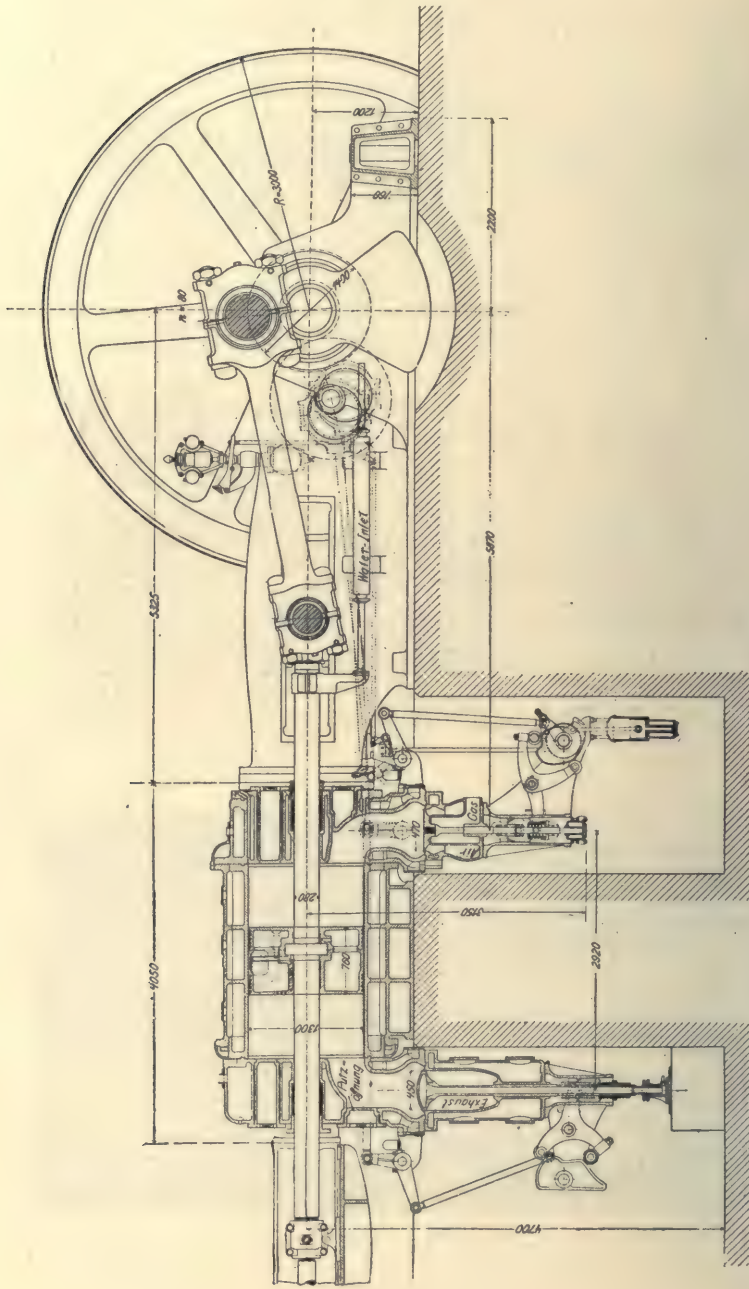


Fig. 12-80.

to-day and is shown in section in Fig. 12-82. In this figure at the left, the eccentric, through its rod *a* and the lever *b*, operates the cam *c* which positively opens and closes the exhaust valve through the triple lever *d*. The inlet valve eccentric, Fig. 12-82, at the right, in a similar manner operates the gas valve cam *c* and the inlet cam *c'*. The lever *b* actuating the gas valve cam is disengaged from the rod *a* when the trip arrangement *f-f'* is brought into play by the cam disc *e*. The position of this disc on its shaft is regulated by the governor, through the linkage shown, thus effecting speed regulation. The dash pot *h* allows the gas valve to seat noiselessly after its linkage is released.



FIG. 12-81. — Cockerill Double-acting Tandem Engine

The Cockerill engine has found considerable application in Europe, there being about 80,000 B. H. P. in operation in 121 engines, ranging from 200 to 3000 B. H. P. The fuel used is mainly blast furnace gas.

The Nürnberg Engine. — Although the Allis-Chalmers Company of Milwaukee have been the American licensees of the Maschinen-Gesellschaft Nürnberg, makers of the Nürnberg engine, the large gas engine now turned out by the American firm, differs in some of the important details from the original German design.

The Nürnberg engine is to-day perhaps the most important four-cycle gas engine built in Germany, and for that reason a description is first given of the German machine, to be followed by a few details of the Allis-Chalmers engine as far as they could be obtained.

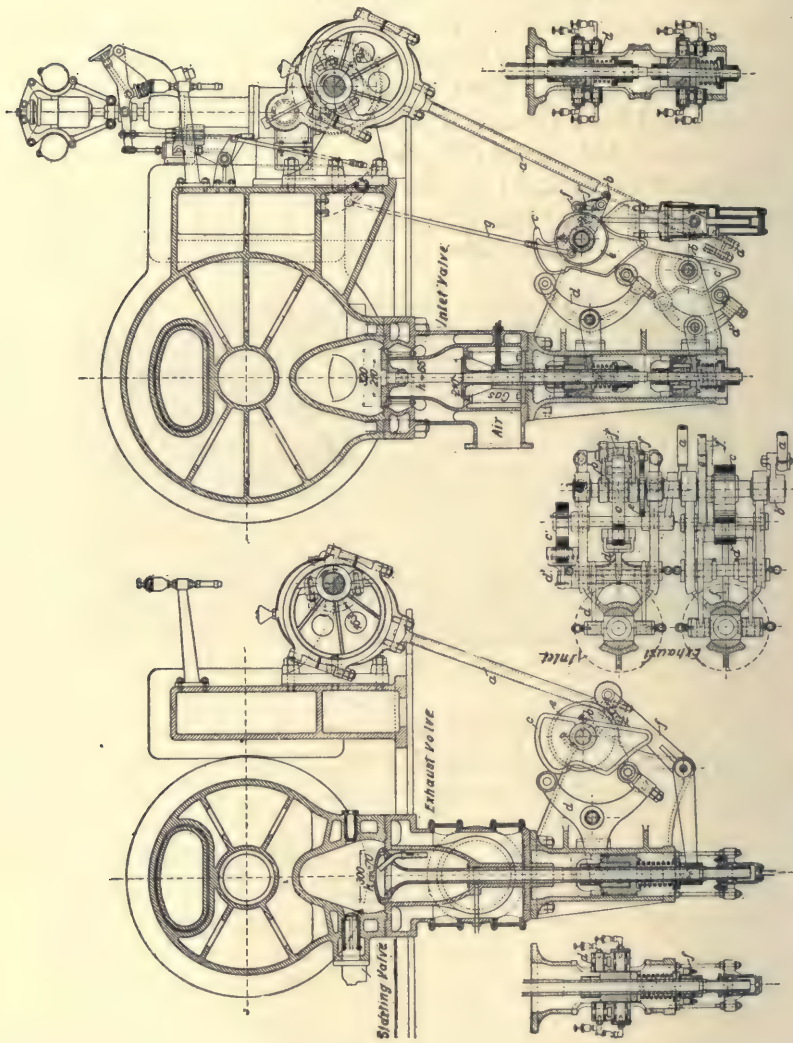


Fig. 12-82. — Valve Gear Details of Cockerill Double-acting Tandem Engine.

All of the medium sized and large Nürnberg engines are double-acting, either single-cylinder or tandem. They range in size from 250 to 6000 horse-power, the larger powers being the twin-tandem type. Probably the best description ever given of this machine is contained in Riedler's "*Gross Gasmaschinen*," from which the cross-section, Fig. 12-83, together with the two following figures, is taken. This cut shows frame, cylinder, and valve construction very clearly. The only part rigidly fastened to the foundation is the main frame, which is of the center crank type, as preferred by all European builders. The cylinders rest on supports such that they can freely expand and contract under temperature changes. The gas and inlet valves are placed on top and the exhaust valve at the bottom of the cylinder. The inlet and exhaust ports are cast in one part with the cylinder and jacket walls. This reduces the cylinder heads to simple water-jacketed covers, a point of great advantage as compared with the complicated cylinder heads of former days. All valve cages with their valves are easily removable for inspection. The exhaust valves are water-cooled. The valves are operated from a lay shaft running alongside, Fig. 12-84, by means of eccentrics and not by cams. How this motion is transmitted to the valve stems by roller levers to avoid shock and noise is very clearly shown in Fig. 12-85. The pistons are as simple as those of a steam engine. The method of fastening them on the shaft together with the water-cooling arrangements for rods and pistons are indicated in Fig. 18-83. The weight of piston and rod is carried by outside bearings, which relieves both cylinder and stuffing-boxes.

The greatest attention to accessibility has been paid in the design of this engine. As shown in Fig. 12-86, by disconnecting the piston rod between the cylinders, disconnecting the connecting rod and sliding the rod and cross-head forward, and by taking off the front and rear cylinder covers, the entire engine interior is at once open to inspection.

The Nürnberg engine regulates by pure quality regulation, that is, the amount of gas only is cut down as the load drops. To accomplish this there is a gas valve placed ahead of each main inlet valve on the top of the cylinder. Fig. 12-83 shows the construction of these valves in section and the method of operating them by eccentrics from the lay shaft may be seen in Fig. 12-84.

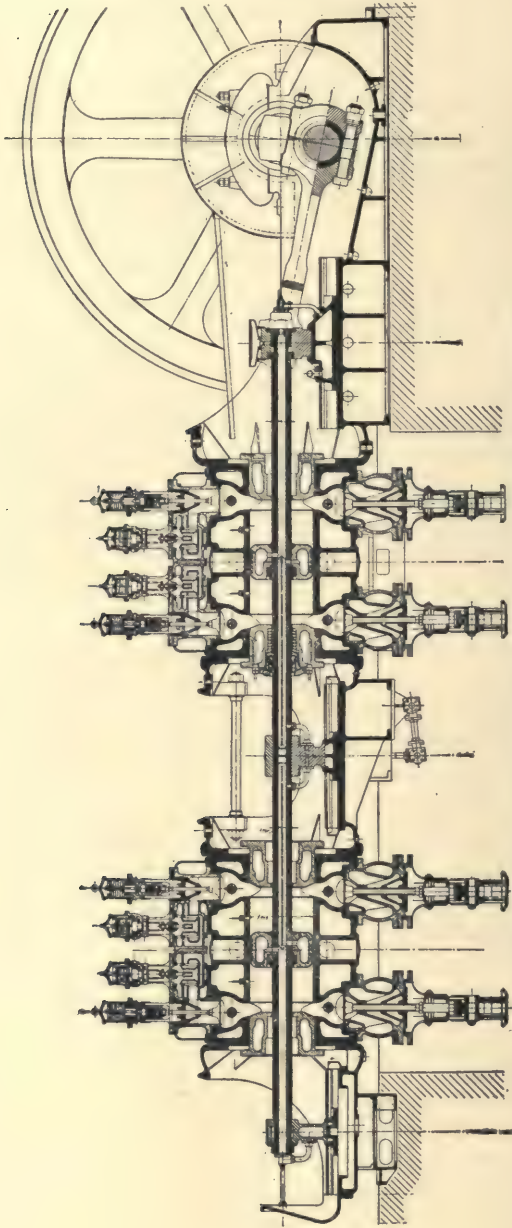


Fig. 12-83. — Nürnberg Double-acting Tandem Gas Engine.



FIG. 12-84. — Nürnberg Double-acting Tandem Engine.

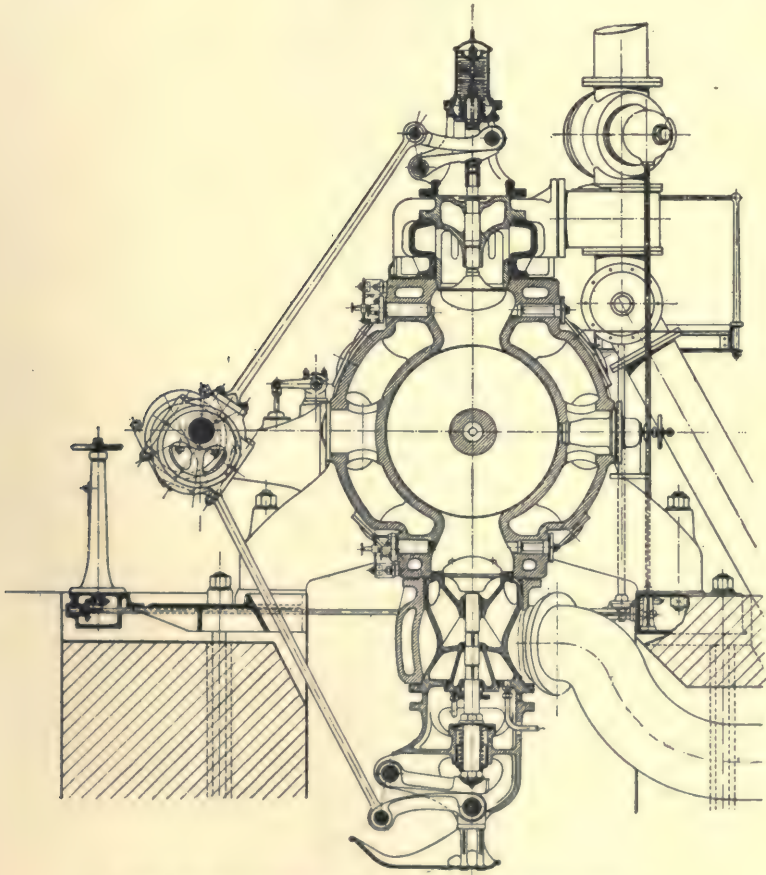


FIG. 12-85. — Details of Valve Gear, Nürnberg Engine.

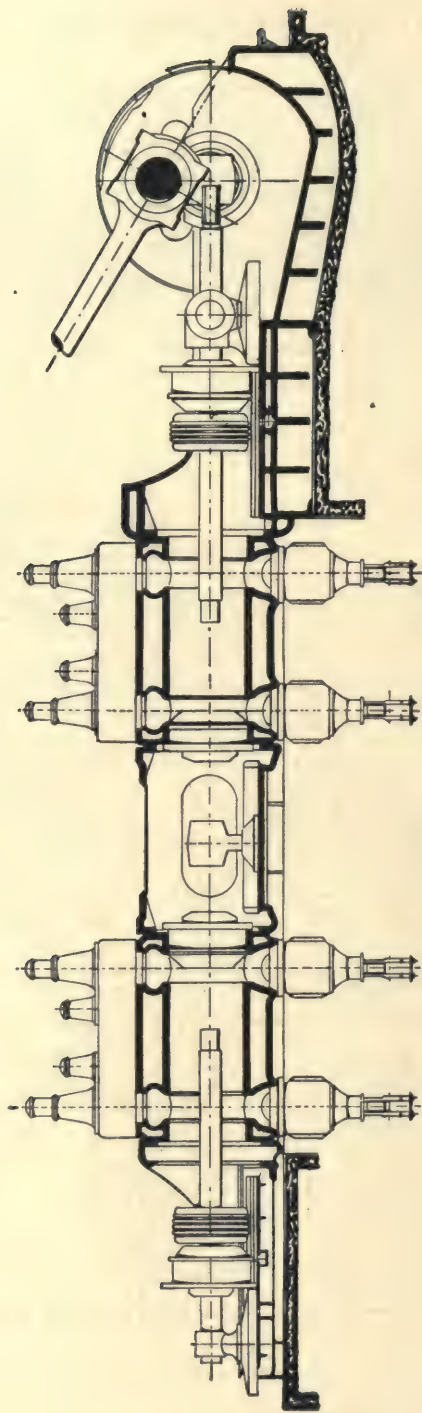


FIG. 12-86. — Showing Accessibility of Nürnberg Engine.

The latter illustration also shows the centrifugal governor and the governor shaft running alongside of the cylinders. From this governor shaft reach rods run to the gas valves and control the time of the opening of these valves in the manner explained in Chapter XIV. In some of the later engines the details of the governor mechanism are changed somewhat * but the principle of operation is the same in all, *i.e.*, to open the gas valve later in the stroke as the load drops and to keep the time of closure the same. The air is not throttled at any time, hence the compression remains about the same. It is interesting to trace out the sequence of events in a four-cycle tandem engine, for which purpose Fig. 12-87 published by the Allis-Chalmers Company is given.

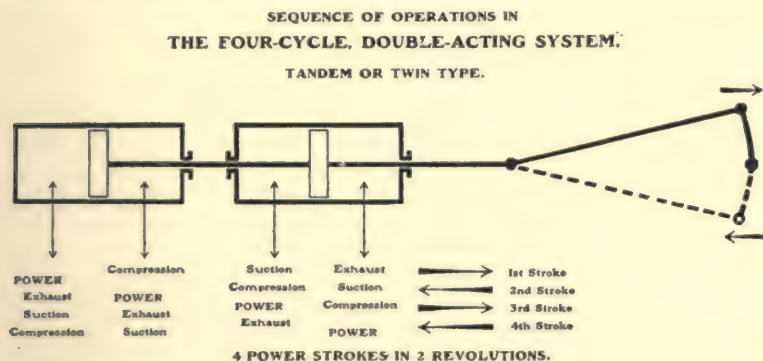


FIG. 12-87.

Most Nürnberg engines operate on blast furnace gas. The table on page 346, also from the catalogue of the Allis-Chalmers Company, will serve to give some idea of the cylinder sizes, speeds, floor-space, etc.

It has already been mentioned that the engine now built by the Allis-Chalmers Company is not quite like the Nürnberg machine. The following is a description of one of these engines, as given in *Power*, January 21, 1908. The engine, Fig. 12-88 is of the twin-tandem, double-acting type and direct connected to a 1040 K.W. Crocker-Wheeler generator:

"It is of the side-crank type so generally used in steam engine

* See *Zeitschrift des Vereins deutscher Ingenieure*, Aug. 11, 1906, and Sept. 22, 1906.

construction. The pistons are supported entirely by the piston rods, which are turned with sufficient camber to make them dead straight when the weight of the pistons is put on them. The rods are equipped with intermediate and tail shoes, as usual with large tandem construction, running on guides between the cylinders and behind the rear cylinder, in addition to the main cross-head.

NÜRNBERG GAS ENGINE

TABLE OF STANDARD SIZES

TANDEM						TWIN						TWIN-TANDEM					
Size of Cylinders		Speed. Revolutions per Min.	B. H. P.	Floor Space		Size of Cylinders		Speed. Revolutions per Min.	B. H. P.	Floor Space		Size of Cylinders		Speed. Revolutions per Min.	B. H. P.	Floor Space	
Diam. Inches	Stroke. Inches			Length Rear End to c. of Shaft. Feet	Width Overall. Feet	Diam. Inches	Stroke. Inches			Length Rear End to c. of Shaft. Feet	Width Overall. Feet	Diam. Inches	Stroke. Inches			Length Rear End to c. of Shaft. Feet	Width Overall. Feet
18	24	150	260	29	11	18	24	150	245	19	17	18	24	150	520	29	17
20	24	150	320	29	11	20	24	150	305	19	17	20	24	150	640	29	17
21	30	125	370	33	13	21	30	125	350	22	20	21	30	125	740	33	20
22	30	125	405	33	13	22	30	125	385	22	20	22	30	125	810	33	20
24	30	125	490	33	13	24	30	125	465	22	20	24	30	125	980	33	20
24	36	115	545	38	15	24	36	115	515	25	23	24	36	115	1090	38	23
26	36	115	630	38	15	26	36	115	600	25	23	26	36	115	1260	38	23
28	36	115	740	38	15	28	36	115	700	25	23	28	36	115	1480	38	23
30	42	100	855	44	17	30	42	100	810	29	27	30	42	100	1710	44	27
32	42	100	985	44	17	32	42	100	935	29	27	32	42	100	1970	44	27
34	42	100	1105	44	17	34	42	100	1050	29	27	34	42	100	2210	44	27
36	48	92	1300	50	21	36	48	92	1240	33	32	36	48	92	2600	50	32
38	48	92	1460	50	21	38	48	92	1400	33	32	38	48	92	2920	50	32
40	48	92	1630	50	21	40	48	92	1550	33	32	40	48	92	3260	50	32
42	54	86	1875	60	26	42	54	86	1780	40	38	42	54	86	3750	60	38
44	54	86	2080	60	26	44	54	86	1980	40	38	44	54	86	4160	60	38
46	54	86	2280	60	26	46	54	86	2170	40	38	46	54	86	4560	60	38
48	60	78	2475	70	30	48	60	78	2350	45	44	48	60	78	4950	70	44
50	60	78	2720	70	30	50	60	78	2580	45	44	50	60	78	5440	70	44
52	60	78	2950	70	30	52	60	78	2800	45	44	52	60	78	5900	70	44

NOTE — The overall widths given in the above tables allow for a plain fly-wheel; proper addition must be made if a band-wheel is substituted or an electric generator direct connected upon the crank-shaft.

“There are two inlet valves to each combustion chamber, one for air and one for gas, but both are mounted in a single cage. The air valve is of the piston type and the gas valve is of the poppet type, its axis being in line with that of the air valve. The latter is opened at the beginning of the suction stroke and

kept open throughout that stroke. The gas valve, however, is open during varying proportions of the suction stroke, according to the requirements of the load. The engine, therefore, operates with constant compression and varying mixture proportions. The compression pressure is about 180 pounds per square inch, absolute.

"The ignition is by make-and-break mechanism electrically operated; that is, the movable electrode is rocked by means of an electromagnet and the latter is energized by the ignition current controlled by a 'timer' or so-called commutator driven synchro-

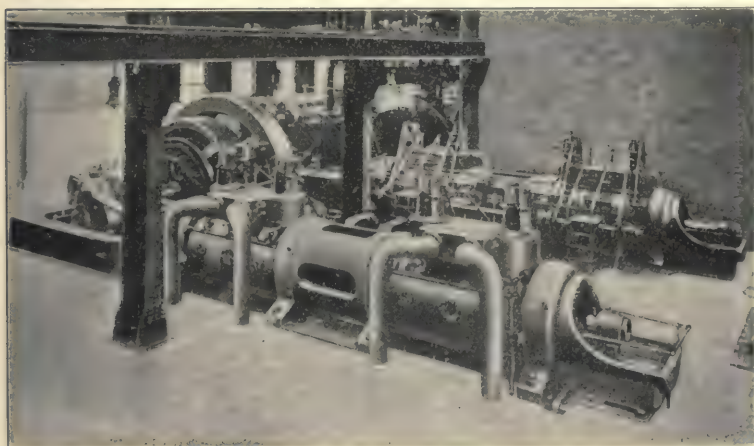


FIG. 12-88. — Allis-Chalmers Double-acting Twin Tandem Engine.

nously with the cam shaft. Tell-tale incandescent lamps are connected in circuit with the igniter magnets and indicate the performance or default."

The main differences between this and the Nürnberg engine then appear to be different cylinder supports, the combination of the gas and inlet valves in one housing, and the use of the side-crank frame.

Premier Engine. — Probably the best description of this engine is found in Robinson's "Gas and Petroleum Engines." It is of what is known as the positive scavenger type, *i.e.*, the combustion chamber is thoroughly washed out with air before a new charge is admitted. The cylinder is single-acting, and single-

cylinder and tandem units are built. The former go up to 250 horse-power, the latter up to 1200 horse-power. The pump serving to furnish the air for scavenging is usually placed ahead of the first power cylinder, but in some of the later designs the air pump is placed obliquely above the first cylinder.

Figures 12-89 and 12-90 are two illustrations from Robinson. The first shows the general appearance of the machine, the method of operating the inlet and exhaust valves from the lay shaft, the oblique rod to operate the air-pump valve, and the governor details. The second shows several sectional views from which the operation may be explained. The piston *D* of the single-acting air pump is rigidly connected to the piston *C* of the first power cylinder. The second power piston is connected by means of the yoke *K* and the side rods *R R* to the air pump piston. Thus the use of a stuffing-box in the combustion chamber of the forward power piston is avoided. *H H* are the combination air and gas inlet valves, and *G G* the exhaust valves, operated as shown in the transverse cross-section.

The operation is as follows: On the out stroke, air is admitted to the air pump *D* through the grid valve *F*, shown in the section *X X*. On the return stroke this air is compressed into the passage *D-E*, and serves to scavenge out the power cylinder just exhausting when the inlet valve *H* into that cylinder is opened about one-half exhaust stroke. On the next out stroke the air pump takes a new charge, but at the same time the valve *F* has also opened communication to the passage *E*, so that the cylinder just charging may draw air freely. Above the inlet valve *H* there is placed a cylindrical valve, which during the scavenging action opens the air ports completely and keeps the gas ports closed, but which, at the beginning of the charging stroke, shifts its position to give the proper relation between air and gas. While the exhaust and charging strokes above described take place in one, say the first, cylinder, the second has completed its compression and expansion strokes. On the third (the in stroke) of the pump, therefore, we shall have compression in the first cylinder and exhaust in the second. The pump then scavenges out the second cylinder during the last half of its exhaust stroke.

Speed regulation in this engine is effected by the governor cutting out the gas from the back cylinder altogether below a

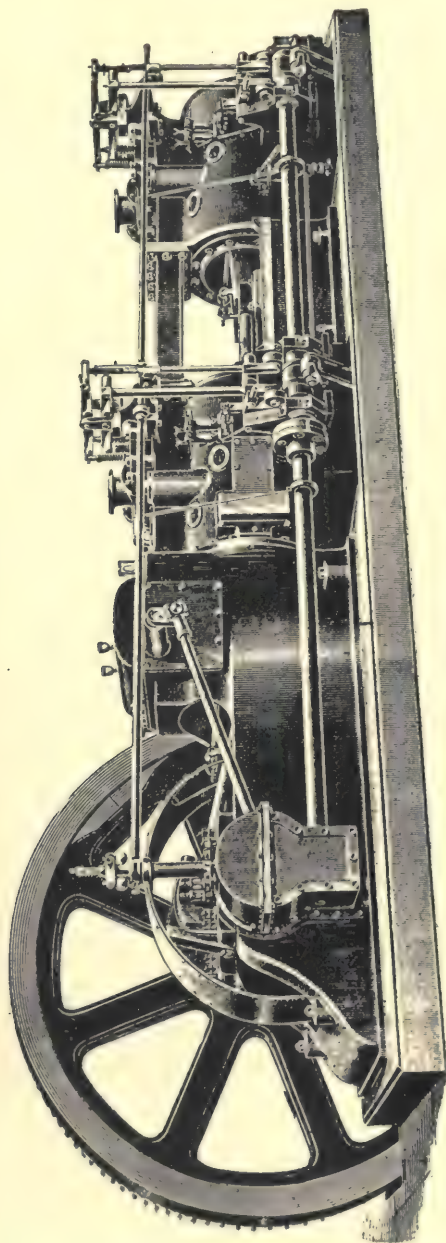


FIG. 12-89. — Premier Gas Engine.

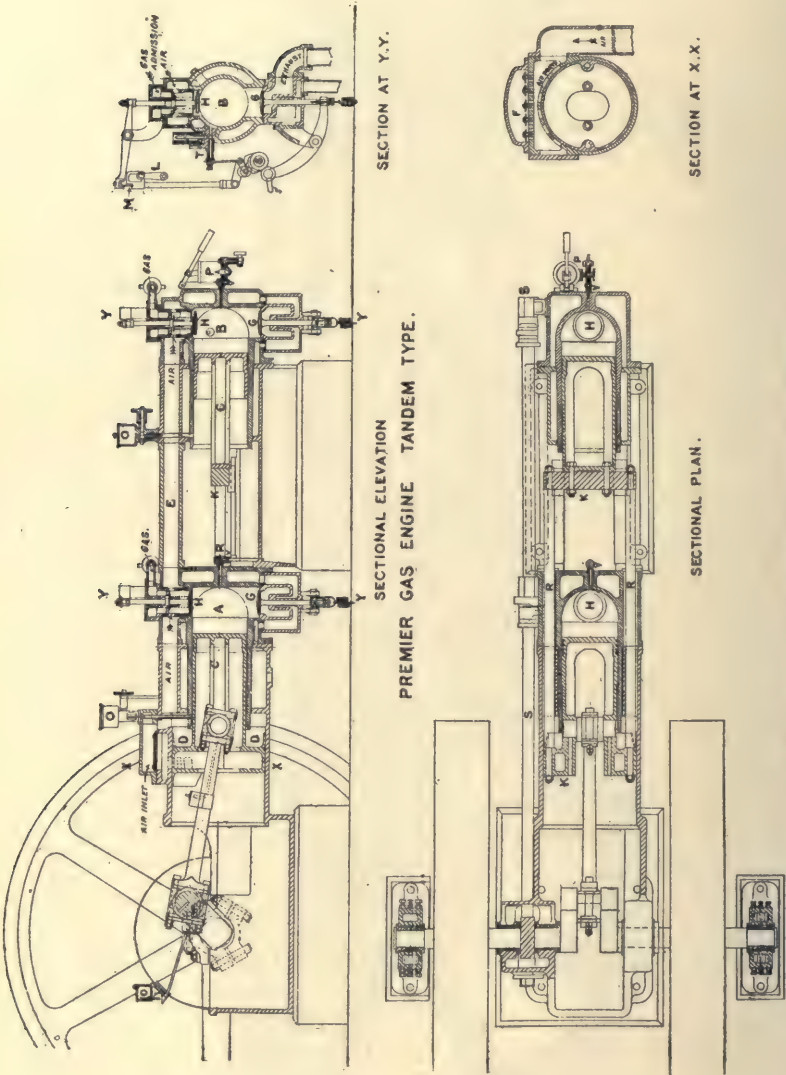


Fig. 12-90. — Details of Premier Gas Engine.

certain load. Above this a charge of gas is admitted occasionally, while above half power both cylinders work practically continuously.

Robinson states that the tandem design and the positive scavenging action make the Premier engine well adapted for the burning of cheap fuel gas. Güldner judges, from the high efficiencies obtained in conjunction with mean effective pressures exceeding 110 pounds per square inch, that the combustion process in this engine must be very perfect.

The Deutz Engine. — The Deutz Company of Deutz-Cologne were the first firm to build Otto engines and they have from the first been prominently identified with the development of this type of engine. Their present-day constructions embrace several designs of excellent form.

The large engines are all double-acting and are made either single-cylinder, twin or tandem. The general features of the design of a 600 B. H. P. twin engine are shown in longitudinal cross-section in Fig. 12-91 and in transverse section in Fig. 12-92.* The cylinder differs from that of the Nürnberg engine in that the jacket wall is not continuous. This is done, of course, to prevent temperature stresses. The central space is closed by a saddle casting as shown. Inlet and exhaust valves are placed in separate cages easily removable. The details of piston design and the water-cooling arrangements are clearly indicated. The manner of operating the valves from the lay shaft is shown in Fig. 12-92. All Deutz engines govern by throttling a mixture of constant composition. In the particular engine under discussion the throttle valve is a multi-ported cylinder surrounding the inlet valve stem. It is so designed as to keep the ratio of gas to air the same as that set by the hand-operated valves shown in the gas and air passages, but depending on the load, the mixture is throttled more or less. How the movement of the valve is controlled by varying the position of the fulcrum about which the throttle valve lever turns can be easily traced out by following the governor linkage.

The arrangement of the throttle valve is somewhat different in smaller engines. Thus in the 250 B. H. P. engine, a cross-section of which is shown in Fig. 12-93, the throttle valve is

* From H. Dubbel, *Zeitschrift d. V. d. I.*, Sept. 2, 1905.

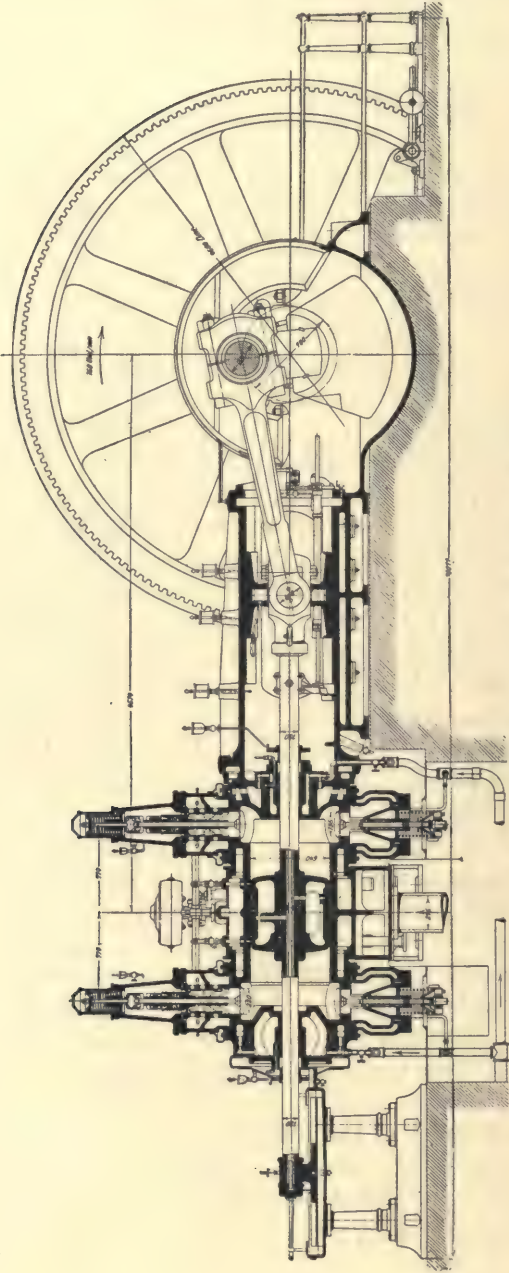


FIG. 12-91. — 600 B. H. P. Deutz Engine.

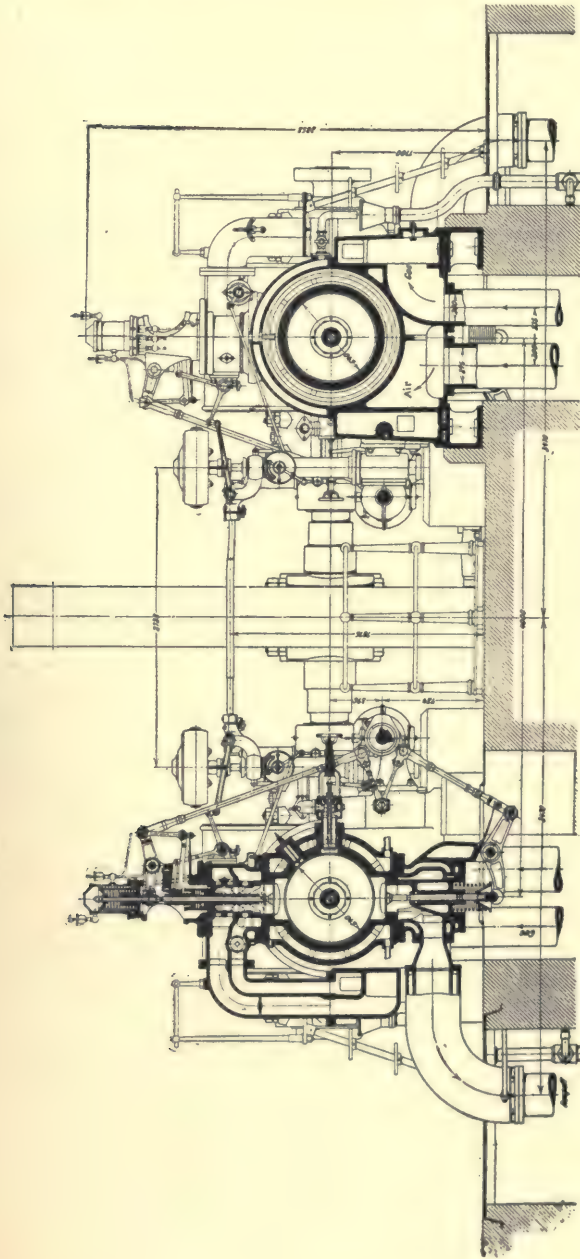


FIG. 12-92. — 600 B. H. P. Deutz Engine.

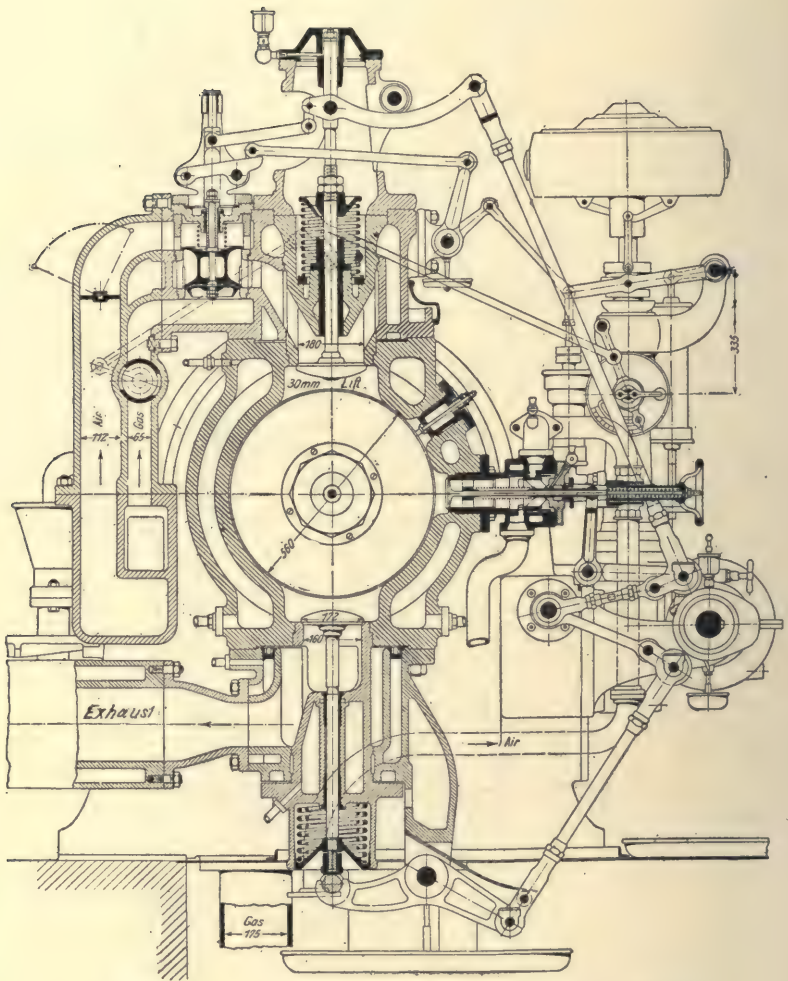


FIG. 12-93. — Valve Gear Details, 250 B. H. P. Deutz Engine.

independent of the main inlet valve. The governing features, however, are quite similar.

The Oechelhäuser Engine. — The Oechelhäuser Engine, built by several firms in Germany, is a two-cycle machine of distinctive design, as may be seen from the cross-sections, Figs. 12-94, which represents a 1000 horse-power machine built by A. Borsig.*

The power cylinder is open at both ends and contains two single-acting pistons. The front piston is connected to the middle crank of a three-throw crank shaft by piston and connecting rod in the ordinary manner. The rod of the back piston is fastened to a yoke which transmits the motion through rods on each side of the cylinder to cross-heads and connecting rods working on the two outside crank pins. This construction, while complex and probably costly, results in almost perfect balance. There are no valves as such. The exhaust gases escape through a ring of ports which is uncovered by the front piston near the end of the out stroke. Similarly the back piston near the end of its out stroke uncovers first a ring of ports admitting a charge of air for scavenging, and a moment later the gas or mixture ports. On the return stroke these rings of ports are covered one after the other and compression ensues between the two pistons. When in their inner dead center position, ignition is made to take place electrically, and the pistons are driven apart on their power strokes.

Gas and air under certain small pressures are furnished to the receivers surrounding the inlet ports by means of a combination air and gas pump which is usually operated by a tail rod. In blowing engines the blowing cylinder is usually so connected, and the air and gas pump is then placed under floor.

At full load the mixture follows the preliminary charge of pure air used for scavenging to about three-quarters or seven-eighths of the stroke. Regulation is effected by controlling the amount of mixture admitted to the cylinder. The means for doing this are discussed in Chapter XIV.

Oechelhäuser engines have given good satisfaction on blast-furnace and coke-oven gas. The general appearance of a twin engine of this type is shown in Fig. 12-95.

* Hoffman, Zeitschrift d. V. d. I., Sept. 15, 1906.

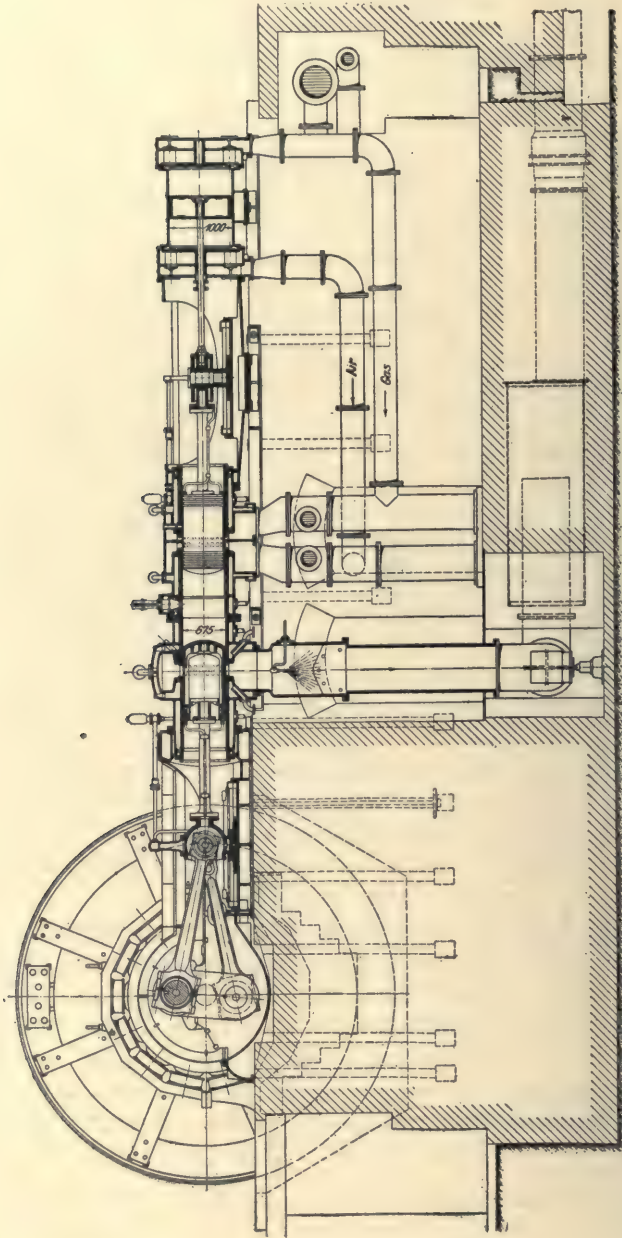


Fig. 12-94. — 1000 H. P. Borsig-Oechelhäuser Two-cycle Engine.

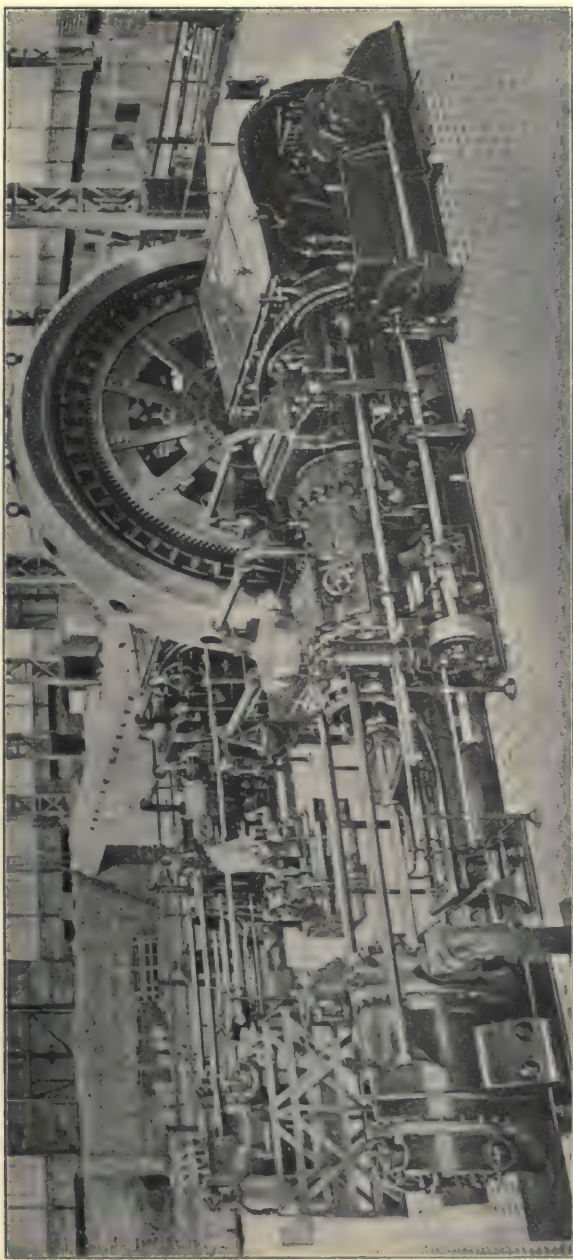


FIG. 12-95. — Twin Type Oechelhäuser Two-cycle Engines.

B. Liquid Fuel Engines

3. GASOLINE ENGINES. — The very great majority of all portable internal combustion engines are gasoline engines, and the same is true of a large percentage of stationary internal combustion engines for small powers. We may thus divide all gasoline engines into three classes — stationary engines, marine engines, and automobile engines. The number of firms engaged in the manufacture of these engines is very large. Usually the various makes differ only in minor detail, and for that reason only one or two *type examples* under each class will be considered.

Stationary Gasoline Engines. — The general type of this machine either vertical or horizontal does not differ much from that of the small-powered stationary gas engine, several makes of which have already been discussed. It is usually possible to convert any gas engine of this type into a gasoline engine by the simple addition of a carbureting device. A number of the latter have been described in Chapter VIII.

The Foos Gasoline Engine. — This machine is made by the Foos Gas Engine Company of Springfield, Ohio. The cylinder, Fig. 12-96, is partly supported by the frame, making an especially rigid construction. The cylinder head is a plain flat cover. Both valves, which are of the poppet type, work upward and are mechanically operated; they are not affected by any governor action. Thus if the governor keeps the fuel valve closed, pure air is worked through the engine, cooling the cylinder and clearing it thoroughly from burned gases. The valves are operated by bell cranks and rods as shown. These rods are in turn actuated by cams on the shaft of the secondary gear, *A*, Fig. 12-96. The valves have their seat castings separate from the cylinder, but in order to remove the valves for inspection or regrinding it is necessary only to remove the plugs in the top of the valve cages. In Fig. 12-96, *B* is the rod operating the fuel valve, *C* the fuel pump, and *D* the igniter rod. The fuel may be gasoline, naphtha, or distillate.

Foos engines are governed on the hit-and-miss principle. In Fig. 12-97, *E* is the igniter rod, *C* the fuel valve lever which is oscillated by a cam on the shaft of the secondary gear *G*. This gear, through a pinion, also drives the governor *D*. The latter is

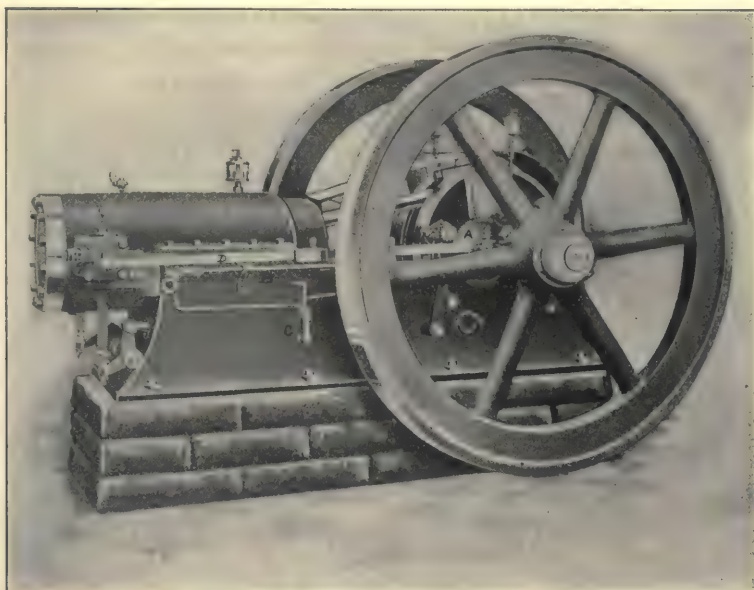


FIG. 12-96. — Foos Gasoline Engine.

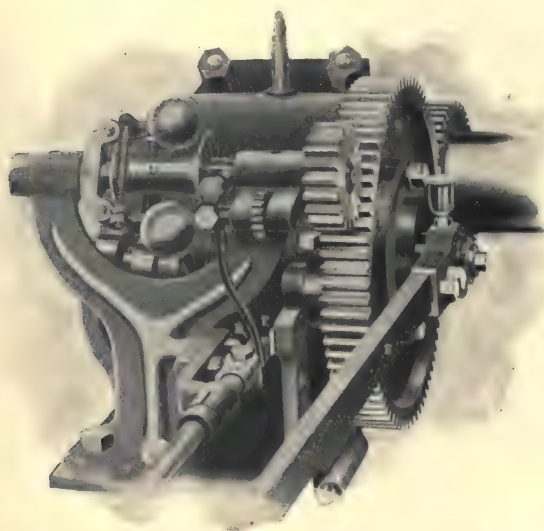


FIG. 12-97. — Governing Details, Foos Engine.

of the fly-ball type, and, when the speed becomes excessive, pulls the block *B*, on the lower end of the governor lever *A*, out of line with the blade *F*. Thus *F* misses the fuel valve rod and the en-

gine fails to receive a charge. The speed of the engine may be adjusted during operation by varying the position of the fulcrum *A* by turning the nut *H*.

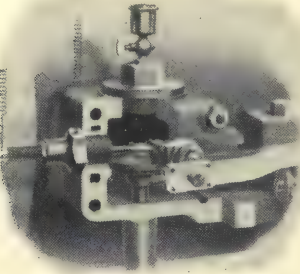


FIG. 12-98. — Wipe Spark Igniter, Foos Engine.

In place of the ordinary hammer break system, a wipe spark igniter is employed. In Fig. 12-98, the revolving electrode, every second turn of the engine, wipes over and snaps off the insulated electrode. Thus the points of contact are always

kept clean and bright. The igniter is placed directly over the inlet valve to insure a good combustible mixture.

The Olds Gasoline Engine. — Fig. 12-99 shows the carbureter

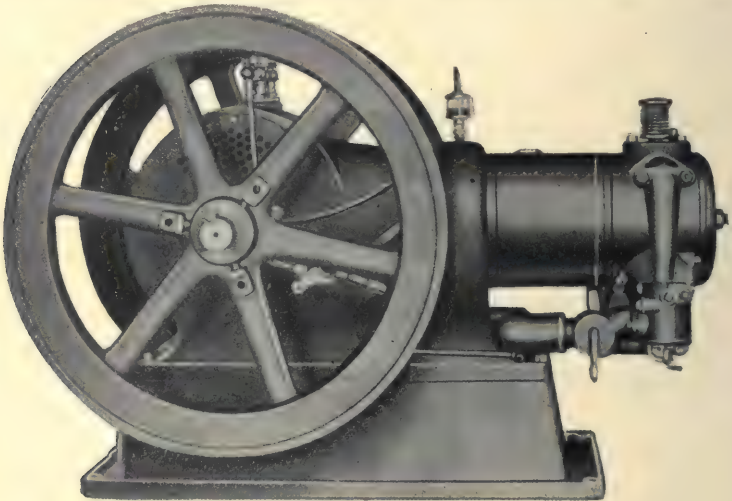


FIG. 12-99. — Olds Gasoline Engine.

side and Fig. 12-100 the valve construction of the Olds Type A gasoline engine. This is an engine of very simple design. Both

valves are of the poppet type, the upper, the inlet valve, being automatic while the exhaust valve is operated by bell crank and push rod. The latter is actuated by a cam. Fig. 12-99 shows the carbureter and its adjusting valve. Until recently the gasoline was fed to the carbureter from a small reservoir kept filled to a certain level by a small plunger pump driven from the shaft. In some of the recent designs this pump has been eliminated, the carbureter getting fuel by simple suction feed.

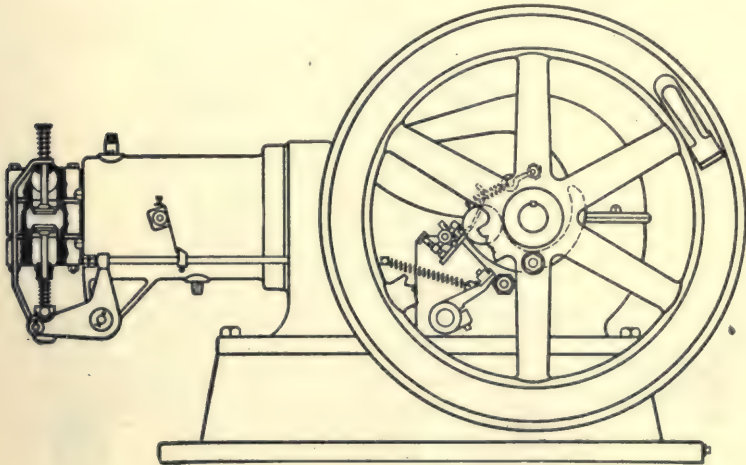


FIG. 12-100. — Olds Gasoline Engine.

The governor, which is of the fly-wheel type, is shown in Fig. 12-100. It operates to keep the exhaust valve open when the speed exceeds the normal, at the same time locking the inlet valve, so that no charge can enter the cylinder. The governor may be adjusted to give speeds varying from 200 to 600, and a change of about 50 turns per minute may be made while the engine is in operation.

The jump spark ignition system is used, which is unusual in small stationary engines. The governor serves also to throw the commutator of the system out of action should the engine fail to take a charge on a miss-stroke.

Type A Olds gasoline engines are built in six sizes from 3 to 18 horse-power.

Marine Gasoline Engines. — These engines are of either the

two- or four-cycle type, but in nearly all cases vertical. The maximum power developed in one cylinder, in the ordinary launch motor, is usually about 5-8 horse-power, higher power than this being obtained by the multiplication of cylinders.

Perhaps the majority of engines of this type, especially those of fairly high speed, 600 to 800, are equipped with the jump spark system; many builders, however, favor the hammer break ignition.

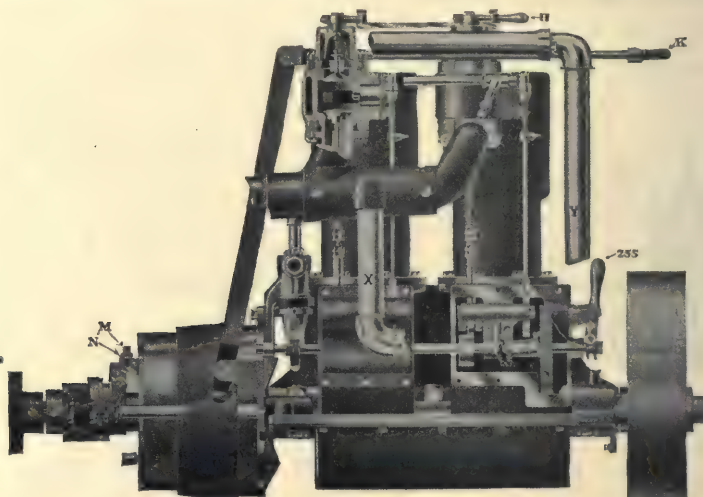


FIG. 12-101. — Strelinger Four-cycle Marine Engine.

Small gasoline boat engines are very rarely fitted with governor control. The speed is changed in most cases with the throttle or the spark, or both, as in automobile engines. A favorite way of checking the speed of small boats is by the use of a reversible propeller, in which case the speed of the engine need not be changed in any way.

The following two types of engines illustrate the general features of the four- and two-cycle marine engines.

The Strelinger Four-cycle Marine Gasoline Engine. — A 10 horse-power engine made by the C. A. Strelinger Company is illustrated in Fig. 12-101 and Fig. 12-102. In this design the heads are cast in one part with the cylinders. The latter are rigidly bolted to the crank case casting. The cam shaft and its drive are enclosed in the crank case. The cams on this shaft

operate the exhaust valve and the trip gear of the make-and-break igniter. By pushing in the lever, marked 255 in Fig. 12-101, at starting, the compression is partly relieved and the spark retarded on all of the cylinders, making starting easier. After starting the lever is returned to its former position. There seems to be no other spark control.

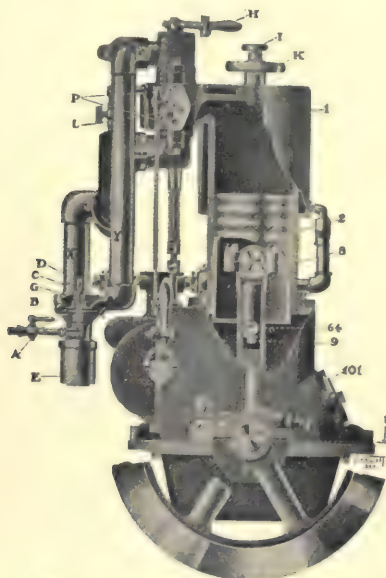


FIG. 12-102. —Streling-r Engine.

The inlet valve is automatic. Above each inlet valve there is a throttle valve whose position is controlled by the lever *H*. The combustible mixture is formed by drawing the air, for the purpose of warming it, from around the exhaust pipe, and through the pipe *X*, Fig. 12-101, through the mixing valve *B*, Fig. 12-102. Here it picks up a certain quantity of gasoline, which is furnished through pipe *A* and the needle valve *C*, and then passes through pipe *Y* to the cylinders. Mixing valve *B* is automatic, adjusting the amount of gasoline to the amount of air passing. The latter of course depends upon the position of the throttle valve and the load on the engine. The mixture is claimed to be uniform through the range of speeds.

The Lozier Two-cycle Marine Engine. — Like nearly all small two-cycle engines, this machine precompresses the charge in the crank case. In Fig. 12-103 * an explosion has just taken place above the piston. The new charge of gasoline vapor and air has just been drawn into the crank case *B* through the opening *A* from the carbureter. The explosion forces the piston down and compresses the charge in *B* to a pressure in the neighborhood of 5 pounds. Near the end of the down stroke the upper edge of the piston uncovers the exhaust port *F*, Fig. 12-104, and the larger part of the burned gases escape. A moment later the inlet port *C*, Fig. 12-105, is also opened, and the new charge enters, being deflected upward by the baffle *G* and driving out the rest of the burned gases. On the next succeeding up stroke the piston closes first the inlet port, next the exhaust port, and compression commences. Ignition takes place when the igniter gear moves one of the electrodes and breaks the contact at *E*, Fig. 12-103. The igniter gear is shown in detail in Fig. 12-106. Normally the outside blade *E* which pivots about *F* is held down by the plunger *D*, so that the lower electrode inside of the cylinder is not in contact with the upper. The rod *B* is moved up and down by an eccentric on the engine shaft. On the upward motion the plunger *D* is forced upward, allowing plunger *M* to raise *E* so that just before the spark is desired the electrodes inside are in contact and the circuit is made. In the meantime the point of the adjustable screw *J* commences to force the trigger *C* to one side until, at the moment the spark is desired, the plunger *D* snaps off suddenly, breaking contact inside by forcing down the blade *E*.

The carbureting device, Fig. 12-107, is simple and effective. The air is pre-heated by passing it around the exhaust pipe. Gasoline enters at *F*, and mixes with the air when the inrush due to the suction in the crank case lifts the automatic valve *B*, flowing out from opening *A* in the seat of the valve. The dial *D* indicates the position of the gasoline valve.

The speed of the engine is controlled by the position of a butterfly throttle valve in the transfer passage, as indicated in Fig. 12-103.

The particular construction of the two-cycle machine above described is known as the two-port two-cycle. In this type the

* Sibley College Thesis of Bayne and Speiden.

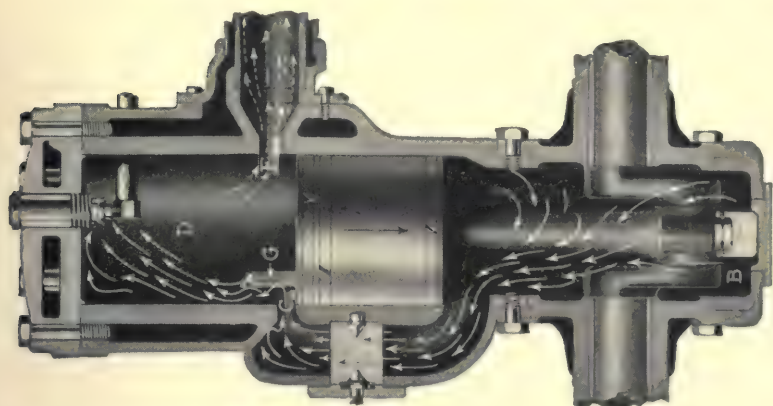


Fig. 12-105.

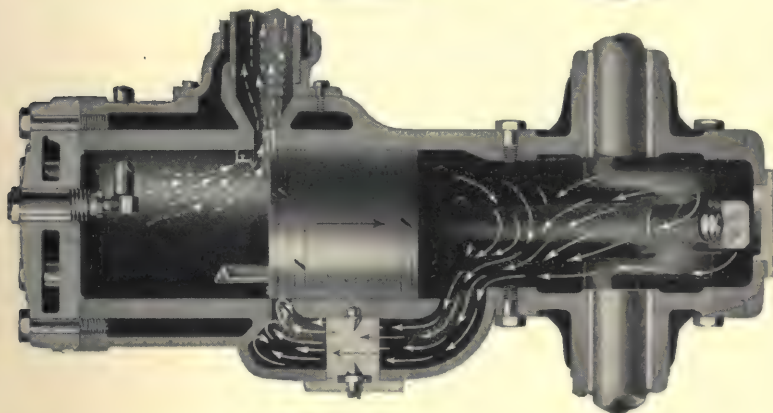


Fig. 12-104.

Operation of Lozier Two-cycle Marine Engine.

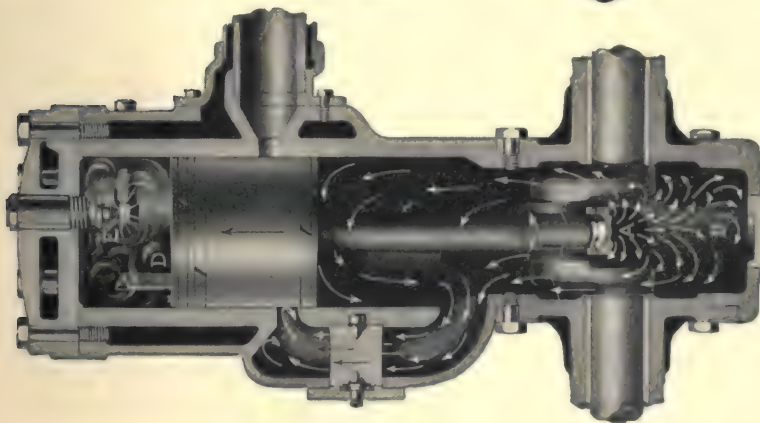


Fig. 12-103.

port admitting the charge to the crank case is at no time covered by the piston. Hence the carbureting device is subject to the pressures generated by possible explosions in the crank case, and if this is of such type as to be hurt by such explosion, it must be suitably protected by check valve. This difficulty is overcome by the use of the three-port two-cycle engine. This is the type of engine in which the piston also controls the inlet port into the crank case, as is clearly shown in Fig. 12-108, which illustrates

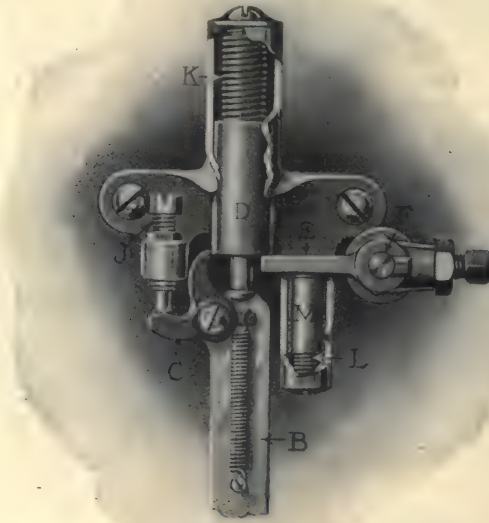


FIG. 12-106. — Igniter Gear Lozier Two-cycle Marine Engine.

the construction and operation of the Fairbanks vertical Marine Engine.

The application of the internal combustion engine to the propulsion of vessels other than pleasure launches is becoming of more and more importance. At the present day several rather small sized cargo boats and barges are already fitted with suction gas apparatus and engines. The question has perhaps received the greatest amount of attention in England, where

Crossley Brothers, Thornycroft, and Vickers Sons & Maxim have built suction gas apparatus for marine propulsion.* In this country the Standard Motor Construction Company of Jersey City have lately turned out a marine gas engine which deserves special attention.

The Standard Marine Gasoline Engine.—The following description of this engine appeared in *International Marine Engineering*, September, 1907. The data given refers to the 300 horse-power engine of the motor yacht Standard, but a 500 horse-power engine of the same type for the schooner Northland has already been built.

Figure 12-109 shows a cross-section of the Standard's engine, and Fig. 12-110 a view of the inlet side. The following is the description given:

"These engines have in reality twelve working cylinders,

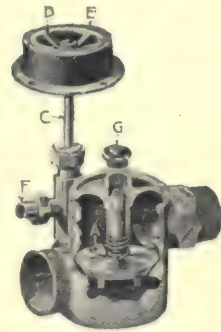


FIG. 12-107. — Carburetor Lozier Two-cycle Marine Engine.

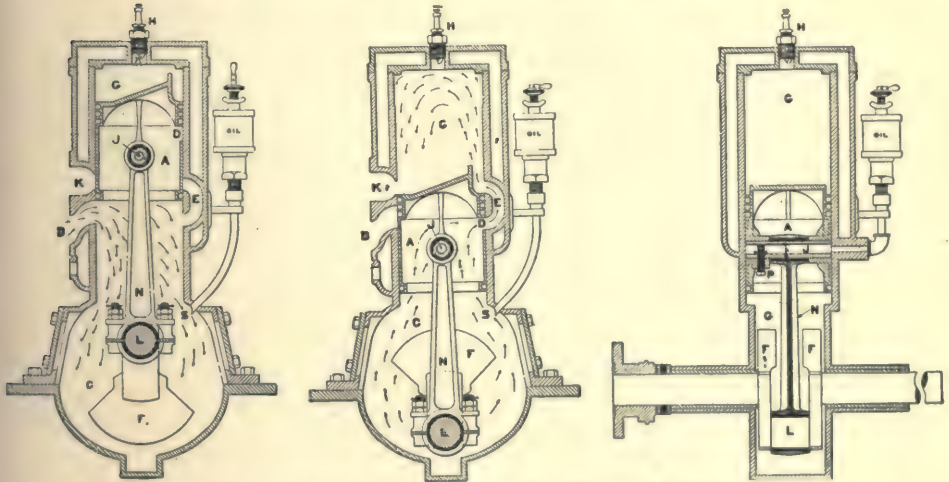


FIG. 12-108. — Fairbank Vertical Three Port Two-cycle Marine Engine.

figured from the point of view of the usual construction of gas engines. The result is an extremely smooth and quiet running

* See an interesting article by A. V. Coster on "Gas Power on Shipboard," in *Cassier's Magazine*, November, 1907.

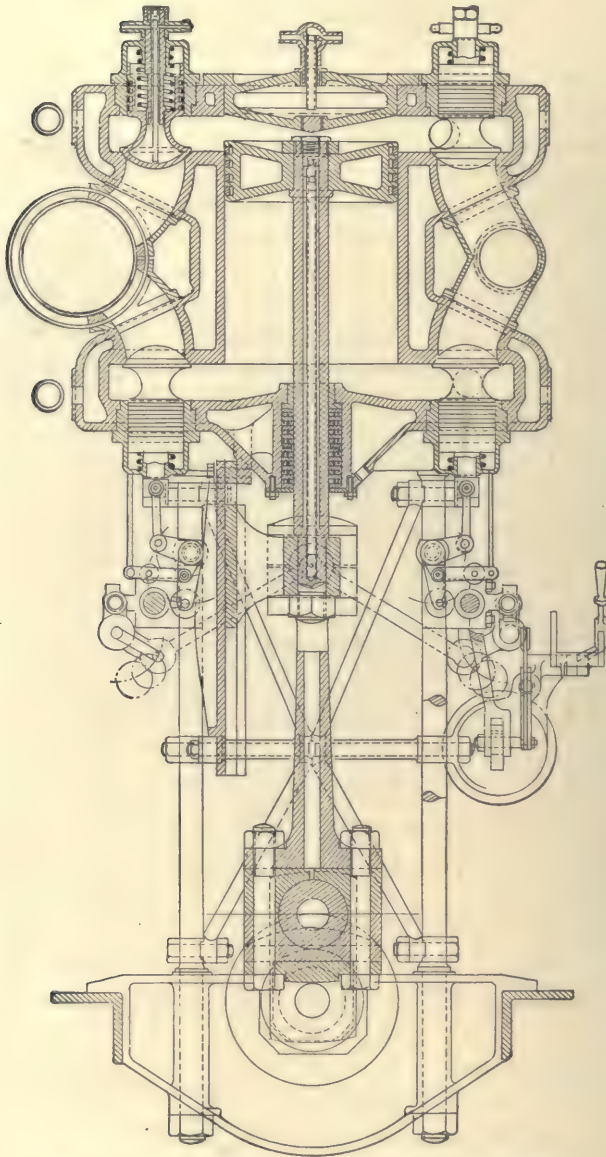


FIG. 12-109. — Cross-section of 300 H.P. Standard Marine Gasoline Engine.

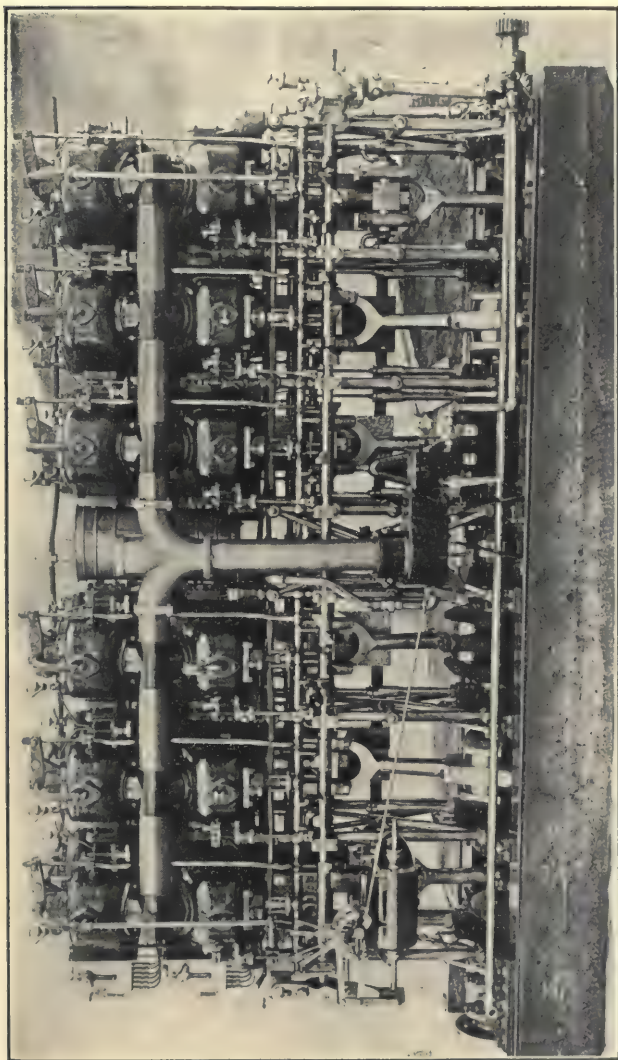


Fig. 12-110. — Inlet Side of 300 H.P. Standard Marine Gasoline Engine.

machine, well balanced, and with the valves so arranged that practically the only vibration noticeable is occasioned by the force feed oil pumps, which give individual feed to every cylinder and bearing. Ignition is of the make-and-break type, while pistons and piston rods are water-cooled, and water flows freely also through the valves. A very noticeable advantage of the double-acting engine is the practical impossibility of any leakage of gas into the engine room, because the piston, instead of being open to the atmosphere, as in most types of single-acting engine, is operated from a piston rod running through a metallic stuffing-box. The operation of the valve shaft is obtained, as in a large steam engine, by using a small air cylinder; this is also used for turning the engine over.

"The bore and stroke of the Standard's engine are each 10 inches; the weight is 7500 pounds, or 25 pounds per horse-power; the length over cylinders is 8 feet 3 inches; length over all, 10 feet 4 inches; the total height is 5 feet 6½ inches, of which 4 feet 9½ inches come above the center of the shaft; the width of the base is 30 inches; while the greatest width over cylinders is 34 inches.

"The illustrations of the new motor, as shown, serve to confirm the impression of a torpedo boat engine, as the same type of supports, connecting rods, cross-heads, and guides are here used that one is accustomed to in the other kind of engine. The double-acting principle necessitates some radical changes from the usual marine gasoline motor design, such as water-cooling the pistons, connecting rods, valves and other parts exposed to the intense heat produced in cylinders of such large volume. Inlet and exhaust valves are located on the opposite sides of the head, as is customary with many automobile and marine engine builders. The upper and lower ends of the cylinders are alike, with a regular marine engine piston and connecting rod.

"The method of getting the gas into the cylinders is very neatly and simply worked out, as is shown in the inlet side. One branch pipe leads up to the cylinders from the center, and then runs to each end of three cylinders. The spark and throttle control levers are mounted on top of the air cylinder, which controls the travel of the cam shaft. One essential point of difference between the ordinary motor and this motor is that the valves are pulled up instead of being pushed up, that they are

balanced and that they are water-cooled by a stream of water which flows through them constantly. This type of valve has been adopted by the Standard Company for all their large type of motors, and has been found to work exceedingly well. On this side, also, are located the trips which operate the sparkers for all cylinders.

"The exhaust valves are operated from a cam shaft which is a duplicate of that upon the inlet side. These valves are also water-cooled and discharge directly into a large water-cooled exhaust box, from which the gases are led to the muffler. The oil feeds are directly under the exhaust box, with individual leads to distribute the oil to the different bearings. Directly below and behind this are shown the air inlets to the cylinders for starting. In a large motor of this kind the problem of properly cooling it and keeping it well oiled is a difficult one, and the working out of the systems by which these results are accomplished is more complicated than it would be for a small motor, but the owner of a motor of this size could hardly expect to operate his own engine, and in reality the successful working of the motor does not demand a higher order of skill than is to be expected from the engineer of an ordinary triple-expansion steam engine. While the appearance of the motor is complicated, this complication is more apparent than real. Every function of the motor has been carefully thought out and provision made to assure its proper working under all conditions. All Standard motors of large power have been made self-starting and reversing, the same principles which have been found so successful being employed in this latest type: but in the double-acting type both the inlet and exhaust valves are mechanically operated, as against the exhaust valves only in the other self-starting and reversing motors. Another important difference is that in this type all the cylinders are cast separately, and the motor is really two three-cylinder motors coupled together for purposes of economy in construction and replacement, should such be necessary.

"The self-starting is accomplished by compressed air being admitted on one end of three cylinders by a special set of cams. The cylinders turn the motor until it takes up its cycle upon gasoline. The cam shafts which actuate all valves are so made as to move longitudinally on their axes, and to bring appropriate cams into action for either direction. As the physical labor required to

perform this operation would be considerable in a motor of this size, an air cylinder is added to perform this work, so that the only manual labor in connection with running the motor is that in operating the two handles shown on the left side of Fig. 12-110. One lever controls the position of the cams, whether for ahead or astern, while the other controls the spark and throttle. In this motor the necessity of a fly-wheel is entirely done away with, and operating at any speed, from maximum to minimum, little or no vibration is felt. The motor is mounted upon a base of angle iron with castings for each individual bearing, and has the usual marine collar thrust bearing."

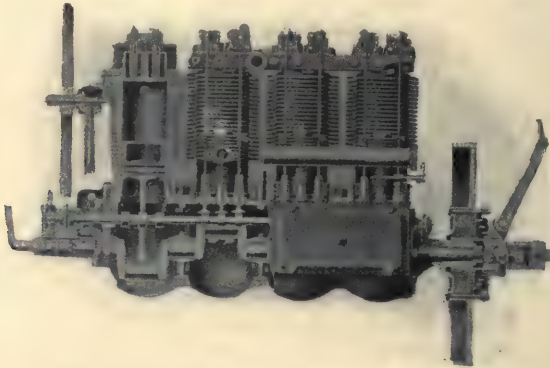


FIG. 12-111. — Engine of 1907 Franklin Car.

The Automobile Gasoline Engine. — It would be beyond the scope of this book to enter into any extensive notice of automobile engines. For that reason only a few illustrations are given to show the various methods of placing the valves and operating them, the methods of cooling the cylinder, cylinder and frame construction, etc. In general the four-cycle engine monopolizes the automobile field, there being but one or two makers who use two-cycle engines. For light cars the horizontal opposed two-cylinder type of engine is often employed, but the heavier cars universally use four- or six-cylinder vertical engines. Regarding the position of the valves, some makers place both inlet and exhaust valves in the head. This type is best exemplified by the Franklin Engine of 1907, Fig. 12-111. This construction is of advantage because it does away with all pockets in the combus-

tion chamber. In this engine both valves are mechanically operated. Some makers use the automatic type of inlet valve,

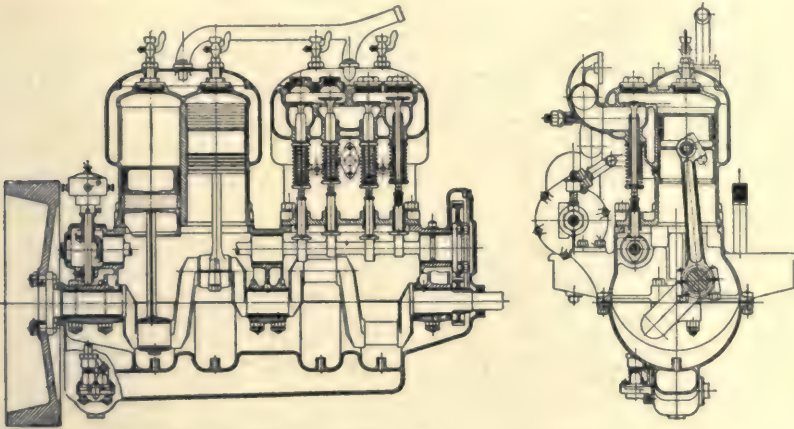


FIG. 12-112. — Continental Automobile Engine.

which in such cases nearly always opens downward. This valve, while it permits of simpler engine construction than the mechanically operated valve, does not give as good service, and for that reason is not as frequently used as formerly. In the Continental Engine,* Fig. 12-112, both valves are placed at one side of the cylinder and both are mechanically operated, opening upward. In the 18 horse-power Horch engine, Fig. 12-113 † the inlet valve is placed in the head, the exhaust valve at the side. The 35 horse-power engine of the same maker, Fig. 12-114 ‡ has

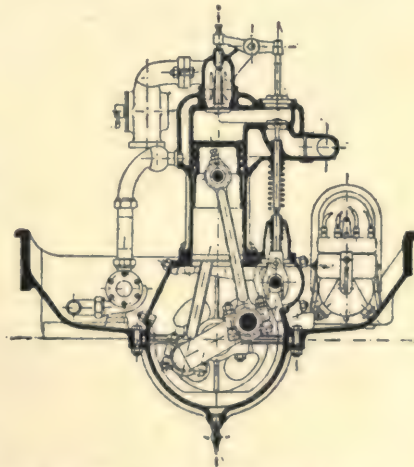


FIG. 12-113. — 18 H.P. Horch Automobile Engine.

* The Cycle and Automobile Trade Journal, Oct. 1, 1907.

† Gasmotorentechnik, April, 1906. ‡ Gasmotorentechnik, April, 1906.

both valves placed at one side, but the inlet valve over the exhaust valve. Both are mechanically operated.

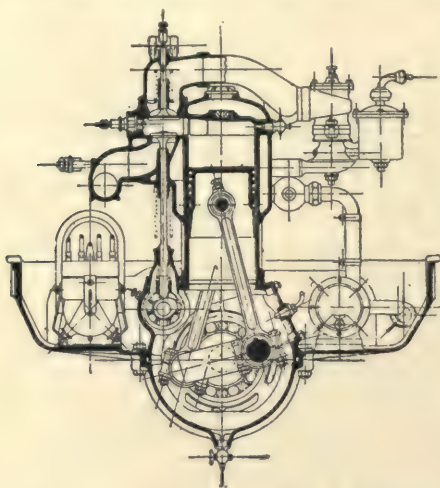


FIG. 12-114. — 35 H.P. Horch Automobile Engine.

of combustion chamber. The outside, larger, valve is the inlet valve. The large inlet area improves the volumetric efficiency. This, however, is in large part also made possible by the fact that the greater part of the hot burned gases escapes through the auxiliary exhaust valve which opens when the piston is near the lower dead center. The remainder of the gases passing out through the inner valve at the top during the up stroke of the piston does not tend to heat the valve very much.

Of the automobile engines

The Moore engine, Fig. 12-115,* shows the valves upon opposite sides, both mechanically operated. The 1908 model of the Franklin engine finally shows a type of valve gear different from any of those so far described in that the main exhaust and the inlet valves are combined in one concentric valve placed in the head. This, as may be seen from Fig. 12-116, results in an ideal form

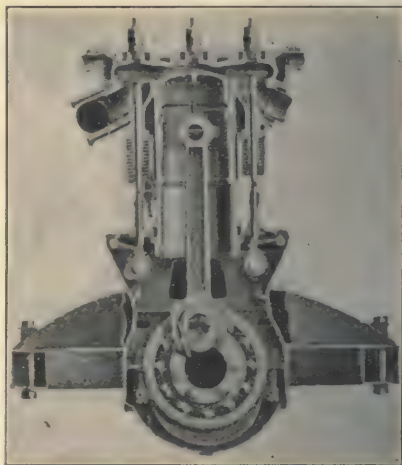


FIG. 12-115. — Moore Automobile Engine.

* Cycle and Automobile Trade Journal, April, 1906.

illustrated, the Franklin engine shows the construction employed for air-cooled cylinders; all of the other engines are water-cooled.

4. OIL ENGINES. — The term "oil engines" usually refers to engines using kerosene, crude oil, or any one of the so-called distillates. All of these fuels are more difficult to vaporize than gasoline and the formation of the proper fuel mixture is therefore generally a less simple process. Some of the types use a special vaporizer, in others the fuel is sprayed directly into the combustion chamber or into an extension of it.

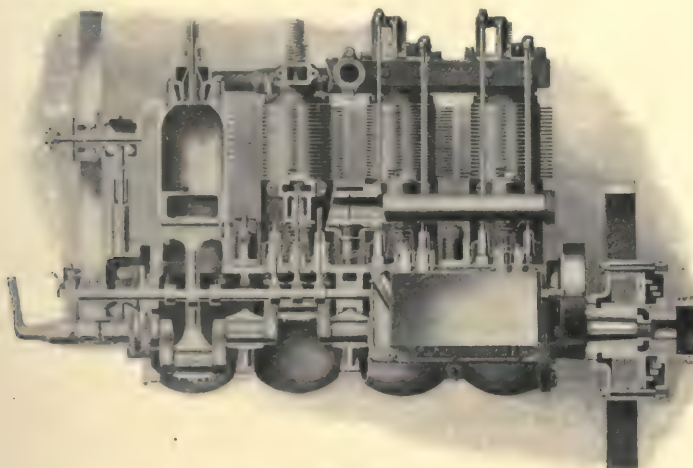


FIG. 12-116. — 1908 Model, Franklin Engine.

Liquid fuel engines in general labor under the disadvantage as compared with gas engines in that the limit of power in a single cylinder is reached much earlier. The reason for this is that as the cylinder volume grows, the difficulties of forming and maintaining a uniform fuel mixture increase very rapidly, and the difficulties of proper ignition increase correspondingly. The result is, at least as far as present practice is concerned, that while the economic limit in one single-acting cylinder using gas is in the neighborhood of perhaps 400 horse-power, the limit in single-cylinder single acting oil engines is not over 200 horse-power. Hence the subdivision of the power required among several cylinders commences much sooner in oil than in gas engines.

The most important point of distinction among the various

oil engines is probably the way in which the combustible mixture is formed. We distinguish the following methods:

(a) The fuel is forced directly into the combustion chamber at the end of or during the compression stroke. Usually a spraying nozzle is employed.

(b) The fuel is mechanically atomized and sprayed into the current of air on the suction stroke.

(c) The fuel is sprayed into a vaporizing chamber connected to the cylinder without interposition of a valve.

(d) The fuel is vaporized by the agency of heat in a separate vaporizer. The air passing through the vaporizer forms the fuel mixture and this enters the engine already prepared.

The following descriptions of various oil engines will illustrate the various methods outlined:

Among the most important oil engines found on the American market are the following: The Hornsby-Akroyd kerosene engine, a machine of English origin made by the De La Vergne Machine Company, of New York; the De La Vergne two-cycle oil engine, brought out by the same company within the last month or two; the Mietz & Weiss oil engine made by the A. Mietz Iron Foundry & Machine Works of New York; and the American Diesel engine manufactured by the American Diesel Engine Company. It should be stated that many of the engines described under the head of small and medium sized gas engines can be run on oil by using suitable vaporizers. Thus the Fairbanks-Morse Company and several other makers furnish vaporizing attachments by means of which their engines may be successfully run on kerosene, crude oil, or distillate.

The Hornsby-Akroyd Oil Engine. — Figs. 12-117 and 12-118 show a longitudinal and a transverse section respectively of this important oil engine, while Fig. 12-119 shows the general appearance of a single-cylinder engine.* The Hornsby engines built in this country are all horizontal machines of the four-cycle type. The exhaust and inlet valves are of the poppet type and located in a valve box at the side of the cylinder, Fig. 12-118. They open upward and are operated by levers passing under the cylinder by means of cams on the half-time shaft. The exhaust cam is so designed that on starting the compression can be relieved

* Catalogue of the De La Vergne Machine Co.

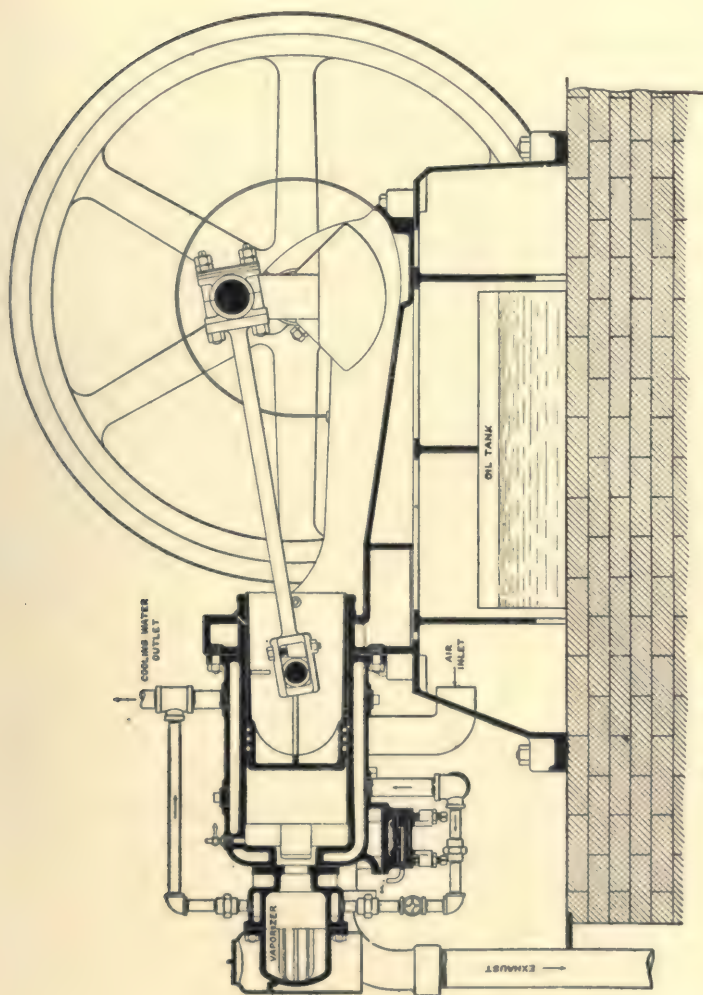


Fig. 12-117. — Cross-section Hornsby-Akroyd Oil Engine.

by shifting the cam on the shaft. The supply of oil is taken from a tank in the base of the machine by a pump operated from the lay shaft, and forced into the vaporizer chamber *A*, through a spray nozzle. The governor is of the fly-ball type and controls the speed by dividing the constant quantity of oil furnished by the pump into two parts, one of which, in proportion to the load, enters the nozzle, the other part flows back to the tank. The nozzle and overflow valve are shown in greater detail in Chapter VIII.

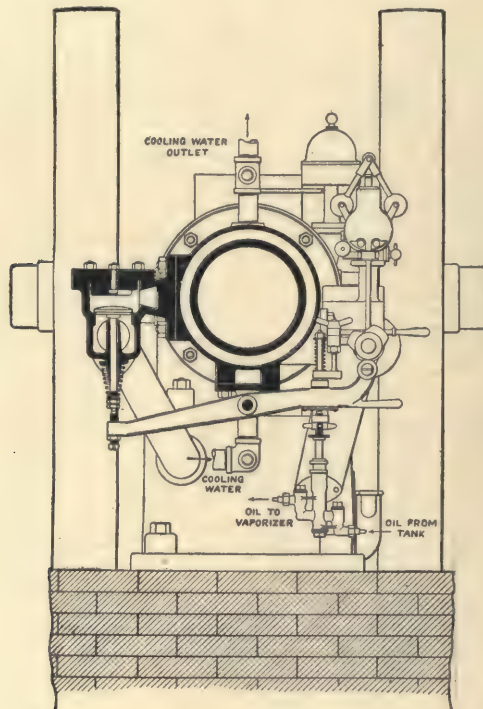


FIG. 12-118. — Transverse Section Hornsby-Akroyd Oil Engine.

The vaporizer chamber is furnished with internal webs to increase the vaporizing surface, and is protected against radiation on the outside by a hood.

To start the engine the vaporizer is first heated by a lamp which constitutes a part of the equipment. After the chamber

is hot enough, a few quick strokes of the pump by means of the hand lever, Fig. 12-118, while the engine is being turned over in the normal direction, usually suffices to start it. After starting, the heat of combustion is enough to keep the vaporizer at a dull red heat and to explode the charges regularly, so that no special igniter is required.

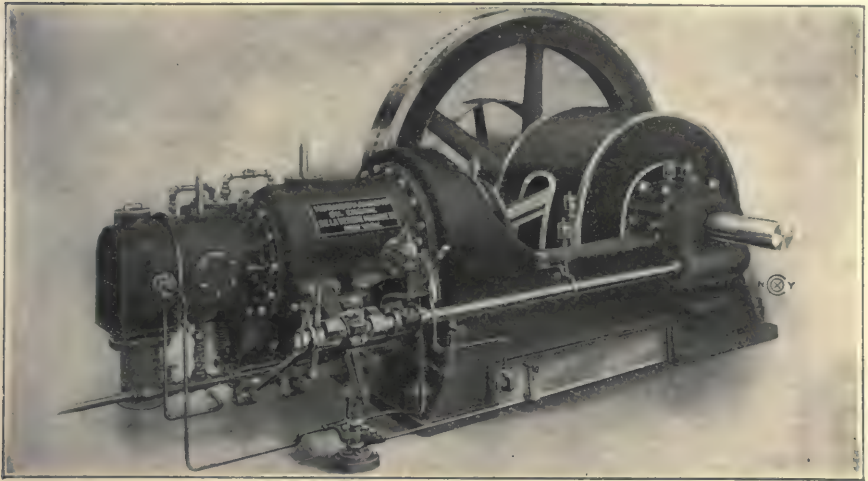


FIG. 12-119. — Single Cylinder Hornsby-Akroyd Oil Engine.

The method of operation may be explained as follows: On the suction stroke of the piston the pump injects oil into the vaporizer. This is almost instantly vaporized, but as yet the mixture is not explosive because the vapor is mixed mainly with burned gases which remain from the previous explosion. On the return stroke, the piston compresses the air and forces a part of it into the vaporizer. It is possible that some time during the compression stroke the vapor may commence to burn in the vaporizer, but the flame does not strike out because the velocity of air flowing in through the narrow neck of the vaporizer is greater than the velocity of flame propagation. Near the end of the compression stroke the reverse takes place, the flame strikes out with explosive force and drives the piston forward on the expansion stroke. This is followed by the exhaust stroke, after which the operation is repeated.

These engines have given very satisfactory service and many of them are in use for a variety of purposes. They are made in sizes from $2\frac{1}{2}$ to 125 horse-power, those above 32 horse-power being of the two-cylinder type illustrated in Fig. 12-120. This design has lately been modified in that the two overhanging fly-wheels have been replaced by a single wheel placed next to the belt pulley between the two cylinders.

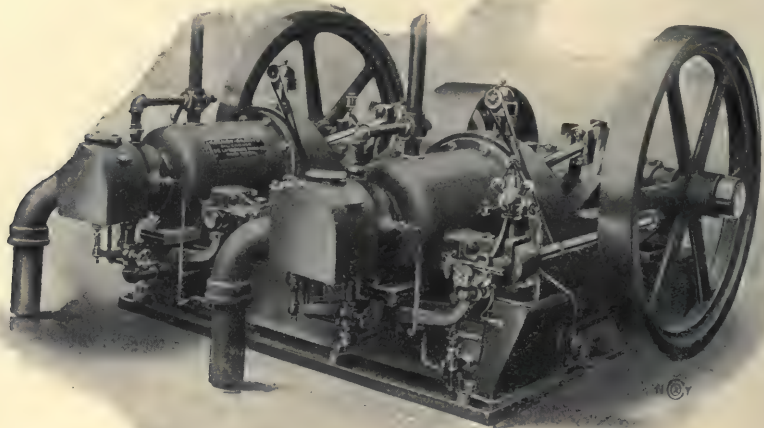


FIG. 12-120. — Twin Cylinder Hornsby-Akroyd Oil Engine.

The De La Vergne Two-cycle Oil Engine. — This is a vertical machine recently brought out by the De La Vergne Machine Company and described in *Power*, November, 1907, to which the following illustrations are due:

Figure 12-121 shows that the cylinder is of the ordinary two-cycle construction, the piston controlling the inlet and exhaust ports. The vaporizer chamber *V* is formed by an extension of the cylinder, but, in contradistinction to the Hornsby engine, no contracted neck is used opening into the vaporizer. On the down stroke of the piston the air compressed in the crank case rushes into the cylinder as soon as the inlet port is uncovered. On the up stroke only air is compressed, the oil not being injected by the

pump through the nozzle *N* until near the upper dead center. The oil instantly vaporizes and burns, ignition being produced by the hot vaporizer walls. Of course the vaporizer must be

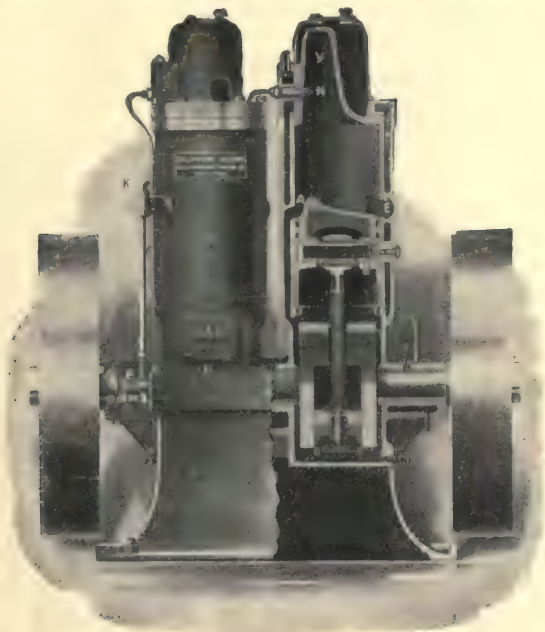


FIG. 12-121. — De La Vergne Two-cycle Oil Engine.

externally heated to start the engine. The method of operation outlined has the advantage that since only air is compressed no pre-ignition can take place.

The details of the spray nozzle *N* are shown in Fig. 12-122.



FIG. 12-122. — Spray Nozzle De La Vergne Two-cycle Oil Engine.

They are so simple as to hardly require explanation. The ball check shown serves to protect the oil pipe against the force of the explosions.

the cam projection *C*, which lifts the roller *A* once each revolution of the fly-wheel, thereby actuating the oil-pump plunger *P*. The length of stroke imparted to the plunger is determined by the lever *L*, pivoted to the frame. A wedge *W* on the lever *L* separates the cam ring from the frame *F*. When the engine is started the governor does not come into action until normal speed is approached. A decrease in load will cause the speed to increase, when the centrifugal force of the counterweight *K* will overcome the tension of the spring *S*, moving the weight outward and thereby withdrawing the wedge *W*. The spring *E* keeps the roller *A* in contact with the cam ring *R*, and when the wedge is withdrawn the buffer *G* cannot actuate the pump plunger. The knob *H* is used for injecting oil at the start, and the lock nuts *N* serve for limiting the stroke of the pump. The two concentric slots in the frame *F* allow for adjustment when it is desired to greatly change the normal speed of the engine. For smaller speed variations the spring *S* and the weight *K* can be shifted in the holes of the lever *L*."

At present two sizes of this engine are made. That illustrated is of 15 horse-power, the single cylinder type gives $7\frac{1}{2}$ horse-power. In each case the cylinders are 7 inches by 7.5 inches, the normal speed being 450 r.p.m.

The Mietz & Weiss Oil Engine. — This is a very successful engine which has been on the market for some years. While it operates on the ordinary three-port two-cycle principle, it embodies some unusual features. Fig. 12-124 shows the horizontal type in cross-section, and Fig. 12-125 its general appearance in elevation. From Fig. 12-124 the operation of the engine must be clear without much further explanation.

The fuel pump *P* takes the oil from a tank mounted on the crank case and injects it into the cylinder just after the piston has covered the exhaust port *E*. The oil falls on the projection *V* and is instantly vaporized by heat from the hot bulb *I*, and from the cylinder head, which, as will be noted, is not water-jacketed. Ignition is produced by means of the bulb *I*, which acts very much like the ordinary hot tube. A kerosene or oil lamp, shown in position, serves to heat the bulb before starting. Five minutes is usually sufficient for this operation.

The unusual feature of this engine consists in the cooling

water arrangements. Instead of circulating the water, as is ordinarily done, it is allowed to evaporate in the jacket, being kept at a constant level by a float valve. The vapor formed collects in the dome *S*, Fig. 12-124, and is by means of the bent pipe shown led to the intake port of the cylinder where it mixes with the air. There are several excellent reasons for this arrangement in oil engines. The water vapor helps to form a mixture of high specific heat, thus reducing the danger of pre-ignition and allow-

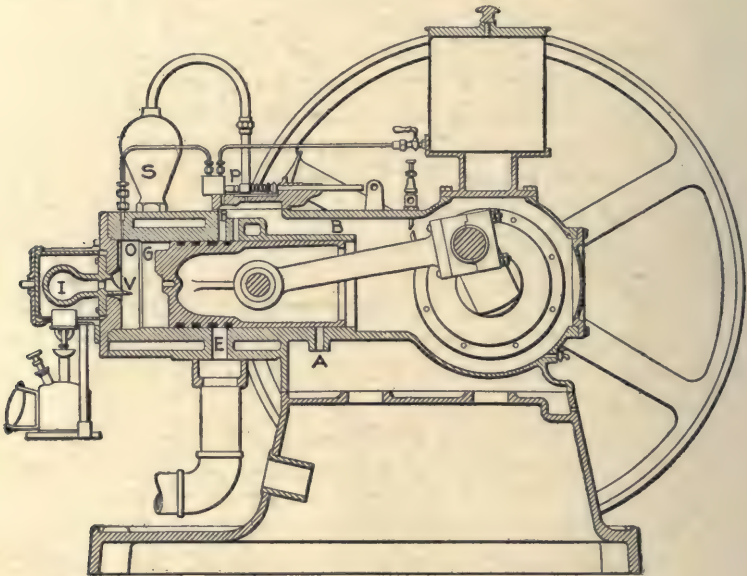


FIG. 12-124. — Details of Mietz & Weiss Two-cycle Oil Engine.

ing of higher compression pressures. The principle, however, is not new, since Bánki and perhaps several others before him have used it. It is also claimed that the vapor assists in the prevention of carbon deposits. The method further has the general advantage that but little jacket water is used compared with the ordinary method of operation.

The method of governing this engine is not clearly shown, but it consists in adjusting the stroke of the fuel pump to suit the load by means of a shifting eccentric on the main shaft.

The stationary Mietz & Weiss engine is built in single-cylinder

units from 1 to 30 horse-power, while the 40 and 60 horse-power sizes are twin engines.



FIG. 12-125. — Mietz & Weiss, Two-cycle Oil Engine.

This firm also builds vertical marine engines, the operation of which is the same as that of the horizontal machine except that the water injection scheme is not used.

The Diesel Engine. — The Diesel engine is to-day built by a number of firms in Europe and by the American Diesel Engine

Company in this country. In all cases the various constructions are of the vertical four-cycle type, but European builders favor the open A-frame, while the American makers have adopted the enclosed box frame.

Figure 12-126 gives a general idea of the appearance of the American Diesel engine, while Fig. 12-127 shows the construction.

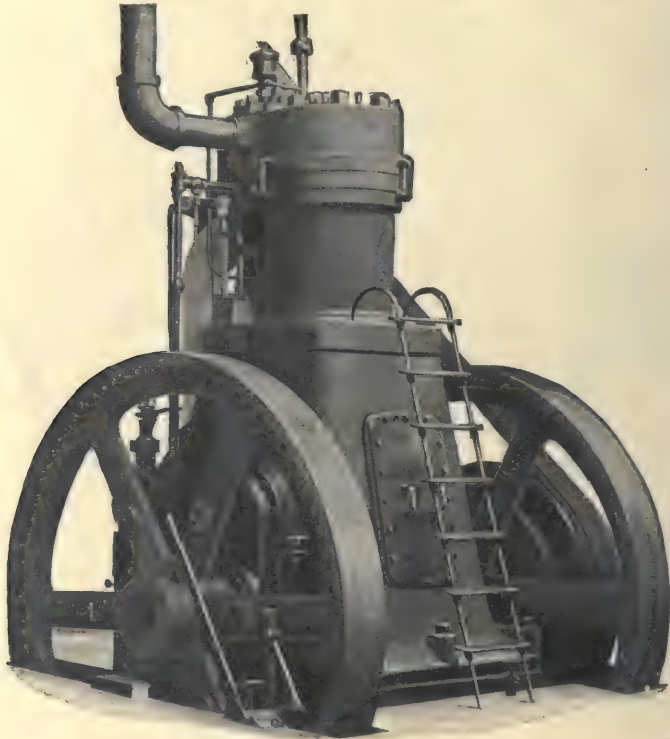


FIG. 12-126. — American Diesel Engine.

The massive self-contained build of this machine, necessitated of course by the high pressures occurring in its cycle of operation, is very noticeable. The method of operation of this machine has already been explained in Chapter XI, to which the reader is referred.

The valve construction of this engine is very simple, as shown in Fig. 12-128. The exhaust valve opens upward, the inlet valve

downward; both are located in a small chamber at the side of the cylinder. The fuel injection valve *I* is opened by the bell-crank *B*, which is operated by a cam on the lay shaft, and closed by a helical spring *S*. Surrounding the spindle of the injection valve

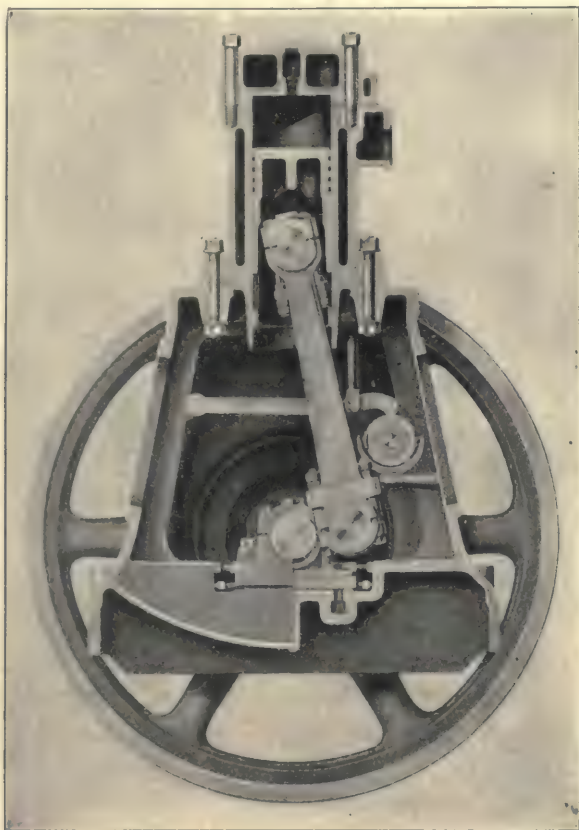


FIG. 12-127. — Cross-section American Diesel Engine.

are placed the atomizing arrangements by which the oil is very finely divided through the agency of highly compressed air, as soon as *B* opens the valve. The stroke of the lever *B* is uniform, hence the injection valve always opens to the same amount and for the same length of time, whatever the load on the engine. To govern the speed, the governor controls the stroke of the

pump which furnishes the oil to the valve. The lower the load on the engine, the later in the stroke of the oil pump does the delivery of oil to the injection valve commence. One method of doing this is explained in Chapter XIV, under Details of Governors.

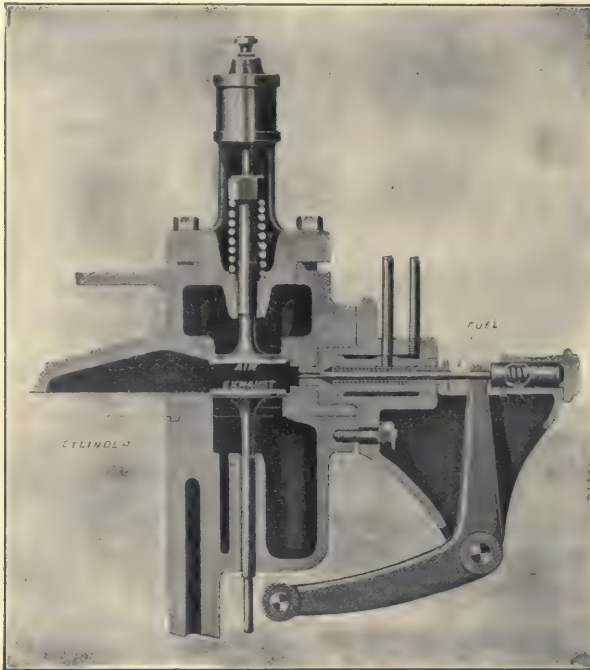


FIG. 12-128. — Valve Construction, American Diesel Engine.

The American Diesel engine is built in sizes from 75 to 450 B. H. P., mostly in three-cylinder units.

The Priestman Oil Engine. — This English machine, Fig. 12-129,* is mentioned here because the means used for forming the combustible mixture are different from those so far described. The engine is of the horizontal single-acting type. The exhaust valve is mechanically operated by an eccentric on the shaft. The same eccentric rod also operates a small air pump *e* which keeps up an air pressure of from 30 to 40 pounds on top of the oil in the

* Güldner, p. 118.

supply tank *b*. The inlet valve *c* is automatic. On the suction stroke the piston draws a charge of finely divided oil, mixed with air furnished by the spray maker, into the vaporizer *a*, together with a large quantity of auxiliary air to form the proper combustible mixture. The vaporizer, heated at the start by external means, is during operation kept by the exhaust gases at sufficient heat to completely vaporize the oil before it passes out on its way to the inlet valve. Thus the mixture reaches the cylinder completely prepared. The spray maker and vaporizer are explained in greater detail in Chapter VIII.

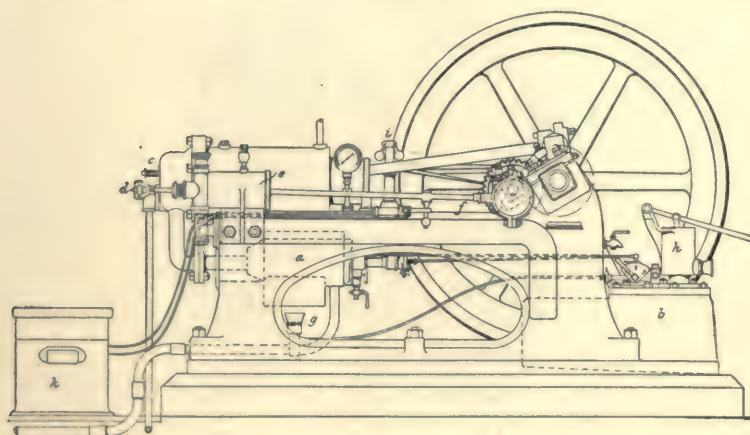


FIG. 12-129. — Priestman Oil Engine.

The cylinder operates on the ordinary four-cycle principle; ignition is by electric spark. In the later Priestman engines a small amount of water from the jacket is admitted to the cylinder each cycle, after the principle of Bánki.

The Fairbanks-Morse Crude Oil Vaporizer. — In the fourth type of vaporizer the oil is not preliminarily sprayed or atomized, as is done in the Priestman vaporizer, but simply vaporized by the heat of the exhaust gases. The piston then generally draws a part of the necessary air through the vaporizer and saturates this with the oil vapor. The rest is added to form the proper mixture just before the inlet valve. Of this type is the "Economist" retort, already described in Chapter VIII. Another type is that made by the Fairbanks-Morse Company, and illustrated

in Fig. 12-130. *G* is the main vaporizer chamber. The oil pump furnishes oil through the pipe *F* to the reservoir *R* on top of the chamber. The regulating valve *T* returns the excess pumped to the main supply through the pipe *O*. From *R* the oil is allowed to trickle slowly downward over surfaces heated by the exhaust gases. These come in through the pipe *N*, but the volume entering *G* is controlled by the position of the valve *E*, which sends a part into *G*, the rest directly out through *X*, depending upon the demands of the vaporizer. Air enters the chamber through *C*.

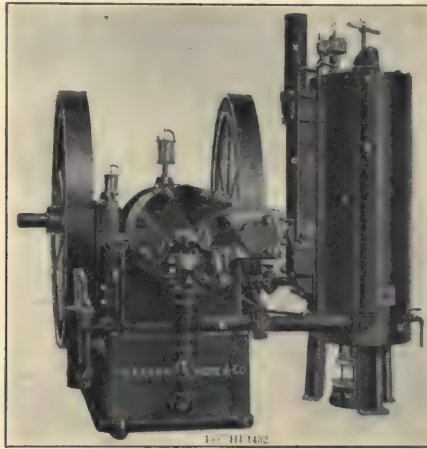


FIG. 12-130. — Fairbanks-Morse Engine
with Crude Oil Vaporizer.

On its way upward it saturates itself with oil vapor and finally flows out through *B* to the engine. The auxiliary air supply is furnished through *A*.

Any vaporizer of this type labors under the disadvantage, already mentioned in the case of the "Economist" retort, that not all of the oil can be utilized. As the vaporization proceeds, the oil gets heavier, the amount of vapor evolved grows less at the temperature maintained, and the useless residue must finally be drawn off. In the apparatus above described provision for this has been made through the drain cock *D*. *W* is a heating lamp to heat the vaporizer on starting.

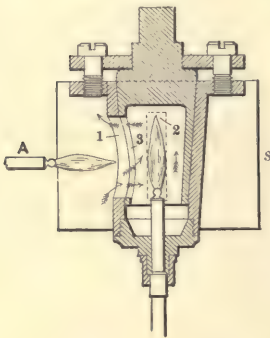
5. THE ALCOHOL ENGINE. — The points of difference between the alcohol engine and any other gas engine have already been

mentioned in Chapter VIII. In constructive details these engines do not differ from the rest except that the compression is carried higher than in other liquid fuel engines. The main feature distinguishing them is in the arrangements for forming the combustible mixture, and the various expedients adopted have been thoroughly discussed under the head of vaporizers in the chapter mentioned. Recent experiments have disproven the old statement that an alcohol engine cannot be started from the cold. Much depends upon the position of the carbureter with reference to the inlet valve ports, and after paying due attention to this point, a gasoline automobile engine has been successfully operated on alcohol without change. This bears out the experience of the Deutz Company in whose alcohol engines only a spray nozzle placed very close to the inlet valve is used. An ordinary gasoline carbureter can be made to act in somewhat the same way. American practice regarding alcohol engines is for obvious reasons somewhat behind that of Europe, but the indications are at present that this condition will not long exist.

CHAPTER XIII

GAS ENGINE AUXILIARIES: IGNITION, MUFFLERS, AND STARTING APPARATUS

Ignition. — There are four methods of igniting the combustible charge in a gas engine. Some of these are still in use, others belong to the period of gas-engine development. These methods are the following:



1. Ignition by an open flame.
2. Ignition by hot tube.
3. Ignition by heat of compression, and
4. Ignition by electric spark.

Ignition by open flame is practically obsolete, and ignition by hot tube is also fast falling into disuse. As a matter of fact, except for the Diesel engine, the Hornsby-Akroyd and a few others, which ignite the charge or fuel by heat of compression, the method of igniting the charge by the electric spark is to-day the means most generally employed.

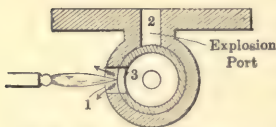


FIG. 13-1. — Barnett's Ignition Cock.

1. Ignition by Open Flame. — This method has been superseded probably

because of its occasional failure and the obvious danger connected with its use under certain conditions.

The simplest arrangement of this type is Barnett's ignition cock, Fig. 13-1.* This consists of a hollow plug which works in a shell having two ports, 1 and 2: The former opens to the atmosphere and communicates with an outside flame, A, the latter opens into the cylinder. The port 3 in the plug is of such a size that it may communicate either with port 1 or 2, but never

* Clerk, The Gas and Oil Engine, p. 207.

with both at the same time. Inside the plug is placed a gas jet as shown. Gas should be admitted to this at such a rate that the flame burns inside of the plug and not out through the ports 3 and 1. The proper size of the ports has much to do with the proper admission of air to the inside of the plug to keep the flame alive, as shown by the arrows. If now the plug is quickly turned through 90 degrees, making the port 3 register with port 2, enough air is contained in the plug to keep the flame burning during the interval, and the combustible mixture, entering the plug much as the air enters it in the first position, is instantly ignited. Here again the proper size of the ports is of importance, for if the mixture cannot circulate through the plug, it must reach the flame by diffusion. The chances are that in that time the flame has died out and ignition fails. The flame is blown out by the force of the explosion, or dies out for lack of air, but is immediately relighted by the outside flame, *A*, when the plug returns to its former position.

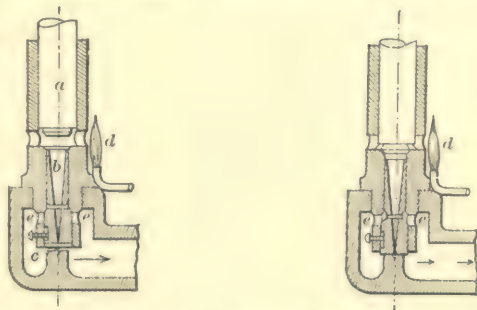


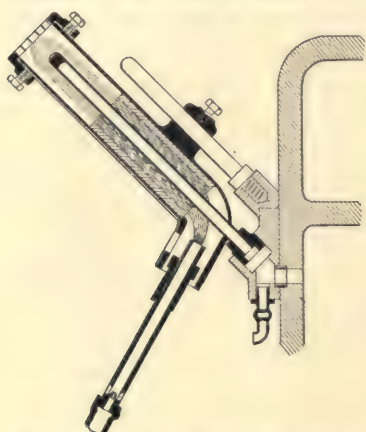
FIG. 13-2. — Koerting Igniter.

Barnett's scheme was open to the objection that since the flame chamber in the plug was always under atmospheric pressure, the combustible mixture, if compressed to any extent, might extinguish the flame by sudden inrush when communication was established. Several methods to obviate this were invented, notably by Otto and by Clerk. The latter differs from the former in that it will operate at higher engine speeds; Otto's scheme failing at comparatively low speeds. A very simple solution of the problem is shown in Koerting's igniter, Fig. 13-2.* The plug, *b*, see left-hand section, is practically a divergent nozzle. The pressure of the combustible mixture during compression raises the plug, and some of the mixture, escaping through the fine opening, *c*, and expanding through *b*, is ignited by the open flame, *d*. At the instant the piston reverses, the plug is forced down by the plunger,

* Schöttler, Die Gasmachine.

a, closing both the top and the bottom openings. But the mixture contained in the nozzle, *b*, keeps on burning until, at the instant the side openings, *e*, are freed, the flame strikes into the cylinder and ignites the charge. The right-hand section, Fig. 13-2, shows the ignition position.

2. Ignition by Hot Tube. — The simplest form of the hot tube ignition apparatus has already been shown in Fig. 11-5 Chapter XI. It consists merely of a small tube 3 or 4 inches long, of steel, porcelain, or platinum. The open end of this tube is in communication with the combustion chamber, the other end is closed. The tube is kept red hot for a certain part of its length,



generally by means of a Bunsen burner. A chimney surrounds both burner and tube to prevent loss of heat by radiation as far as possible.

The action of the hot tube may be explained as follows: At the end of the exhaust stroke the tube is filled with burned gases, and these are not replaced by the fresh mixture even at the end of the next suction stroke, because the time available is too short for diffusion.

FIG. 13-3.—Adjustable Hot Tube. During the compression stroke the burned gases are being compressed into the closed end of the tube and are followed up by the fresh mixture. But no explosion follows even if this mixture reaches the red-hot part of the tube as long as the velocity of flame propagation out of the tube is less than the velocity of the fresh charge into the tube. When the former becomes greater than the latter, which happens at or just before the piston reaches the dead center, the flame shoots out and ignites the charge. It is plain, however, that in the device shown in Fig. 11-5 the position of the hot zone along the tube must be about right or pre-ignition may result. Want of adjustment in this arrangement has led to the improved hot tube shown in Fig. 13-3. In this case the position of the hot zone along the tube may be varied as shown, thus giving some control over the time of ignition.

In order to completely control the time of ignition the ordinary hot tube has been perfected by the addition of a so-called timing valve.

In Fig. 13-4, *G* is the tube kept hot in the ordinary way. Timing valve *E* is normally kept closed by the coil spring *C*. At the proper time in the cycle the ignition cam (not shown), through the link, *B*, and the bell-crank, *A-D*, compresses the spring, *C*, and opens the valve. Ignition then ensues. The valve is kept open during the expansion and exhaust strokes. The time of ignition may be changed by changing the position of the cam.

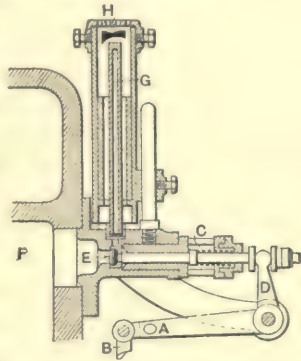


FIG. 13-4. — Hot Tube with Timing Valve.

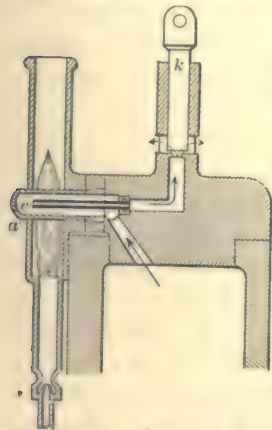


FIG. 13-5. — Koerting Hot Tube Igniter.

Timing valves are open to the objection that they are very difficult to keep in shape under the high temperatures occurring. To avoid the use of the small valve in the cylinder, Koerting has used the scheme shown in Fig. 13-5; *a* is an open hot tube made of porcelain. In it there is placed the small platinum tube, *c*. During compression some of the mixture escapes through *c* and the valve *k*. When ignition is desired, *k* shuts the exit and the flame in *a* strikes back into the cylinder.

Hot tubes may be from two to four inches long, and from one-quarter to one-half inches internal diameter. They may be made of steel, platinum, or Porcelain. Porcelain is best because cheap and nearly indestructible by heat.

The hot tube finds application in small and medium sized stationary machines only. It is fully as cheap to operate as electric ignition and just as certain.

In large machines this method of ignition is not as satisfactory, because the ignition itself is hardly sharp enough for the large volume of gas, and because in many cases the distance

the flame has to strike is too great. Care should be taken to place the tube at the proper point, *i.e.*, where a good mixture at the opening of the tube is insured, and where the opening cannot be clogged by oil or water.

3. Igniting the Charge by Heat of Compression. — This method of igniting the charge is practically limited to liquid fuels and is carried out in several ways.

(a) Only air is compressed to a very high degree so that its temperature is high enough to ignite the fuel as it is injected at the beginning of the working stroke. This is Diesel's method.

(b) The charge may be ignited by means of a hot bulb or chamber connected to the combustion chamber proper by a narrow neck or opening. There are two modifications of this method. In the one the fuel is injected into the combustion chamber on the suction stroke. During the next stroke the mixture is compressed into the hot bulb and ignites. The combustion, however, is confined to the bulb until, near the end of the compression stroke, the velocity of flame propagation exceeds the velocity of gases entering the narrow neck of the bulb, when the flame strikes out and general ignition ensues. The action of the bulb is therefore very similar to that of the open hot tube. The main difference is that after the bulb has been externally heated at the start, the heat of compression soon keeps the walls of the bulb at a sufficiently high temperature so that the external flame can be extinguished.

In the second modification, the hot bulb or chamber is used at the same time as a vaporizer. Thus in the Hornsby-Akroyd engine, the fuel is injected into the chamber by a pump at the beginning of the suction stroke. The piston draws nothing but air on this stroke, which air is partly forced into the bulb on the return stroke. Here it mixes with the oil vapor, which formed, due to contact with the hot walls, and while combustion may ensue it cannot be general because hardly enough oxygen is present in the bulb or vaporizer. Near the end of the compression stroke, however, the flame strikes out, and the combustion becomes explosive. As in the former case, the vaporizer is heated by a lamp at the start, but after a few minutes of operation the walls of the vaporizer, if well protected, remain at a dull red heat, due to the heat of compression and explosion.

Capitaine * employs a method which differs from that used in the Hornsby engine in that, at the moment the fuel is injected into the vaporizer, a little auxiliary air is also admitted which sweeps the oil vapor formed into the combustion chamber proper, where it meets the main body of air and is compressed with it. Ignition ensues from the hot walls of the vaporizer as in the other cases.

4. Ignition by Means of the Electric Spark. — Electric Ignition is to-day used more than any other. In fact in some branches of the industry, automobile work for instance, it is used exclusively. The reasons for this are not far to seek. As compared with the hot tube, there is no flame, and no fuel required to feed it. The system is perfectly flexible and susceptible of perfect timing.

There are a number of electric-ignition systems in use, differing in their methods of wiring, their sources of current, etc., but con-

sidering for the moment nothing but basic principles, all the systems may be grouped under two heads. These are:

1. Make-and-Break Ignition, and
2. Jump-spark Ignition.

In what follows, only the elementary principles of electric ignition will be discussed. For a comprehensive exposition of the subject, consult "Electric Ignition for Motor Vehicles" by W. Hibbert.†

1. MAKE-AND-BREAK IGNITION. — The simplest kind of make-and-break circuit is shown in diagram in Fig. 13-6.‡ In this figure, *B* is a source of current and *c* a so-called spark coil. In this case such a coil consists merely of a number of turns of comparatively heavy wire wound about a bundle of wrought-

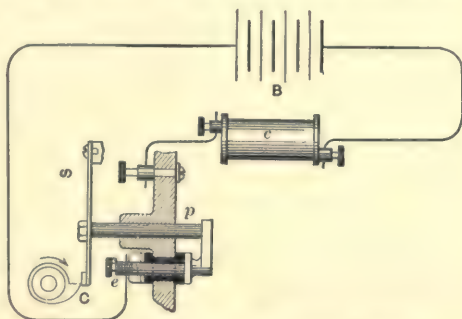


FIG. 13-6. — Make-and-Break Circuit.

* Zeitschrift d. V. d. I., 1907, p. 919.

† Whittaker & Co., 64-66 Fifth Ave., New York City.

‡ Roberts, The Gas Engine Handbook.

iron wires. This coil is in series with the circuit, and acts as an inductive resistance. When the circuit is broken, it serves to intensify the pressure, causing a hot spark at the point of break. For this reason the writer prefers to call this kind of coil an intensifying coil rather than a spark coil, which, as used in jump-spark ignition, is a very different thing.

The make-and-break mechanism consists in this case of a stationary electrode, *e*, insulated from the rest of the engine, and a movable electrode, *p*. The latter is connected to a flat spring, *S*, which in turn is in contact with the cam, *C*. The current

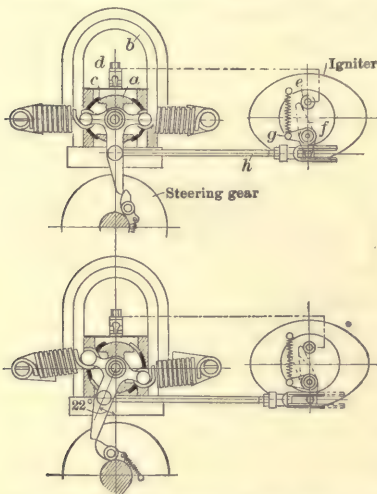


FIG. 13-7.—Make-and-Break Ignition Apparatus.

flows from *B*, through the intensifying coil, *c*, to the electrode, *p*, and from here through the electrode, *e*, back to *B*, thus completing the circuit. The operation is as follows: Cam *C*, rotating in the direction of the arrow, first presses electrode *p* against electrode *e*, making the circuit. At the proper moment, spring *S* slips off the cam, suddenly forming a gap between *p* and *e*, across which the spark jumps.

This type of make and break mechanism is known as the hammer break. An example from practice is shown in Fig. 13-7.* The source of current in this case is a Bosch magneto. The current flows from *d* to *e*, the stationary electrode, and returns through *f*, the movable electrode, and the forked rod, *h*. Actuated by a latching arrangement on the half-time shaft, the armature lever is pulled to the left about 20 degrees, as shown in the lower figure. This puts the two powerful helical springs shown in tension, so that when the latch releases, the armature sleeve instantaneously returns to its normal position, generating the required current by cutting the lines of force with great rapidity. At the same instant the fork, *h*, strikes the bell crank, *g*,

* Güldner, *Verbrennungsmotoren*, p. 365.

thus separating f from e , and causing the spark. This method is susceptible of adjustment by regulating the time of release of the latch.

It should be noted that in this particular instance the two electrodes are in contact until the spark is desired. This is admissible because with the source of current used, electric energy is generated only for an instant, just before the break. If a continuous source of current, such as a battery for instance, is used, it becomes necessary to modify the mechanism so that the electrodes are in contact only for a short time before the break; otherwise the system would be very wasteful of current.

The hammer-break mechanism is open to two objections, rapid wearing away of the points and fouling. The former is aggravated if too strong a current is used. It is usual, therefore, to make the points of contact of some metal that will not easily corrode or wear away under heat. Platinum, or platinum-iridium is extensively used for this purpose. There are, however, some special alloys on the market, such as Baker & Co.'s "Special," which are somewhat less costly, but do the work fully as well or better. Platinum is practically indestructible by heat, but it is hardly hard enough to stand the wear. The only remedy for fouling is periodic cleaning, although the claim is made for some of the special alloys that they remain bright indefinitely.

To overcome the objection of fouling, a modification of the make-and-break system known as the wipe spark is sometimes employed. In this, one electrode is made to revolve and a projection on it "wipes" across the other electrode at the proper time, causing a spark on the break. The spark produced in this way is perhaps hotter than that formed by the hammer break, and fouling of the sparking surfaces is effectually prevented. On the other hand, the wear is much greater.

Make-and-break ignition has the advantage that only a low voltage is required to operate it. The pressure ordinarily used is from six to eight volts, while in many cases from two to four volts is quite sufficient. There is thus much less danger from leakage of current and short-circuiting in this system than there is in the jump spark method.

The disadvantages of the system regarding wear and fouling have been already pointed out. Another, as compared with the

jump spark, consists in the fact that some mechanically operated gearing is required to "trip" the igniter. Both this fact and the rapid wear of the contact points have led designers to adopt the jump-spark system for high speed work. Lately, however, there

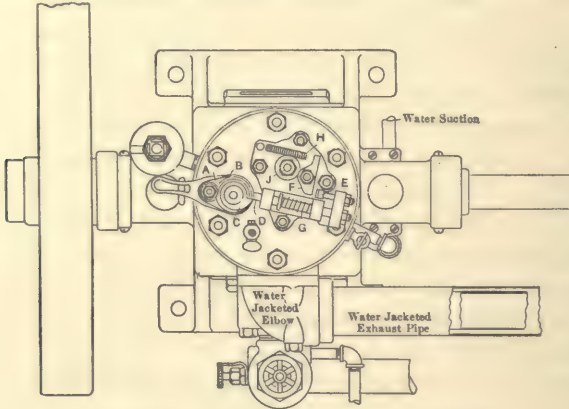


FIG. 13-8. — Plan, Fay & Bowen Engine.

seems to be a tendency to adapt the make-and-break system also to high speeds, caused no doubt by the very obvious disadvantages of the jump spark. There are ways of efficiently operating a high-speed trip gear. One of these, used by the Fay & Bowen

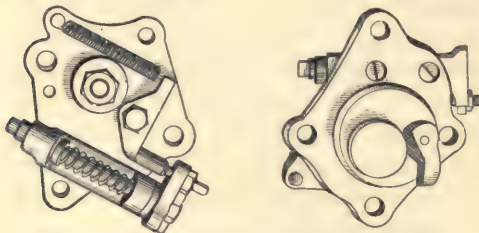


FIG. 13-9. — Igniter Block, Fay & Bowen Engine.

Engine Co. for medium high speeds, is shown in Figs. 13-8 and 13-9. Fig. 13-8 shows a plan view of the vertical engine. The igniter shaft, A, passes vertically downward through the water-jacket space, and is driven from the crank shaft by a pair of bevel gears. It runs in bronze bearings, and where it passes through the jacket it is encased in a water-tight tube. At the top this shaft carries a small gear which meshes with a somewhat larger gear, B, under the igniter cam, C. All the gears are cut gears and run practically without noise. The driving is positive and

there can be no slip. As the cam, *C*, revolves, it engages the plunger *D* and forces it back against the spring *G*. When the plunger slips off the cam, the hammer, *E*, strikes the movable electrode, *F*, separating it from the stationary electrode, *J*, causing the spark. This action is carried out with the same rapidity no matter how fast the fly-wheel is revolved at the start. For the greater part of its revolution, cam *C* is not in contact with the plunger, *D*, and hence the electrodes are separated, thus maintaining an open circuit for the greater part of the time and preventing the waste of current. Just as soon as *C* commences to push back the plunger *D*, the spring *H* pulls back the movable electrode *F*, and contact is made for a sufficient length of time to insure a good flow of current.

The igniter plug, shown in greater detail in Fig. 13-9, is entirely independent of the driving gear and is held in place by four bolts, which can be removed at a moment's notice. The seat of the plug is a ground joint. The spark points can therefore be examined and the plug replaced in a very short time, or a new plug may be substituted for the old one. The chances for wear in the whole arrangement, however, are very small and there seems to be no reason why this igniter gear should not be used for speeds much higher than those for which the designers now use it. Adjustment of the spark in this gear is made in a very simple way by pivoting the gear *B* about the center of the shaft *A*, thus changing the position of the cam, *C*, with relation to the plunger. The adjustment is controlled by the hand lever shown. Should the lever by any accident be left in the advanced spark position, so that the engine may get an explosion turning it the wrong way the next time it is started, a small clutch located under the igniter cam, *C*, immediately frees the cam so that no second back explosion can take place.

2. JUMP SPARK IGNITION.—Figure 13-10* shows diagrammatically the simplest type of jump-spark system. There are in all cases a primary or low-tension and a secondary or high-tension circuit. The primary circuit is shown in heavy line and contains the source of current, *B*. The current flows from *B* through an arrangement, *T*, called the interrupter, commutator, or timer, which serves to make and break the primary current at

* T. H. White, *Petrol Motors and Motor Cars*.

the proper time. It then passes through the primary winding, *P*, of the spark coil and returns to the source, completing the primary circuit. The secondary circuit, shown by a light line, consists of the secondary winding, *S*, of the spark coil and a spark plug in the cylinder of the engine, indicated in the figure by *Z*. It should be noted, in connection with the secondary circuit, that this circuit is never actually closed, since a spark gap always exists in the spark plug. Hence current cannot be said to flow in this circuit until the tension or voltage becomes high enough to bridge this gap by a spark.

To understand the operation of the jump-spark system it is necessary first to study the action of the spark coil. There are

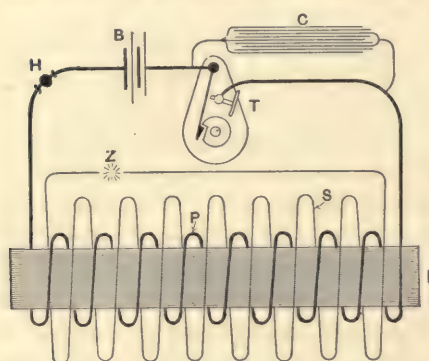


FIG. 13-10.—Simple Jump-spark System.

two kinds of these coils, the non-trembler and the trembler coil.

The former is the type indicated in Fig. 13-10. Its actual construction is about as follows: *I* is the core of the coil consisting of a bundle of fine iron wires. This is covered with a layer of some insulating material, and around this is wound the primary winding. This

consists generally of several layers of insulated copper wire, about No. 20 or 22. A light layer of insulation next separates this from the secondary winding, which consists generally of some 10 to 15000 turns of very fine insulated wire. Each layer of this wire is separated from the next by a layer of insulation to prevent short-circuiting under the very high pressures occurring.

To understand easily what follows, it is necessary merely to remember that if any conductor of electricity is moved across a magnetic field, or if a magnetic field is moved across a conductor, an electric current will immediately be set up in this conductor. Further, that if a current be passed through a conductor, a magnetic field will immediately be set up around the conductor.

Now, in the spark coil described, a current is sent through the

primary winding as soon as the contact is closed at *T*. This converts the iron core of the coil into an electro-magnet, setting up a strong magnetic field. The magnetic lines move outward across the windings of the secondary circuit and induce a high tension in this circuit. But, owing to self-induction, the building up of the magnetic field is much slower than the collapse of the field when the primary current is suddenly interrupted at *T*. The magnetic lines then move inward across the secondary winding with much greater rapidity, hence the pressure induced is much higher than that existing during the building up of the field, and, if the spark plug is right for the coil, a spark will bridge across the gap in the cylinder, igniting the charge. The fact that

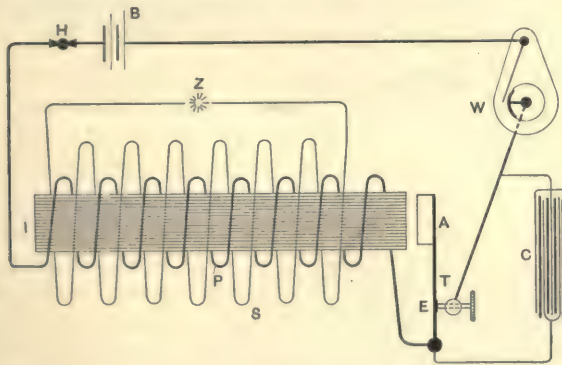


FIG. 13-11. — Jump-spark System with Trembler Coil.

the voltage induced on the making of the current is not high enough to bridge the gap prevents the occurrence of a double spark in the cylinder, which might lead to pre-ignition of the charge.

Since with the non-trembler coil the current in the primary is established only once when ignition is desired, only a single spark will occur in the cylinder. It is possible that this single spark may fail to fire and a series of sparks at the time of ignition is hence an advantage. This has led to the adoption of the trembler coil, Fig. 13-11*. The circuit shown in this figure is the same as that of Fig. 13-10, except that a trembler or "buzzer" *T* and a timer or commutator *W* have been substituted for the

* T. H. White, Petrol Motor and Motor Cars.

simple make-and-break mechanism, *T*, of Fig. 13-10. The action of the trembler is simple. As soon as *W* makes contact, the primary current converts the core, *I*, into an electro-magnet which attracts the armature, *A*, of the trembler blade. This action, however, breaks the primary current by pulling the spring blade, *T*, away from the constant screw at *E*. A spark then jumps over in the cylinder as before explained. The breaking of the primary current, however, releases the armature, *A*, which returns to its normal position, again establishing the primary circuit at *E*. The operation is then repeated. This action establishes a pulsating pressure in the secondary winding, causing a series of sparks as long as contact is maintained at *W*.

The advantage of the trembler coil has already been pointed out. The disadvantages exist in the fact that a second moving part is introduced into the primary circuit which must be kept carefully adjusted if the system is to work satisfactorily.

In both Figs. 13-10 and 13-11 it will be noticed that there is an arrangement, *C*, called a condenser, connected across the make-and-break mechanism, in the non-trembler coil across the interrupter, in the trembler coil across the vibrator or buzzer. The condenser consists of a large number of sheets of tinfoil, the number depending upon the capacity desired. Each sheet is separated from the next by a layer of insulation, and the alternate sheets are connected together. This manner of construction is clearly shown in the diagram. The object of the condenser is to prevent serious sparking at the make-and-break contacts in the primary circuit. The reasons why such a spark occurs at all in such a circuit is that the collapse of the magnetic field not only induces a high pressure in the secondary winding, but also causes a momentary increase in the pressure in the primary, thus bridging any small gap by a spark, and causing rapid wear of the contact points of the trembler at *E*, Fig. 13-11. When the primary circuit is now broken at *E*, the current induced, instead of jumping across, is expended in charging the condenser. The action is very similar to that of an air chamber on a hydraulic pipe line, absorbing shock by compressing air. The next time the primary circuit is closed at *E*, the condenser discharges and helps to send a current through the primary.

As actually constructed, spark coils are very compact. The

condenser is generally placed under the coils, and the whole is enclosed in a tight wooden box. Externally nothing shows but the terminals and the trembler, if the coil is of that type. In



FIG. 13-12. — Three-Terminal Spark Coil.

some coils one end of the secondary coil is connected to one end of the primary winding, so that only three terminals show, as in Fig. 13-12. Fig. 13-13 shows a four-terminal coil, the secondary terminals being on top. The tremblers are of various constructions, nearly each maker having his own design. They must give a quick break. They should be easy of fine adjustment, but the adjustment, once made, should stay. In many cases, as for automobile and marine purposes, the entire spark coil is enclosed in a second box with tight cover, so as to prevent fouling by mud or water. An example of this is shown in Fig. 13-14.

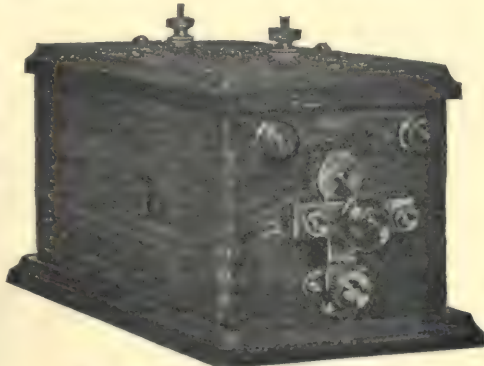


FIG. 13-13. — Four-Terminal Coil.

Timers. — A very important part of a jump-spark system is the device making and breaking the primary circuit, for everything depends upon the non-failing regularity of its performance.

There is a large number of such timers or commutators on the market, all more or less good. Figs. 13-15 to 13-18 show a few

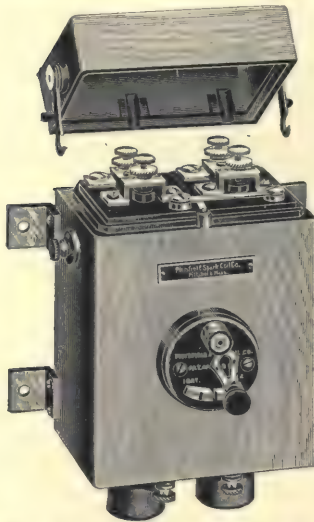


FIG. 13-14. — Dash-board Coil.

of the designs. The fundamental idea in all of these is the same. The half-time shaft actuates a cam or wiper inside of a case, which cam, at the proper time, makes and breaks contact with insulated terminals held by the surrounding case. The number of such terminals depends upon the number of cylinders. A great deal of ingenuity is shown in the prevention of friction between the cam and the terminal. The action of the Sintz timer, Fig. 13-15, is obvious. Here we have roller contact, the ends of the terminals are hardened steel, and the case is dust proof. Of somewhat similar design is the Lacoste timer, Fig. 13-16. The cross-section shows clearly the manner of construction. Somewhat more complicated, but of excellent design, is the Pittsfield timer, Fig. 13-17. In the Crouse-Hinds double ball timer, Fig. 13-18, the cam on the half-time shaft passes between two steel balls, held as shown. This makes the contact positive, keeps the surfaces clean, and the wear is very small.

With any of the above devices, the time of sparking may be varied by shifting the terminals with reference to the cam or wiper on the half-time shaft. Some timers incorporate governors to automatically time the spark.

Spark Plugs. — A spark plug consists of two electrodes or sparking points which are held a certain distance apart in the cylinder. The central electrode is insulated, while the metallic

ends of the terminals are hardened steel, and the case is dust proof. Of somewhat similar design is the Lacoste timer, Fig. 13-16. The cross-section shows clearly the manner of construction. Somewhat more complicated, but of excellent design, is the Pittsfield timer, Fig. 13-17. In the Crouse-Hinds double ball timer, Fig. 13-18, the cam on the half-time shaft passes between two steel balls, held as shown. This makes the contact positive, keeps the surfaces clean, and the wear is very small.



FIG. 13-15. — Sintz Timer.

jacket enclosing the insulation generally carries the other spark point. This point, therefore, can be put in the circuit by fastening a wire anywhere to the engine. The essential requirements of

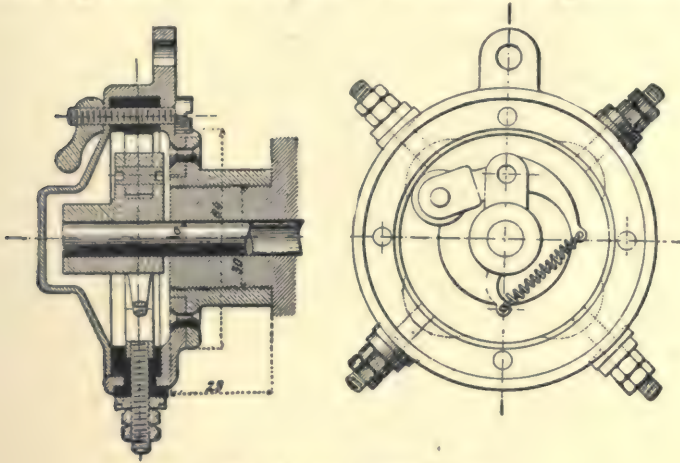


FIG. 13-16. — Lacoste Timer.

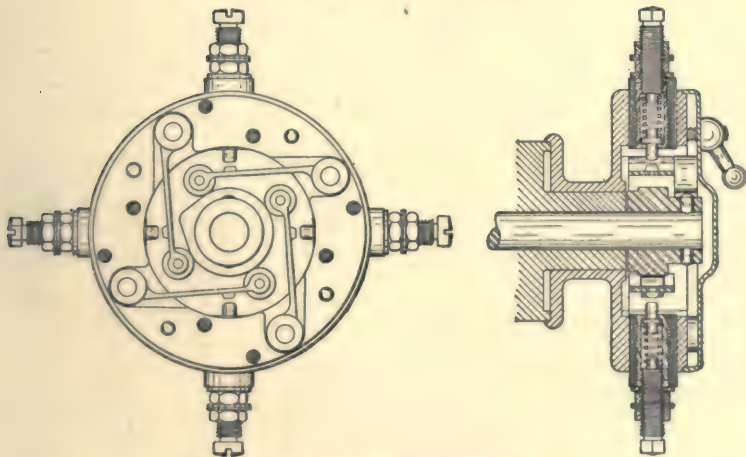


FIG. 13-17. — Pittsfield Timer.

the construction are that the insulation of the central electrode be sufficient and not liable to breaking down, and that the electrode points be so constructed that the plug is not easily subject to fouling.

The most important part of the entire plug is perhaps the insulation of the central electrode. Among the materials used

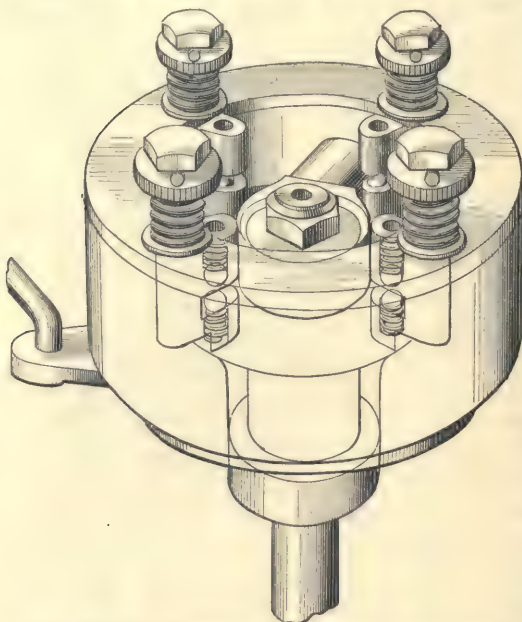


FIG. 13-18. — Crouse-Hinds Double Ball Timer.

for this purpose, porcelain and mica take the lead. Porcelain, while excellent, is very liable to break under any uneven expansion by heat, and the insulation must therefore be carefully designed with this point in view. Mica is not open to that objection and its electrical resistance is very high, but owing to its laminated structure, oil or soot may after a time be forced between the laminations under

the high pressures existing, thus short-circuiting the plug.

How various manufacturers have tried to take into account the requirements mentioned, is shown in Fig. 13-19.* The first six plugs there shown have porcelain, and the last two mica insulation.

It should be remembered in connection with spark plugs, that since the electrical resistance across the spark gap is greater when in actual operation in the engine than when in ordinary air, a plug may give a fair spark

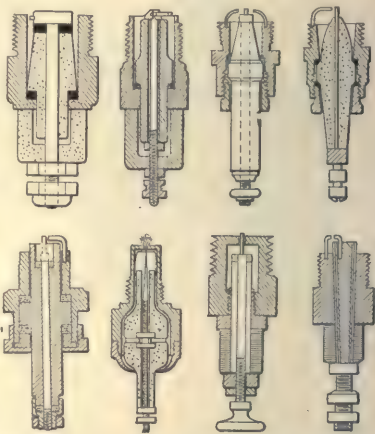


FIG. 13-19. — Various Designs of Spark Plugs.

* From Homans, *Automobiles*, p. 284.

when tested in air, and may still fail in operation. It should also be remembered that heat will lower the electrical resistance of porcelain, so that when the plug is very hot, short-circuiting through the insulation may result. It has been shown by experiment that while the resistance of porcelain cold was about 100 megohms, this fell to 2 megohms when the plug was at a dull red heat and under this condition sparking ceased. The spark, however, was immediately restored by an external spark gap, and continued even when the resistance had fallen to 800,000 ohms. Without the external gap, if the plug was allowed to cool down, sparking recommenced when the resistance of the porcelain had again risen to 5 megohms.

Auxiliary Spark Gap.—As the name implies, this is a second spark gap placed in the secondary circuit outside of the

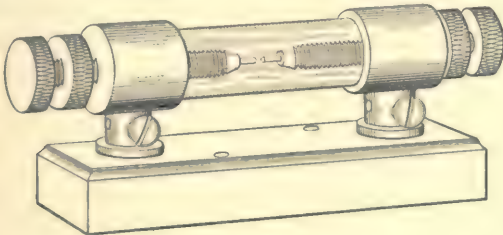


FIG. 13-20. — Auxiliary Spark-gap.

cylinder. This gap acts like an electrical condenser, above explained. The pressure builds up on one of the terminals of this gap, until it is high enough to break through the intervening air, causing an impulse of very high pressure through the circuit, thus giving a good spark across the main gap in the cylinder. Fig. 13-20.* shows one form of auxiliary spark gap. The advantages claimed for the device are:

(a) Greater certainty of sparking in the cylinder, since the higher pressure generated will cause a spark even across a partially fouled plug.

(b) Greater life of battery, since current cannot leap across a fouled plug as long as the auxiliary gap is not bridged.

(c) The sparking can be watched, since a spark across the gap always means a spark in the cylinder.

* Homans, *Automobiles*, p. 290.

In spite of these facts the auxiliary spark gap has not found extended application.

RELATIVE ADVANTAGES AND DISADVANTAGES OF MAKE-AND-BREAK
AND JUMP-SPARK SYSTEMS

Make and Break Ignition. — Low tension throughout the circuit, requiring less thorough insulation, and causing less trouble from short-circuiting. The system is electrically more simple, while mechanically it is somewhat more complex than the jump-spark system. This latter fact makes it somewhat difficult to apply to high-speed engines.

Jump-spark Ignition. — Electrically more complex than the other, but has no moving parts inside of the cylinder.

Can be operated under very high-speeds with entire success, and has the greatest flexibility with regard to spark adjustment.

Sources of Current. — All sources of electrical current used for electric ignition may be classed under two heads:

1. Chemical Generators, under which come
 - (a) Primary sources, as wet and dry cells, and
 - (b) Secondary sources, as the storage battery or accumulator.
2. Mechanical Generators, variously called dynamos and magnetos.

1. *Chemical Sources of Current.*

(a) **WET AND DRY CELLS.** — All chemical cells consist of three essential parts, a positive and a negative electrode and an exciting liquid, called the electrolyte. As the name implies, in the wet cell this electrolyte is used in its liquid form, while in the dry cell it is mixed with some absorbing material, and the paste is used to fill the space between the electrodes. Take the dry cell as an example. The negative element is usually a carbon rod placed at the center of the circular case which forms the envelope of the cell. This rod is surrounded generally first by a layer of manganese dioxide, the purpose of which will appear later, and the rest of the space between this and the positive element, usually zinc in the shape of a cylinder, is then filled with the electrolyte paste, the original liquid being usually sal-ammoniac and water. The top of the cell is then covered with pitch or other substance that prevents the evaporation of the liquid in the paste, except that a small vent hole is left to allow

of the escape of any gas that may form within the cell due to the chemical action going on. In such a cell the current generated by the action of the electrolyte passes from the zinc to the carbon electrode, so that as far as the terminals of the cell are concerned, the carbon is the positive terminal. The chemical action destroys the zinc after a time and produces hydrogen gas on the carbon element. The greater the amount of this gas deposited on this element, the slower the generation of current, so that it may finally cease altogether. The cell is then said to be *polarized*. In dry cells the gas is taken care of in two ways; the vent hole in the top allows some of it to escape, while the layer of manganese dioxide above mentioned absorbs another part. But it is a fact that by these means not all of the gas is rendered harmless and hence the cells will polarize with more or less rapidity. This merely means that if current is drawn from them continuously for any considerable length of time, their strength will fail, making the cell appear dead. The same reasoning applies to wet cells where the hydrogen is allowed to escape through the liquid. Now, assuming that the zinc is not yet destroyed, if a cell so polarized is allowed to recuperate, it will again attain nearly its normal strength and may be used as before. The cells are said to be adapted to "open-circuit work." From all of this it is quite evident that in places where the requirement for current is not very great and, above all, not continuous, the primary cell will give satisfactory service. But where the draft of current is nearly continuous, as in high-speed four-cylinder machines for instance, the cell will rapidly polarize and soon fail to give sufficient voltage to operate the spark coil. The average size of a dry cell is about $2\frac{1}{2}$ " x 7". It will give when fresh from 1.3 to 1.5 volts and from 12 to 15 amperes.

It should be understood that there are other combinations of electrodes and electrolytes which may be used to generate current. Thus the so-called soda-cell is made up of a zinc plate and a copper-oxide plate with a caustic soda solution as the electrolyte.

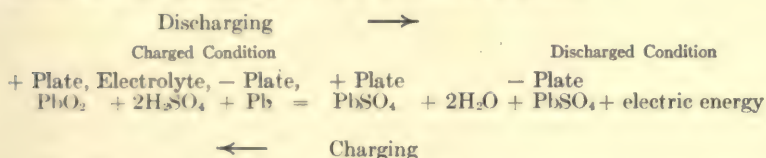
(b) STORAGE BATTERIES OR ACCUMULATORS. — A storage cell, like a primary cell, consists of two electrodes dipped in an electrolyte, but contrary to the primary cell, it cannot give off electrical energy in its original state when the circuit is closed. It is necessary to charge a storage cell before it can return electrical

energy on the discharge. The charging action causes chemical changes in the material of the electrodes and in the electrolyte. The energy so rendered latent is nearly all restored, when, after the charging current is disconnected, the outside circuit is closed. Chemical changes, producing a current in the reverse direction, then take place in the cell, which return both the electrodes and the electrolyte to their original condition. Some exhausted primary cells may be partially restored by passing a current through them in the reverse way, but in most cases the trouble is not worth while. The possibility of a nearly complete regeneration of a storage cell is the chief difference between it and a primary cell.

There are a number of materials which can be used as electrodes and electrolytes, but the usual type of storage cell to-day is that using some lead compound for the former and sulfuric acid and water for the latter. Hence only this lead storage cell will be here considered.

In its modern form, both the positive and negative plates of a cell consist of cast grids of lead, to which antimony is sometimes added to stiffen them. The perforations in the positive plate are first filled with some compound of lead, as Pb_3O_4 , which is afterward converted to peroxide of lead, PbO_2 . Similarly the negative plate is filled with PbO which is afterwards converted into spongy metallic lead. A number of plates so prepared are then placed side by side in a glass jar, or if the battery is to be used for automobile work, in a vessel of hard rubber or of wood lined with rubber or lead. Positive and negative plates alternate, and all the plates of like kind are connected together. There should always be one more negative than positive plates so that each side of each positive plate shall face a negative plate. The arrangement of plates presents a large plate surface in a compact space. Suitable insulation separates the plates from each other and keeps them from touching the bottom, in order to prevent any short-circuiting by contact or by dipping into any sediment that may form. In automobile batteries, the top is enclosed to prevent the spilling of the electrolyte, and nothing shows but the two terminals and an opening for filling. This is usually kept closed by a rubber cork with a small vent hole to allow of the escape of any gases that may form.

The chemical reactions that occur during charging and discharging are not yet fully understood, but it is agreed that the main action is the formation of lead peroxide on the positive and metallic lead on the negative plate during charging, and the formation of lead sulphate on both plates during discharge. The action is best explained by the following diagram.*



Such a lead cell when fully charged should show a voltage of from 2.2 to 2.25 on open circuit, and from 2.10 to 2.15 when the engine is running. The voltage soon drops to 2.0 and then slowly to 1.8. Three-quarters of the total discharge takes place between the latter figures. It is usual to discontinue discharging a cell when the voltage has reached 1.75. Beyond this point the formation of the insoluble lead sulfate becomes troublesome and, discharging much below this figure, the cell may be destroyed or at least seriously impaired.

Rating of Storage Batteries. — The amperage of storage cells depends on the weight of material in the cell converted by the chemical reactions, while the rate at which electrical energy can be taken off depends upon the surface of the active materials exposed to chemical action. Cells are rated by their ampere-hour capacity and nearly every maker states the normal rate of discharge recommended. For ordinary constructions the normal discharge rate is about .04 ampere per square inch of total positive plate surface, and the discharge capacity about 4 ampere-hours per pound of plate, including negative and positive. In order to be able to compare different cells, the capacity rating is based upon a current that will cause the voltage of the cell to fall to 1.75 volts in eight hours. Thus, if to produce this result a current of say 25 amperes must be drawn, the capacity of the cell is said to be $8 \times 25 = 200$ ampere-hours. If the rate of discharge is faster than this, it is obtained at the expense of capacity. Thus if a current of 40 amperes were drawn, the capacity might

* International Library of Technology.

be only 160 ampere-hours. Conversely, if the rate of discharge is slower than the standard, the limiting voltage of 1.75 may not be reached for say twelve hours instead of eight. These variations depend largely upon the make of cell.

Charging a Cell. — In charging a cell it is absolutely necessary to determine the polarity of the terminals of the source of current. The positive terminal must be connected to the positive terminal of the cell. The charging rate of lead cells should be about the same as the normal eight-hour discharge rate. It is, however, possible to use smaller currents for a longer time. The voltage of the charging current must be somewhat greater, from 5 to 10 per cent, than the discharge voltage, on account of the internal resistance that must be overcome. In one charging test, the charging voltage rose from 2.05 to 2.15 at the end of two hours, to 2.20 at the end of six hours, and to 2.50 volts in eight hours and forty-five minutes. The rate of charging was thus about normal. If charging is continued beyond this point, the electrolyte will have the appearance of boiling, owing to the gas that is being evolved. Slight overcharging will not injure a cell, but a large amount of it leads to sulfating and permanent injury.

Testing of Storage Batteries. — Two tests may be made, one for voltage, the other for sparking. For the former a low-reading voltmeter, 0 to 3 volts, is connected across the terminals of the battery, while the engine is in operation. The reading should be above 1.75 volts. Any cell may give 1.9 to 2 volts *on open circuit*, even if completely run down a short time before. The sparking test is made to determine in a way the state of the charge by noting the kind of spark. This test should be carefully done and not repeated too often. It is a dead short-circuit method and therefore not good for the cell. The use of an ammeter is for that reason not recommended, as it would take too long to get a reading. The sparking test is made by placing one skinned end of a piece of insulated copper wire in contact with one end binding post of the battery, and then drawing the other end rapidly across the other post. The spark should be loud and snappy.

Any storage battery should last from three to four years if properly treated. It is well to adopt a regular charging period,

say once in three weeks for the ordinary automobile battery, whether the battery is run down or not.

2. *Mechanical Forms of Generators: Dynamos and Magnetos.*—Mechanical forms of current producers have the advantage over primary and secondary batteries in that the energy required by them is derived directly from the engine they operate. Hence current will be produced as long as and only when desired. The other forms of generators depend upon sources of energy entirely extraneous to the engine plant, and the supply of current is therefore not in any sense automatic, which would be the ideal condition. The terms dynamo and magneto have been variously used. Some writers designate by "dynamo" any generator having electro-magnets serving to establish the magnetic field, and by "magneto" any machine employing permanent magnets for this service. Others define the difference as existing in the kind of current produced, a dynamo furnishing direct, *i.e.*, continuous current, while a magneto produces alternating, *i.e.*, pulsating, current. Whatever definition is adhered to, it should be remembered that in either machine the current is produced by an electrical conductor cutting the magnetic field. The current is produced in exactly the same way, and for exactly the same reason, as that established in the secondary winding of a spark coil, as explained above. In this case the conductor of electricity is wound upon a piece of metal, called an armature, which is rapidly rotated in a magnetic field. It makes no difference whether this field is produced by permanent magnets or by electro-magnets. If there are a number of such conductors upon the armature, and the current induced in each is properly collected by a so-called commutator upon the armature shaft so as to be practically continuous in its flow through the external circuit, we have what is generally called a dynamo. On the other hand, if the current in the external circuit rises to a maximum value and then dies out to give a maximum value next in the opposite direction, the machine is generally known as a magneto. While in all dynamos and most magnetos the armature constantly rotates in one direction, it should be stated that in all magnetos this is not at all necessary. Thus in the Simms Bosch magneto, the armature is stationary, and only a sleeve surrounding the armature is rapidly oscillated in the magnetic field. It would be beyond the scope

of this book, however, to discuss all the possible modifications, and the reader is hence referred to the works upon this subject.*

In general, the small dynamo used for ignition purposes is driven by means of a friction wheel from the fly-wheel of the engine. There is then no current available from the dynamo when the engine is started, and it becomes necessary to use a battery of some kind for the first minute or two, switching in the dynamo when it is up to speed. This scheme has the disadvantage that the battery is sometimes left in the circuit and the dynamos have been known to burn out under excessive engine speeds. A device called the Auto Sparker, Fig. 13-21, overcomes these difficulties. This little dynamo is fitted with a centrifugal governor which

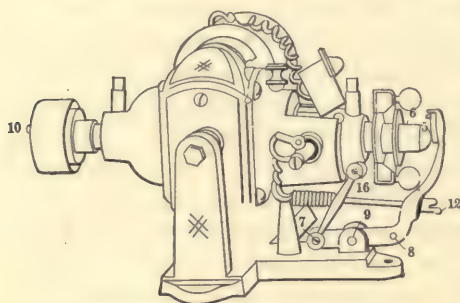


FIG. 13-21. — Auto Sparker.

controls the position of the friction wheel on the fly-wheel rim, so that even at starting the armature rotates rapidly enough to furnish starting current. This does away with an auxiliary battery. As the engine speeds up, the governor of the dynamo acts to keep the armature speed

constant, independent of the diameter of the fly-wheel or the engine speed. By adjusting the governor tension spring, it is possible to control the speed of the dynamo to get any current between 1 and 3 amperes and any voltage between 3 and 10 volts.

Regarding magnetos, the following description of the action of a magneto, together with the explanation of the method of connecting it up, is taken from a catalogue of the Holley Bros. Company of Detroit. For clearness and simplicity this description can hardly be improved upon.

“A magneto, so far as its essential parts are concerned, is a very simple thing. It consists of a U-shaped piece of special steel, which is permanently magnetized; in other words, a common horseshoe magnet and a rotating armature. The armature consists of a soft iron core of approximate *H* cross-section as

* W. Hibbert, *Electric Ignition for Motor Vehicles*.

viewed along the shaft upon which it is supported and on which it is designed to rotate. The magnet, to the free ends of which are affixed soft iron arc-shaped pole pieces, and the armature core with the sides of the *H* correspondingly are shaped, is shown in vertical section in Fig. 13-22. In the slot formed in the armature

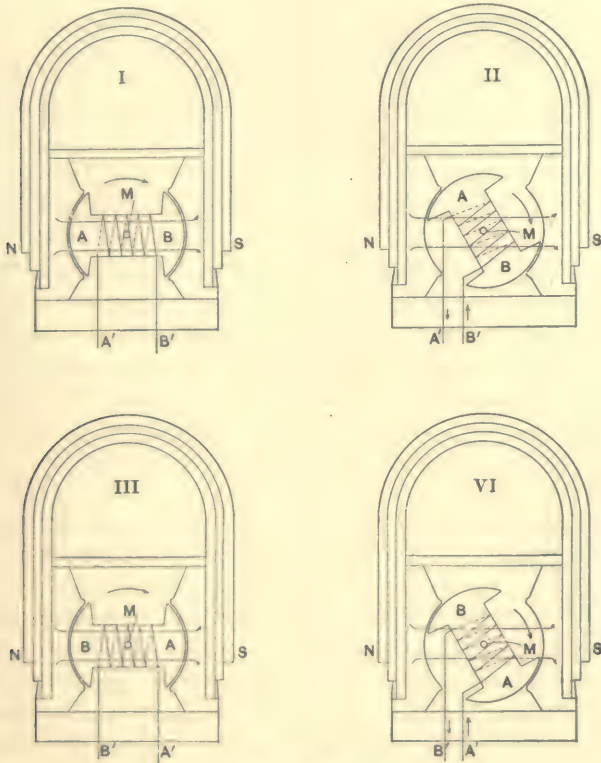


FIG. 13-22.

core by the sides of the *H*, wire is wound in turns lengthwise of the armature shaft. So much for the construction of the elementary magneto. In order to understand how it generates in its armature, when turned, an electric current, it is necessary to remember one law of physics, namely: Whenever a wire is wound about a magnetized soft iron core and the magnetism of the core suddenly dies out, there will be a tendency for a current to be

produced in the wire. A familiar example of the working of this law is found in the operation of the common jump-spark coil. Here we have a core made of soft iron wires and around it is wound a great many turns of fine wire, the ends of which are connected to a spark plug. The core is also wound with a coil of wire which is supplied with current from a battery, and when this current is flowing the core is magnetized. When the current from the battery is interrupted, the magnetism in the core suddenly dies out, and, in accordance with the law above stated, a tendency is created for a current to flow in the fine wire coil which is connected to the spark plug and this 'induced' current jumps at the plug.

"In order to explain how the iron core of the magneto armature with its winding is magnetized and how the magnetism of the core is caused suddenly to die out, it is necessary to refer to four diagrams of Fig. 13-22, showing the armature in different positions of rotation with respect to the pole pieces. In diagram (I) the armature is represented with the two heads of its core in close proximity to the faces of the pole pieces. The space between the pole pieces is thus almost completely filled or bridged with iron, and magnetism passes from one pole piece to the other through the armature core, thoroughly magnetizing it. Next consider diagram (II). Here the armature is shown rotated into such a position that one edge of each pole of the armature core is just leaving the vicinity of one of the pole pieces. As soon as this position is passed, the space from pole piece to pole piece is no longer filled with iron, but with air which is not a conductor of electricity. Thus very little magnetism passes from one pole piece to the other and the core is no longer traversed by the magnetic influence and suddenly ceases to be magnetic. This is exactly the condition prescribed by the above quoted law for the production of a current, and, in fact, when the armature in its rotation leaves position (II), there is a sudden impulse of current produced in the wire of the armature which dies away after the armature rotates a little beyond this position. In position (III), the conditions of armature magnetization existing in position (I) are reproduced, except that the armature has changed ends in respect to the pole pieces and the magnetic influence passes through it in the opposite sense, charging it oppo-

sitely, so that when the magnetism is discharged in position (IV) the current will be in the opposite direction through the wire of the armature winding. As the armature is turned upon its shaft, there are thus produced, in each complete rotation, two rather short impulses of current of opposite direction nearly corresponding with the instants at which the armature heads, so to speak, 'part company' with the pole pieces and are half a revolution apart. During the remainder of the rotation there is no current flowing. It may be readily seen that by connecting one end of the armature wire to the armature core, and by connecting the other to an insulated metallic contact segment, carried by the armature shaft, upon which bears a stationary insulated brush, the current impulses may be taken from the magneto for use.

"Now as to the practical use of such a magneto for ignition purposes. Since it is only during a small part of the armature rotation that current is being generated, it is necessary to rotate the armature shaft at such a speed that these electrical impulses shall be so timed as to correspond with the periods when ignition is required by some one cylinder of the engine. If this were not attended to, the ignition periods of the engine might occur during the parts of the armature revolution, when no current was being produced. In order to bring about this result, the magneto and the engine must, at all times, run at a properly proportioned ratio of speeds and the positions of the engine, crank shaft, and armature must be adjusted right in the first place. If the magneto shaft is geared to the engine at the right ratio and the teeth of the two gears are correctly meshed, the desired result will be brought about. For instance, if the engine be of the four-cylinder, four-cycle type, four sparks will be required for each two crank-shaft rotations. Four sparks will be produced for each two revolutions of the magneto, as well, and thus, if the magneto and the engine run at the same speed, the sparks will be numerically correct. If geared to the crank shaft, the crank-shaft gear and the magneto gear would have the same number of teeth, and if driven from a two to one shaft, the number of teeth in the two to one shaft gear would be twice as great as the teeth of the magneto gear. By changing the particular teeth of one gear which are in mesh with certain teeth

of the other, the current impulses may be made to occur at the moments when the pistons are exactly in the firing positions."

In variable-speed engines, as automobile machines, for instance, the service required of the ignition outfit becomes more exacting as the speed increases, owing to greater compression and less available time. This in the case of mechanical current generators is met by a natural increase in voltage with increase in speed, which constitutes another advantage of this type of generator as compared with primary and secondary cells. Thus less hand manipulation of the spark is required, but all magneto systems should be provided with means of altering the armature position relative to the crank-shaft position in order to alter the time of spark.



FIG. 13-23. — Methods of Connecting Cells.

METHODS OF CONNECTING UP PRIMARY AND SECONDARY BATTERIES, AND SYSTEMS OF WIRING USED. — Primary and secondary cells may be connected in series, in parallel (or multiple) and in multiple-series. The meaning of these terms is explained in Fig. 13-23. For series connections, Fig. 13-23a, each positive element of one cell is connected to the negative element of the next, leaving free the negative element say of the first cell and the positive element of the last for connection to the outside circuit. In the second or multiple method of connection, Fig. 13-23b, all the like elements of the cell are connected together. Fig. 13-23c finally shows six cells in multiple series, *i.e.*, three each are connected in series, and these two sets in multiple or parallel. To compute the voltage and am-

perage that each one of these combinations will furnish to the outside circuit, let

N = number of cells in the combination

V = voltage of one cell, and

A = amperage of one cell.

Then the following formulæ will give the desired information:

Kind of Combination	Series	Multiple	Multiple-series
Voltage of set.....	NV	V	NV
Amperage of set.....	A	NA	2 A

The ordinary dry cell, as stated, furnishes about 1.5 volts and 12 to 15 amperes. A *make-and-break* circuit should operate properly on about 8 to 10 volts, hence from 5 to 7 dry cells in series are required for this service. As far as *jump-spark systems* are concerned the following table gives pressures and currents required to operate some of the well-known spark coils, together with other interesting information.* From this table it is clear that from 4 to 6 dry cells in series are sufficient to operate most jump spark coils:

	Volts	Amps.	Vibration per sec. of Trembler	Prim. Res. Ohms.	Sec. Res. Ohms.
Kingston.....			89		
Apple.....	5.20	2.2	94	.171	3715
Guenet.....	3.7	1.31	111	.300	2337
Guenet.....	5.8		123		2337
Hardy.....	3.78	1.05	122	.274	2779
Fisher.....	5.8	.82	149	.613	2590
Dow.....	3.84	.57	149	.210	5394
Lacoste.....	3.72	1.46	177	.232	2006
Lacoste.....	5.62	1.94	197	.232	2006
Heinze.....	3.66	1.31	210	.320	1302
Pittsfield.....			228		
Induction Coil Co.....	3 62	1.55	360	.312	6180
Milwaukee.....			390	.312	6180

Turning next to the *systems of wiring used*, all make-and-break systems are *low-tension* systems, i.e., the voltage does not generally exceed 8 to 10 volts. Fig. 13-24 † shows such a system in diagram with a magneto as the source of current. The circuit is easy to trace. One side of the electrical conductor on the armature is grounded, that is, connected to the engine frame

* H. G. Chatain in the *Automobile*, July 18, 1907.

† The following three figures are from an article by C. B. Hayward in the *Automobile*, April 4, 1907.

denser and *B* the primary and secondary windings of the spark coil. It is comparatively easy to trace out the complete primary and secondary circuits, if one takes into account the proper ground returns.

The true high-tension jump-spark system differs from the above in the fact that the high-tension magneto embodies the secondary winding and the condenser of the spark coil. Hence the use of a separate spark coil is avoided. In Fig. 13-26 the two windings are indicated on the armature, but the condenser is shown at one side for the sake of clearness. This diagram shows the wiring for four plugs.

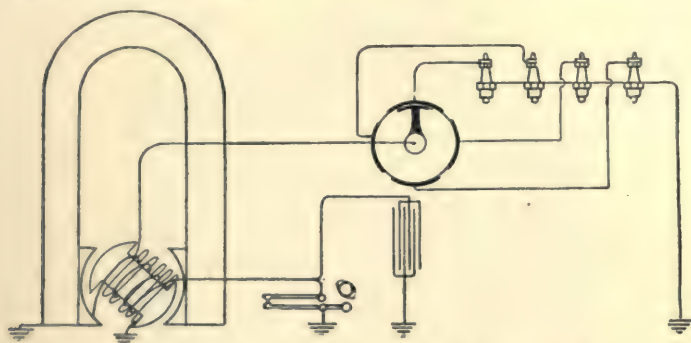


FIG. 13-26. — Wiring Diagram of True High-tension System.

HIGH-TENSION DISTRIBUTOR. — With the ordinary system of jump-spark ignition, as many coils as there are cylinders are required. It is possible, however, by placing a distributor in the high-tension side to serve a number of cylinders from one spark coil. The advantage of such a system is obvious, although it is bought at the cost of placing a make-and-break mechanism under very high voltage. The difficulties inherent in this, however, have been fairly successfully overcome. The difference in the wiring is made clear by Fig. 13-27 and Fig. 13-28,* both applying to four-cylinder engines. The former shows the four-part timer connected to the four spark coils serving the plugs SP_1 to SP_4 . In Fig. 13-28, a high-tension distributor *D* connects the high-tension side of the single coil first with one plug, then with another as may be required. In practice the high-tension distrib-

* Both from Hibbert, Electric Ignition for Motor Vehicles.

utor *D* and the primary commutator or timer, *CM*, are combined in one device. Fig. 13-29 shows the Crouse-Hinds Double Ball Contact distributor and Fig. 13-30 the Leavitt distributor.

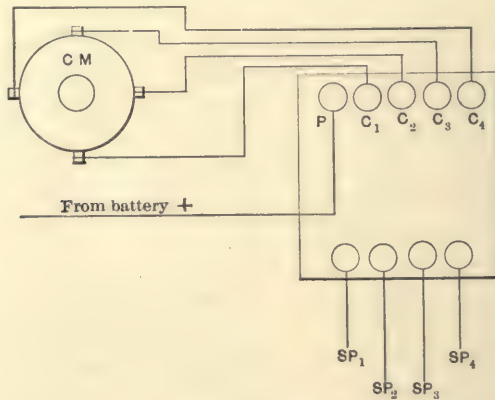


FIG. 13-27.

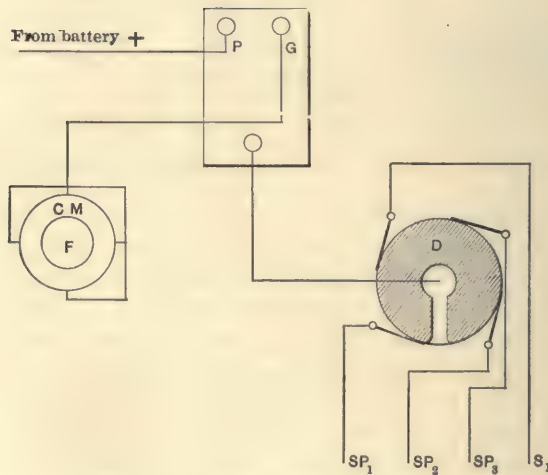


FIG. 13-28.

The essential thing in high-tension distributors is that serious sparking in the high-tension side must be avoided. For that reason, in most of the devices the primary commutator does not establish the current until the high-tension distributor is in con-

tact with its proper plug segment and the primary current is broken before the contact in the high-tension side is over. To quote from the description of the Crouse-Hinds device:

"The principle is exactly the same as that of the commutator already described, Fig. 13-18. The distributor has two cams and two sets of ball contacts, one set for the timer and the other for the distributor, the only difference being that in the latter the balls in each contact are about three-eighths of an inch apart and the cam insulated from the shaft. The connection is

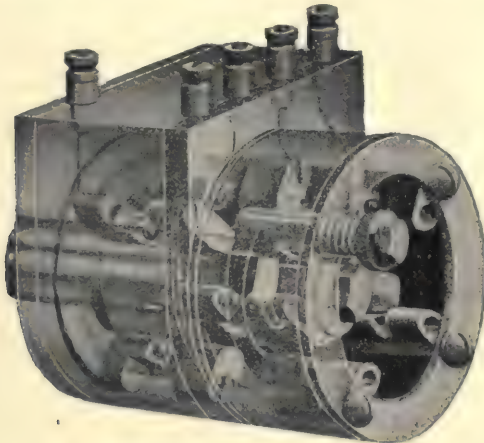


FIG. 13-29. — Crouse-Hinds Distributor.

made and the circuit is closed for each cylinder as the cam passes between the balls."

The following is a description of the Leavitt distributor as given in a catalogue of the Uncas Specialty Company:

"This device, two views of which are shown above, consists of a cylindrical casing, *A*, of hard rubber, into which is let a metal plate, *B*, at one end, and which is covered by a hard rubber cap, *C*, at the other end. Upon a ball bearing in the end plate, *B*, is mounted a driving sleeve, *D*, designed to be secured upon an extension of the cam shaft, and carrying fast upon it contact blocks, *E, E, E, E*, which make contact, successively, with the primary ball contact terminal, *F*. Thus far the device is identical with the ordinary timer. The commutator portion is located

at the opposite end of the cylindrical casing. The latter is enlarged at that end, and into the radial wall between the two cylindrical portions are clamped four flat-head studs, *G, G*, which serve as binding posts for the spark plug connections. Into the end of the metallic sleeve, *D*, is fastened a hard rubber stud, *H*, which at its outer end carries a radial arm, *I*, which is of metal

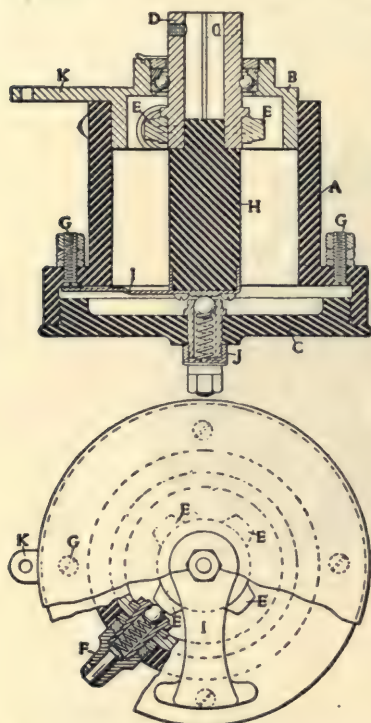


FIG. 13-30. — Leavitt Distributor.

with a relatively wide contact shoe at its end, which when the sleeve, *D*, revolves, passes over the four contact studs, *G*, thus conducting the current successively to the four plugs. The current is conducted to the rotating arm by a central ball contact, *J*, secured into the cap, *C*. When the hard rubber casing is moved around its axis by means of the arm, *K*, to vary the time of spark, both primary and secondary contacts are equally displaced."

Mufflers. — A muffler is an essential part of a gas-engine installation if quiet operation is desired. The sudden release of a body of gas at a pressure normally of 40 pounds per square inch above the atmosphere causes a sharp noise very annoying in the long run. A muffler is merely an enlargement in the

exhaust pipe to allow of gradual expansion of the escaping gases. Many different schemes are used. Thus in some cases the muffler is merely a cast-iron pot or vessel of suitable volume, in other cases the muffler is of more elaborate construction consisting of a vessel filled with baffles or partitions in various ways and intended to expand the gas gradually and to break up the sound waves. Besides efficiency as a dampener of noise there are two other points that should be kept in mind

with regard to mufflers, absence of any serious back pressure and durability.

The increase in back pressure caused by a muffler depends upon the volume of the muffler and upon the amount of choking caused by the baffles. The minimum volume of the muffler should be at least five times the cylinder volume, but for complete silencing twice this volume is none too much. Outside of the plain cast-iron muffler pot, it is probably safe to say that nearly all baffled mufflers increase the back pressure somewhat. This fact is conceded by most manufacturers in that they furnish a cut-out which is called into service when the engine is to be called upon for a hard pull. At least one manufacturer, however, claims the production of a slight vacuum between muffler and engine due to the ejector action of the muffler.

There is little doubt that cast iron is the best material to use for mufflers, as it is least attacked both by heat and the action of gases. This is especially true if a spray is used in the exhaust pipe for the purpose of cooling and condensing the exhaust gas. Many mufflers, however, for the sake of lightness and ease of manufacture, are made of galvanized sheet steel and give quite satisfactory service.

The noise of the air rushing into the inlet pipes of an engine is also sometimes very annoying and in some cases may cause undesirable vibrations of doors and windows, and even walls, of the building. In such a case it is usual to muffle also the inlet pipes, and one of the best ways to do this in small and medium sized engines is to take the air from the hollow sub-base.

In some very large engines the proper silencing of the intake and the exhaust becomes quite a serious problem, as the ordinary muffler would become very large. The expedient sometimes used is to draw the air through an underground masonry duct of ample size leading in from the outside of the building, and to discharge through a similar duct into a chamber from which the gases finally escape. A spray of water into the exhaust pipe of such engines, close to the exhaust valve, helps materially.

Figures 13-31 and 13-32 * show two types of muffler sometimes used. In the first the stream of gas is merely divided, in the second each division is furnished with an enlargement de-

* Mathot, Engineering Magazine, July, 1907.

signed to decrease the gas velocity still further. Fig. 13-33 shows the Powell muffler. The partial section shows how the gas is broken up into many fine streams by passing it through perforated plates. In the so-called ejector muffler; Figs. 13-34 and 13-35, made by the Motor & Mfg. Works of Geneva, N. Y., a part of the gas passes straight out through a central pipe. The rest is made to pass a series of perforated cones as shown. It is claimed that the central pipe acts as an ejector serving to draw the gas through the cones, thus eliminating back pressure and even creating a vacuum ahead of the muffler.

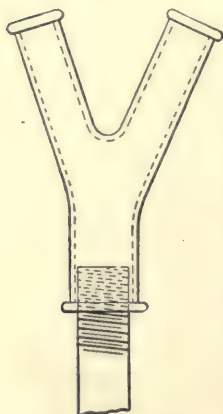


FIG. 13-31.

Starting Apparatus. — The best way of starting small engines, up to say 10 to 12 horse-power, is to turn the fly-wheel over by hand either in the direction of normal rotation until the engine picks up, or, after a charge has been drawn in, by turning it in the opposite direction against the compression and then snapping the spark by hand. In starting an engine in this way, it is essential to make sure first that the time of sparking is rather late, otherwise the engine may "buck," which may possibly lead to an accident to the person starting it.

As the size of the engine increases, however, the manual labor involved in the above scheme soon becomes too great and other means had to be developed. These may be grouped under several heads. It should be noted that none of these are quite able to start an engine under load.

(a) Starting crank.

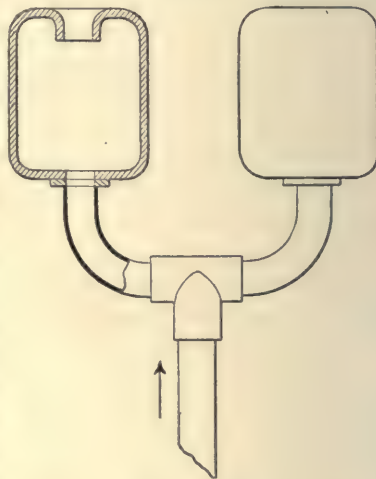


FIG. 13-32.

- (b) Starting by smaller engine or other source of power.
- (c) Starting by mixture.
- (d) Starting by compressed air.
- (e) Electrical starters.

Of the methods above mentioned, (a) is nearly universally used for engines up to 15 to 20 horse-power; beyond this, starting by compressed air, method (d), is generally employed.

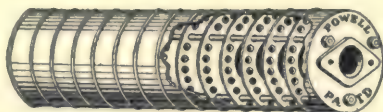


FIG. 13-33. — Powell Muffler.

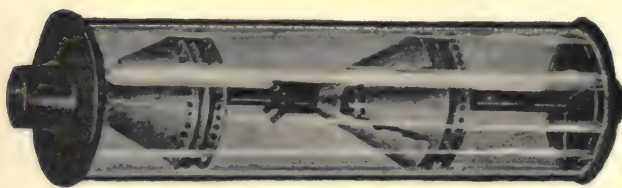


FIG. 13-34. — Ejector Muffler.

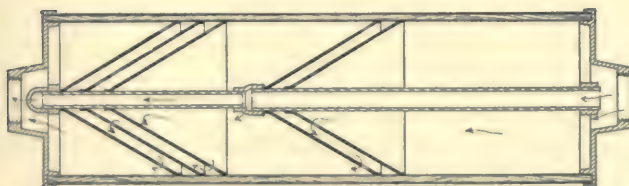


FIG. 13-35. — Ejector Muffler.

(a) Most starting cranks are so arranged that, when turned in the direction of rotation of the engine, they grip the shaft. As soon as the first explosions accelerate the shaft so that it turns faster than the crank is being turned, the latter is released. This scheme does not prevent the crank from "kicking" back into the starter's hand if the spark should happen to be early, and many accidents have resulted therefrom. A crank which avoids this drawback is shown in Fig. 13-36. The following description of this device is from the *Horseless Age*, March 7, 1906:

"A bushing *A*, having a thread of exceedingly high pitch cut on its interior surface, contains a threaded sleeve *B* which serves as bearing for the shaft of the starting crank *C*. Rigidly secured to the shaft of the crank *C* are a ratchet wheel *D* and a ratchet cam *E*, the latter adapted to engage with the ratchet *E'* on the motor shaft. In an extension of the sleeve *B* are a set of spring press pawls *F* which are adapted to engage with the ratchet wheel *D*.

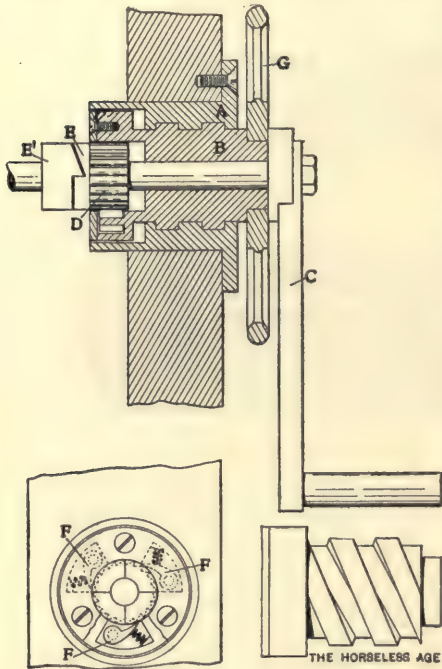


FIG. 13-36. — Starting Crank.

the sleeve *B*, and the ratchet cams *E* and *E'* are thereby disengaged. However, if the motor should kick back, the pawls *F* would engage into the notches in the ratchet wheel *D*, and the sleeve *B* would be rotated and draw the ratchet cams *E* and *E'* out of mesh. The pitch of the thread on the sleeve *B* is so steep that a very slight rotation of the sleeve in the bushing will carry it back far enough to pull the starting spindle out of engagement with the crank shaft. The pawl and ratchet mechanism is completely enclosed by a lateral extension on

"The device is mounted at such a distance from the end of the crank shaft that the ratchet cams *E* and *E'* cannot engage unless the sleeve *B* is screwed to the limit of its motion into the bushing *A* by means of the hand wheel *G*. In starting the motor, the device being in the position shown in the assembly view, the action is the same as that of an ordinary starting crank. When the motor runs up to speed, owing to the pressure between the cam surfaces of ratchet cams *E* and *E'*, the starting spindle is forced back into

the bushing *A* and an end plate bolted to the extension of the sleeve *B*."

(b) If the plant has other engines in operation or if there is a shaft in operation it is quite easy to transmit the motion to the engine to be started. Some large engine installations were equipped with smaller engines the shaft of which carried a pinion which meshed with a ring of teeth on the fly-wheel of the large machine. When the large engine picked up its cycle, the small engine was automatically put out of mesh with the wheel. The cost of fitting a large engine for starting in this matter, however, is considerable. Hence this method has been largely replaced by the use of compressed air.

(c) Starting by means of the fuel mixture is done in various ways. The scheme appears to be reliable in the case of engines using illuminating gas; for other gases it never was in any extended use and in fact is to-day nearly obsolete. Besides the fact that if the first charge should fail there was generally not enough left for a second trial, the storing of an explosive mixture is obviously attended with some danger.

In nearly all cases of starting by the fuel mixture, the engine crank is put a few degrees above center, *i.e.*, well in the beginning of the expansion stroke. One method is to charge the compression space with air at atmosphere pressure, and then to open the gas cock. The mixture formed is allowed to escape through a special check valve and is ignited by a Bunsen burner just at the orifice. When the issuing flame burns reddish, showing that the mixture is rich, the gas valve leading into the cylinder is suddenly closed off. The flame at the orifice of the check valve strikes back into the combustion chamber and explodes the mixture remaining. The pressure generated closes the check valve and drives the piston forward. This is the original method of Clerk and of Green.

The pressure generated behind the piston in the above manner is not very high, and the velocity attained therefore correspondingly low. The next step in the development was then to compress the charge before ignition. The Clerk pressure starter and the Clerk-Lanchester high-pressure starter are of this type. Fig. 13-37 * shows the latter gear. The method of operation is as

* Clerk, *The Gas and Oil Engine*.

follows: As the engine is slowing down for a stop with the main gas valve closed off, valve *W* is opened. This draws fresh air into the chamber *D* and the pipe *D'* through the valve *Y*. When next the engine is to be started, the gas cock *F* is opened. Gas flows into *D* and *D'* and forms a combustible mixture. Through a cock on the cylinder, or a slightly open exhaust valve, a part of the mixture is allowed to fill the combustion chamber through the valve *W*, while another part escapes through a check valve *Y* and is ignited by the Bunsen burner *X*. As soon as the mixture is right, *F* is closed off, the flow stops, and the flame strikes in through *Y* into *D*. The pressure generated closes *Y*. The flame

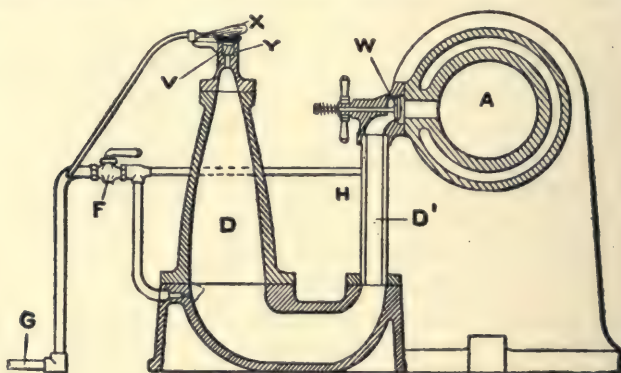


FIG. 13-37. — Clerk-Lanchester Starter.

and pressure wave travels around into *D'*, compressing the still unburned charge ahead of it and finally ignites the charge so compressed in the combustion chamber *A*. The starting pressure so obtained is about twice that obtained by the method first described.

Besides these flame starters, of which there are a number of modifications, other methods are in use. Thus in some engines a mixture is pumped under more or less pressure by hand into the combustion chamber, and ignited either by snapping the spark, or, as it is done by one manufacturer, by suddenly lighting an ordinary parlor match, the head of which is allowed to slightly project into the mixture. The device for doing this is quite simple but the method is not much used.

Another scheme is to charge a pressure tank with the combus-

tible mixture. This is generally done by means of a special valve which, when the engine is in operation, opens somewhere along the compression stroke of the engine, and allows it to compress some of its charge into the tank. The starting is then done either by merely filling the combustion chamber under low pressure from the tank and igniting the mixture by suitable means, or by opening the tank valve wide, utilizing the pressure of the compressed mixture to start the engine, igniting the charge on the next compression stroke in the regular way. This scheme has the advantage that if the first trial fails there is generally enough in the tank for several more attempts, but the storing of any considerable quantity of mixture under pressure is not to be recommended on account of danger of explosions in the tank.

Finally, at least one large German engine has been started by means of the mixture by first placing the crank in the proper position, and then blocking the fly-wheel by a plug of suitable material. A small gas engine is then started by hand and allowed to fill the combustion chamber of the larger engine under pressure in the same way as the tank was charged in the previous method. When the desired pressure is reached, the mixture is fired by hand manipulation of the spark, the impulse of the explosion breaks the plug holding the wheel and the engine picks up the cycle in the regular way.

(d) To-day the starting of internal combustion engines of any size is generally done by compressed air. The latter may be obtained in various ways. In some of the smaller engines, when the engine is to be shut down, the fuel valve is closed and the engine as it slows down is allowed to compress the air drawn in into the tank. Some other installations have a hand-operated air compressor for charging the tank, or the compressor may be belt-driven from the engine for a few minutes. It is hardly necessary to say that all tank and pipe connections must be absolutely air tight, because the failure of the air pressure in a plant of some size would cause serious delay. For engines of the largest capacity, it is usual to employ air compressors completely independent of the engine, thus obviating any failure due to tank leakage.

The method of starting by compressed air is to set the engine beyond the center and then to give an impulse through the starting valve. In some engines this valve is hand operated, in

others it is operated by the valve gear. Again in some, especially single-cylinder, engines the valve-actuating gear is not changed at all, except perhaps to relieve the compression somewhat, while in some multi-cylinder engines the gear on one cylinder is changed to make this cylinder act on the two-cycle principle, *i.e.*, so that it can take an air impulse every turn, until the other cylinders have started regular operation. In any case it is best to retard the spark somewhat for starting.

The starting pressures employed vary from 100 to 150 pounds,

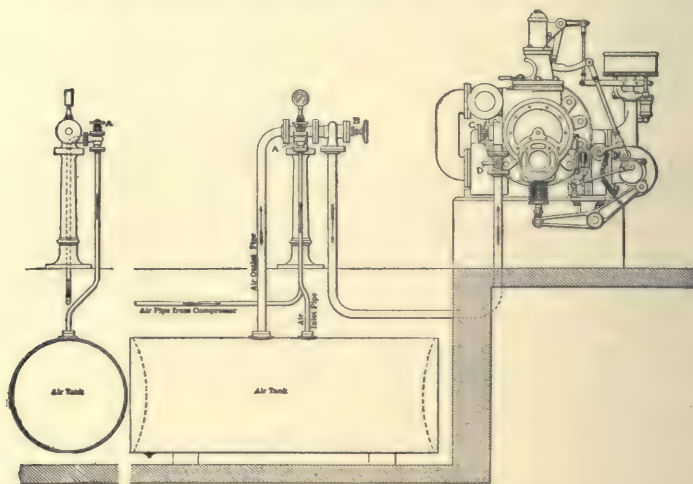


FIG. 13-38. — Air-starting Apparatus.

depending upon how the air is compressed. In general one or, at the most, two impulses are sufficient to start a machine.

The following description of Fig. 13-38, given by F. E. Junge in *Power*, April, 1906, shows the method of starting a large engine by compressed air:

"In this diagram *A* is the valve controlling the flow of air from a separately driven air compressor to the tank and *B* a similar valve in the pipe connecting the tank to the engine. Both valves are mounted on one pillar, which also has screwed on top of it a gage indicating continuously the pressure in the tank. Regulation of the supply of compressed air to the engine cylinder is effected by means of an automatic spring-loaded inlet poppet

valve, the stem and disc of which may be released or held fast by screwing down or unscrewing the hand wheel *C* at the engine end of the air pipe. A plug valve *D* is inserted in the air pipe immediately ahead of the inlet valve. Before starting the engine, the fly-wheel is turned into such a position that the crank is about 30 degrees above the inner dead center. The starting gear is adjusted so as to open both the inlet and the exhaust valves at the proper moments, the action being such as to allow part of the compressed air to escape during a fraction of the return travel of the piston and thereby reduce the compression to about 28 pounds per square inch for rich gases, and about 50 pounds per square inch for poor gases. In the meantime, the electric ignition device has been automatically adjusted so as to retard ignition for the first few strokes. The main fuel or gas valves must, of course, also be set so as to produce the most favorable mixture for starting conditions.

"To start the engine, the air stop valve *B* is opened, the automatic inlet valve released by screwing down the hand wheel *C* to the full extent, and compressed air is then admitted by turning the handle *D* 90 degrees. The piston will then begin to travel slowly on its outward stroke, and just before it reaches the outer dead center the handle *D* must be returned to its original position, shutting off the air supply. The first impulse given to the fly-wheel by compressed air will usually be sufficient to produce several revolutions at a speed of about one-fifth of the normal, when no load is on. During the following (suction) stroke a mixture of gas and air in the correct proportions is taken in, and on the next stroke compressed and ignited. If the right mixture does not happen to be obtained and ignition fails to occur, another compressed air impulse is given, which will always produce the desired result. After the first power stroke has been obtained the air supply valve *B* is closed and the automatic inlet valve held fast by unscrewing the hand wheel *C* until its hub bears against a collar on the valve stem, whereby the valve disc is firmly pressed on its seat. Then the starting gear is pushed back into the running position, so as to allow the mechanism to open the valves at the regular intervals only. The point of ignition is thereby automatically advanced and may now be adjusted by hand or by the governor of the engine so as to suit the changed conditions.

When the main gas admission valve is set in the correct running position, all operations for starting have been duly executed. It may be added that it takes less time to perform the complete cycle of operations than it takes to describe it."

(e) In central stations, or in other locations where electric current is available, starting by electricity is the simplest and most

satisfactory method. There are again several ways in which this may be done.

If the engine drives a dynamo, it is possible to drive this dynamo as a motor from another source of current, until the fly-wheel has attained sufficient velocity. The layout for doing this is not at all simple, however, and must be carefully handled. A storage battery charged during the previous operation may be used as a source of current if no independent source of current is available.

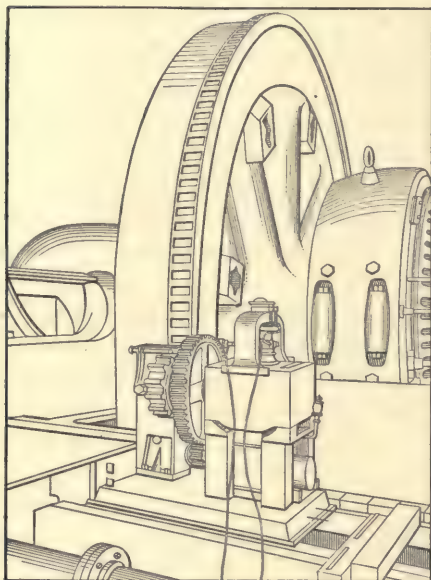


FIG. 13-39. — Motor Starter.

on the fly-wheel as shown in Fig. 13-39.* When the engine picks up the motor is automatically thrown out of gear. This scheme has the merit of great simplicity, absolutely no change in the valve operation of the engine being required for starting.

One method of automatically disengaging the motor is described in the *Zeitschrift d. V. d. I.*, January 5, 1900. A general view of the *Felten* and *Guilleaume* electric starter for large engines is shown in Fig. 13-40, while Fig. 13-41 shows the diagram of connections and the method of operation for smaller sizes. The motor *e* by means of a chain drive operates the pulley *s*₂. Rigidly fastened to this pulley is the gear *z*₂. This gear in turn

* F. E. Junge, *Power*, April, 1906.

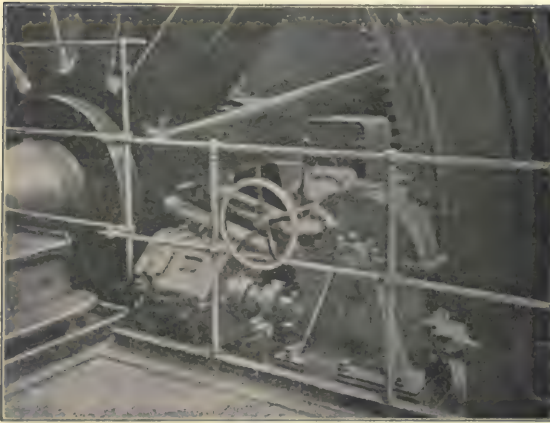


FIG. 13-40. — Felten & Guillaume Electric Starter.

drives a gear z_3 which is pivoted on a swinging lever h_1 as shown. The arc z represents the pitch circle of the annular gear inside of

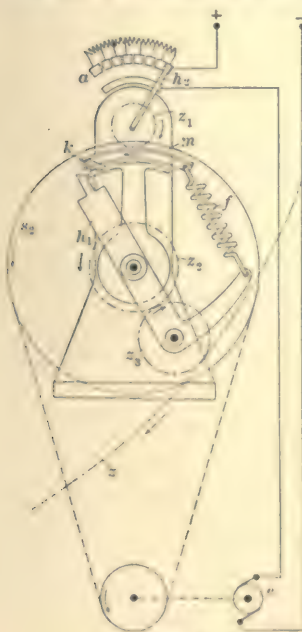


FIG. 13-41.

the fly-wheel. Arrows indicate the direction of operation for each gear. One end of the lever h_1 is connected by means of a strong helical spring f to the toothed segment m . Meshed with this segment is the gear z_1 which is turned in one direction or the other by the lever h_2 , which is the operating handle of the motor starting box a . In the diagram, lever h_2 has been pulled to the right as far as it will go. This action has started the motor e , and, by shoving the segment m to the left, has put the spring under considerable tension. This pulls the lower end of h_1 to the right and causes z_3 to mesh with the fly-wheel z . The gear z_3 , being positively driven from z_1 , starts the fly-wheel revolving. The entire mechanism is held in the position

shown by a latch k at the end of the segment m . If now the engine picks up its cycle, and the wheel z attains a greater velocity than it can receive from z_3 , the lever h_1 by the action of the fly-wheel will be pushed toward the left, putting the spring f under higher tension. This motion proceeds until the upper end of h_1 comes in contact with and unlatches k , when, under the influence of the spring, the segment m is pulled to the right very suddenly and the motor is shut off. At the same time the action of the fly-wheel upon z_3 throws this out of mesh with z . The entire labor connected with this starter therefore consists of the attendants turning the handle h_2 of the starting box to the right to start the motor. Beyond this no further attention is required, the action being entirely automatic.

CHAPTER XIV

REGULATION OF GAS ENGINES

IN gas as in steam engines there are two kinds of speed variation. The first of these is directly due to the impulse of the explosion, and it manifests itself in a variation of the velocity of the crank pin during one engine cycle. To confine this speed variation to within the allowable limits set by the particular service to which the engine is to be put is the function of the fly-wheel. Fly-wheel computations are beyond the scope of this work, but it will be of interest to point out briefly the relation between the various types and combinations of engines as regards the fly-wheel weight required for any given service. This weight depends not only upon the closeness of regulation desired, but largely also upon the variation of the crank effort during one cycle or revolution, and this in turn depends upon the cycle employed and the cylinder combination.

The most complete exposition of this subject relating to gas engines is given by Güldner,* and from the data given by him the following table (see page 440) is adapted.

In deriving these figures it is assumed that the same coefficient of fly-wheel regulation, designated by δ_w , is maintained in all cases. This coefficient

$$\delta_w = \frac{V_{\max} - V_{\min}}{V},$$

where V is the mean velocity of the crank pin.

The second kind of speed variation above mentioned is the change in the number of revolutions of an engine in any given time due to a change of load. This variation is taken care of by the governor. Just as a limit is set to the speed variation during one cycle, so an allowable limit is set to the vari-

* Entwerfen und Berechnen der Verbrennungs-motoren, 2d ed.

TABLE OF RELATIVE FLY-WHEEL WEIGHTS FOR THE SAME COEFFICIENT OF REGULATION; FOR VARIOUS TYPES OF ENGINES AND CYLINDER COMBINATIONS. WEIGHT OF THE FLY-WHEEL OF A SINGLE-ACTING, SINGLE-CYLINDER, 4-CYCLE ENGINE IS TAKEN = 1.00.

Type of Engine and Cylinder Combination	Crank Travel Between Explosions, Degrees		Relative Fly-Wheel Weight for			
			Equal Cyl. Diameter, Stroke, and Revolution		Equal Maximum Horse-power	
	4-Cycle	2-Cycle	4-Cycle	2-Cycle	4-Cycle	2-Cycle
I. Single-Acting, Single Cylinder.	720	360	1.000	.802	1.000	.401
II. Double-Acting, Single Cylinder.	540 & 180	180	1.230	.424	.615	.106
III. 2-Cylinder Tandem Single-Acting, 1 Crank.	360	360	.796	1.595	.398	.399
IV. 2-Cylinder opposed, Single-Acting, 1 Crank.	540 & 180	180	1.290	.335	.645	.084
V. 2 Cylinders in Parallel, Single-Acting 2 Cranks together	360	360	.792	1.602	.396	.401
VI. 2 Cylinders in Parallel, Single-Acting, 2 Cranks, 180° apart.	540 & 180	180	1.290	.335	.645	.084
VII. 3 Cylinders in Parallel, Single-Acting, 3 Cranks, 120° apart.	240	120	.678	.237	.226	.0395
VIII. 4 Cylinders in Parallel, Single-Acting, 4 Cranks, Nos. 1 & 3 together, Nos. 2 & 4 together, and 180° from Nos. 1 & 3.	180	—	.335	—	.084	—

ation that may occur in the number of revolutions from full load to no load, and the governor must be designed and set accordingly. The allowable variation, the so-called coefficient of governor regulation, may be expressed by $\delta_r = \frac{n_{\max} - n_{\min}}{n}$, where n is the mean number of revolutions $\left(= \frac{n_{\max} + n_{\min}}{2} \right)$. What

the values of δ_w or δ_r may be depends altogether upon the kind of service, and the value of δ_r at least is, or should be, clearly stated in all engine specifications. The value of δ_w , that is, the variation in the angular velocity of the engine, can be made anything, depending upon the weight of the wheel put in. It usually varies from $\delta_w = \frac{1}{40}$, for ordinary commerical service, to $\delta_w = \frac{1}{25}$, say, for the most exacting service required for the operation of alternating-current generators in parallel. The value of the co-efficient of governor regulation δ_r usually varies between $\frac{1}{50}$ and $\frac{1}{25}$, i.e., the speed variation is from 2 to 4 per cent.

The theory of centrifugal governor design as applied to gas engines governing by throttling or cut-off cannot be taken up here, except merely to state that it is best, especially in the case of the power gases, to have the governor act upon the mechanism that positively operates the admission gear rather than upon the admission gear direct. In this way the governor does not in general have to be so powerful and above all it is unaffected by any clogging of the admission gear or valves due to tar and other incrustations. It should further be noted that any governor of this type that is too sensitive may react with the speed variation within one revolution and will thus be hunting constantly. Dash pots only forcibly overcome these conditions, and it is better to design these governors with plenty of adjustment regarding their sensitiveness.

The design of hit-and-miss governors (see below) is in general very simple. In contradistinction to the type of governors above mentioned, they can hardly be made too sensitive or astatic for the quicker they act, the better.

In the following we take up, first, Systems of Governing, and, second, Mechanical Details of Governors.

1. Systems of Governing. — At the outset an essential difference between steam and gas engines in the matter of governing should be noted. The working fluid in the steam engine is a comparatively stable medium, and, as long as the pressure remains constant, one position of the governor mechanism always corresponds to the same load, cycle after cycle recurring with the same development of power. This is absolutely essential for close governing, and in this respect the steam engine has some advantage over the gas engine. The conditions in

the latter are very different. The working fluid is prepared by the engine itself, air and fuel being mixed at the engine to produce the medium. Various expedients to this end, more or less successful, are in use, but outside of this, due to accidents of design or other reasons, stratification of the charge more or less complete, and variation in ignition, may result in unequal velocity of pressure propagation through the mass of the charge giving a bundle of different diagrams for the same heat value of the charge. Thus it may result that the same position of the governing mechanism may not, and often does not, indicate the same power developed, and speed fluctuations are the inevitable result. Fortunately the mixing and ignition apparatus of our modern engines can be made perfect enough in their action to confine these fluctuations to within allowable limits.

All gas engine governors come under the following systems as far as their effect upon the diagram is concerned. Mechanically they may be of various designs, as inertia, fly-ball, etc., as shown later:

- I. The Hit-and-Miss System.
- II. Variation of the Ratio of Fuel to Air with Change in Load; Quality Governing.
- III. Variation of the Quantity of the Charge to suit the Load. Ratio Fuel to Air remaining constant; Quantity Governing.
- IV. Combination Systems.
- V. Governing by Varying Time of Ignition.

I. The Hit-and-Miss System

This system effects speed regulation by cutting out explosions altogether, depending on the load. Thus, for instance, if the engine is running at full load, the explosions or cycles will follow each other in regular order until the speed has increased enough above the mean to cause the governor to act, preventing the drawing in of the next charge, thus causing a "miss." This in turn causes the speed to fall sufficiently below the mean to make the governor act the opposite way, causing the explosions to recur. At any other load less than the full load the governor action is the same, except that as we go down in the scale the proportion of "misses" to "hits" constantly increases. This system may be operated in any of the following ways:

(a) By keeping the fuel valve closed, so that the engine draws only air for the miss cycle.

(b) By keeping the inlet valve closed, thus preventing the admission of both fuel and air.

(c) By keeping the exhaust valve open. In this case the admission valve is usually automatic, and its opening is prevented by the fact that on the next stroke no vacuum is formed, the exhaust gases being sucked back into the cylinder.

Theoretically this system of regulation is the simplest, and, from the standpoint of fuel consumption, the most economical; practically, however, it is beset with certain difficulties. In theory the cycles are all gone through under exactly the same conditions, and hence ratio of fuel to air, pressure of compression and point of ignition can all be adjusted once for all to suit the requirements of best thermal efficiency. The thermal efficiency of the cylinder should therefore be the same at all loads.

In practice there is some deviation from this ideal condition, even assuming *perfect governor action*, but the variation depends somewhat upon the manner of governing. Thus in engines in which only the fuel valve is kept closed to produce the miss cycles, it will generally be found that the card directly following a miss period is larger than those following it, at least for loads approaching full load. This is due to the fact that during the miss period the cylinder has been thoroughly scavenged by air, causing the next charge to be purer and somewhat larger in quantity than the average. Under very low loads the effect is apt to be the opposite, that is, owing to a prolonged period of miss strokes the cylinder has cooled so far as to make the first cycles following somewhat slow burning until the cylinder heats up again.

It is evident that these variations must have their effect upon cylinder efficiency, but the effect is perhaps greater with liquid fuel engines than with gas engines proper, because a cool cylinder is likely to condense some of the fuel vapor, thus causing a direct loss.

In engines that govern by keeping the exhaust valve open, drawing the exhaust gases back into the cylinder, the effects above outlined may be less marked, but the method cannot on that account be recommended as better than the other, because the inevitable mixing of the exhaust gases with the incoming charge has its own harmful effects.

In spite of these facts, however, the hit-and-miss system of governing, no matter how carried out, usually shows a somewhat greater economy of fuel in practice than the other systems.

We next turn to the efficiency of this system as a speed regulator. It is evident that the closeness of regulation in case centrifugal governors are employed depends altogether upon the sensitiveness of the governor, that is, upon the facility with which it changes from one position to the other; although it is possible here also to have a governor too sensitive, resulting in needless hunting. But whatever the type of hit-and-miss governor, the regulation will be closest if at the higher loads a constant series of explosions is followed by a single miss cycle, or if at the lower loads a single explosion is followed by a constant series of misses. Thus $\frac{3}{4}$ load should be represented by the series 111-111, etc., and $\frac{1}{2}$ load by 1----1----, etc. Any disturbance of the governor, accidental or otherwise, as through want of care, increased friction, wear, etc., will alter this ideal condition so that a $\frac{3}{4}$ load, for instance, may be represented by the series 111-11-111-11, etc. But such variation at once unfavorably affects the regulation.* These accidental conditions are not under the control of the designer, and not always under the control of the operator, and the net result is that hit-and-miss regulation, though economical, is somewhat unreliable and certainly not as close as that obtained by some of the other methods, unless a very heavy fly-wheel is employed.

Hit-and-miss governing is therefore little employed where close regulation is essential, as for electric current generation. For ordinary commercial power operation, where the regulation need not be closer than say 3 to 5 per cent., the system is quite satisfactory, although it is being slowly replaced even in this field. It should be remembered in this connection that, if the engine is belt-connected to the power consumer, the flexible connection will tend to equalize the speed variations to a certain extent.

II. *Governing by Varying the Ratio of Fuel to Air: Quality Governing*

In this system the governor is usually made to act upon the fuel admission valve, so that as the load on the engine decreases

* See Mollier, *Zeitschrift d. V. d. Ingenieure*, 1903, p. 1704.

the engine receives less and less fuel in the same total charge volume. This of course decreases the area of the indicator card developed to suit the load. Instead of acting upon the fuel valve, this method of governing has also been carried out by sucking back a certain amount of the exhaust gases, thus also decreasing the heat content of the charge. Another way is to regulate the air admission valve, making the fuel valve automatic. All things considered, however, the first mentioned method is the best.

Considered from a thermal standpoint this system has the advantage that, since the total charge volume remains practically the same for all loads, the compression pressure remains constant throughout. The cards obtained will therefore be somewhat as

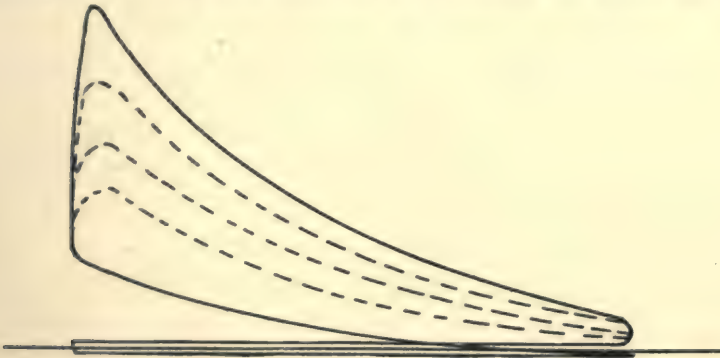


FIG. 14-1.

shown in Fig. 14-1, in which the full line represents the full load diagram. It therefore should follow on theoretical grounds that the thermal efficiency of the cylinder should be about the same for all loads. In practice, however, it has been clearly shown that this system is inferior at low loads to the next one to be described. In fact, the fuel consumption per horse-power usually increases very rapidly as the load drops. The reason is that, as the fuel-ratio is decreased, the mixture rapidly becomes difficult to ignite and, above all, slow burning. This necessarily increases the heat loss to the jackets and the ignition difficulty may go as far as to prevent ignition altogether, causing a direct loss of fuel. In most cases after-burning is clearly recognizable by the slow dropping of the expansion line. Designers have tried to over-

come this difficulty by placing the time of ignition also under control, making it earlier as the load decreases. The scheme, however, does not appear to have been very successful.

As a method of governing, this system is capable of giving close regulation with the proper weight of fly-wheel. The very fact, however, that the compression pressure does not drop in proportion to the maximum pressure introduces a disturbing factor into the crank effort diagram which would tend to make the regulation under this system less close at low loads than under System III.

III. *Governing by Varying the Quantity of Charge of Constant Composition to suit the Load: Quantity Governing*

Governing by changing the quantity of charge to suit the load may be carried out in three ways:

(a) The engine draws a charge full stroke each time, but a part of the charge, depending upon the load, is forced back into the suction passages, the inlet valve being under governor control.

(b) The incoming charge is completely cut off by the governor at the proper time, the charge expanding behind the piston for the rest of the stroke. This is known as the cut-off method.

(c) The charge is throttled down throughout the entire suction stroke, the governor determining the position of the inlet valves. This is called the throttling method.



FIG. 14-2.

Figs. 14-2 and 14-3 show the differences in the diagrams obtained under conditions (b) and (c) outlined above.

Quantity governing in general is, on thermal grounds, open to the objection that the compression pressure decreases with the load, and hence the cylinder efficiency constantly decreases. On the other hand, the mixtures remain readily ignitable down to the friction load, with the result that quantity governing is on the whole more economical than quality governing. The fact, too, that the compression pressure decreases with the maximum pressure has a favorable influence upon the crank-effort diagram, admitting of close regulation.

As between methods (b) and (c), the former is slightly better because less work is lost in the lower loop. Everything considered, where close regulation is essential, the cut-off method of quantity governing is the best.

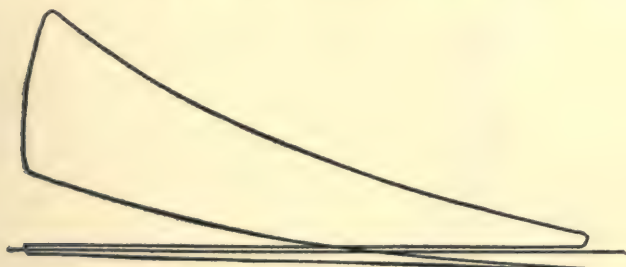


FIG. 14-3.

Regarding the economy of the cut-off method as compared with the hit-and-miss method of governing, E. Meyer* finds that down to about $\frac{1}{2}$ load the two systems are about on a par. Below this load the efficiency of the cut-off as compared with the hit-and-miss method rapidly falls off.

IV. Combination Systems

It has been attempted to perfect quantity regulation by changing the compression space so as to keep the compression pressure the same at all loads. Thermally this is a step in the right direction, but no successful machine operating upon this system has yet appeared.

Another combination system is that of Letombe, which is in successful use. Letombe regulates by lengthening the time of

* Zeitschrift d. V. d. Ingenieure, April 25, 1903.

opening of the inlet valve but decreasing the lift of the gas valve as the load decreases. As far as the fuel is concerned, this is quantity regulation, but the longer time of opening of the inlet valve increases the total charge volume, which means that the leaner mixtures will be more highly compressed than those for higher loads. This is thermally correct. Another point is that the richer mixtures at the higher loads, although less highly compressed, are less in total volume than the leaner mixtures. Hence as the load increases the ratio of expansion increases as compared



FIG 14-4.

to the ratio of compression, which tends to draw down the terminal pressure at the end of expansion and decreases the exhaust loss. The resulting diagrams are shown in Fig. 14-4, given by Güldner. The compression line $a-b$ belongs to the full load card, line $c-d$ to the minimum load card. The latter card shows suction full stroke and a compression pressure of about 190 pounds, the former shows a suction volume equivalent to about 55 per cent stroke and a compression pressure of about 115 pounds. In spite of the thermally excellent features, which gives good

regulation, the economy regarding fuel is no greater than that obtained by a purely cut-off system.

Other combination systems that have been employed are quantity regulation at high loads combined with quality regulation at low loads or vice versa. This is done in some German engines. To compensate for the slow burning of the leaner mixtures the spark is advanced. Lastly, engines that govern either by quantity or quality regulation at the higher loads have been governed by the hit-and-miss method at very low loads. This is done in the American-Crossley engines and also by Letombe in the system above described.

V. Governing by Varying the Time of Ignition

Strictly speaking, the time of ignition should be adjusted to suit the kind of charge. That means, for instance, that in quality regulation the spark should be advanced with a decrease of load.* It has already been mentioned that this has been tried both by governor control or by hand regulation. The former is rather difficult because proper ignition is subject to so many accidental variations, but hand control is quite practicable and all stationary engines should therefore be furnished with adjustable spark gear.

Automobile engines are generally governed by hand regulation of the throttle in combination with the spark.

Governing of Two-Cycle Engines

Small two-cycle engines are usually governed by throttling either the fuel or the charge. In the first case this results in what is practically quality regulation, in the second in quantity regulation. Liquid fuel engines of this type nearly always govern by adjusting the stroke of the pump to suit the load, resulting in quality regulation. In the larger machines, which are nearly always served by separate pumps, it is absolutely essential that the cylinder be thoroughly scavenged. Hence it is usual to first admit air alone directly from the pump or an intermediate receiver, and a little later the fuel or the mixture as the case may be, the point of admission of the latter being under governor control. The governor may act either on the inlet valve or directly on the pump. It should be noted that if reservoirs

are used between pump and engine, there is likely to be a lag of several strokes between the action of the governor and its effect on the engine. For more detailed information on the governing of large two-cycle engines, see the descriptions at the end of this chapter.

2. Mechanical Details of Governors. — For hit-and-miss governing, inertia governors of the so-called pendulum type are extensively used. Besides this, centrifugal governors of the fly-ball type also find application. For the "precision" systems of regulation, *i.e.*, quantity and quality regulation, centrifugal governors of the fly-ball type are mostly used; shaft governors either of the centrifugal or inertia type are, however, lately finding application.

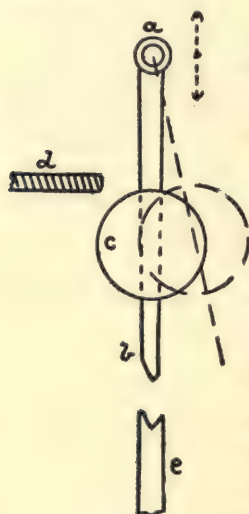


FIG. 14-5.

(a) **PENDULUM OR INERTIA GOVERNORS FOR HIT-AND-MISS REGULATION.** — The simplest form of this governor is shown in Fig. 14-5. The rod *a-b* carries the ball weight *c*, and receives an up-and-down motion usually from the lay shaft as shown by the arrows. As the rod moves down, the weight strikes the projection *d*, and the pendulum is thrown to the right as shown by the dotted position. If the speed is right, the pendulum will have gone back to its normal position by the time the point *b* reaches the end of the valve stem *e*, and the gas or inlet valve will be opened. If the speed is above the normal, *a-b* will not be back in its normal position, and *b* will miss the valve stem *e*, causing a miss-stroke.

A modification of this, the bell-crank pendulum, is shown in Fig. 14-6. The action of this governor is clear from the previous description.

The disadvantage of these two forms may be said to be that they are thrown a considerable distance out of their normal position. This is overcome in what may be called spring-loaded pendulum governors, the fundamental type of which is shown in Fig. 14-7. As the bell crank *a b c* moves downward, the inertia

of the weight, *c*, throws the governor into the dotted position. If by the time the stem of the valve, *e*, is reached, the spring has failed to pull the governor back into its normal position, the valve will not be opened, causing a miss-stroke.

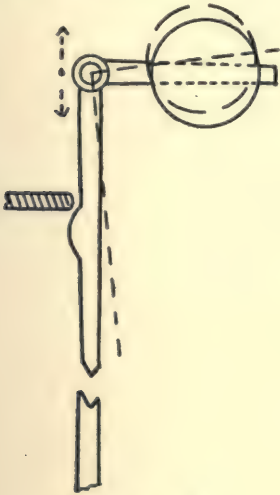


FIG. 14-6.

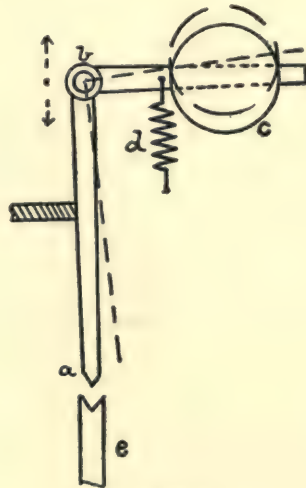


FIG. 14-7.

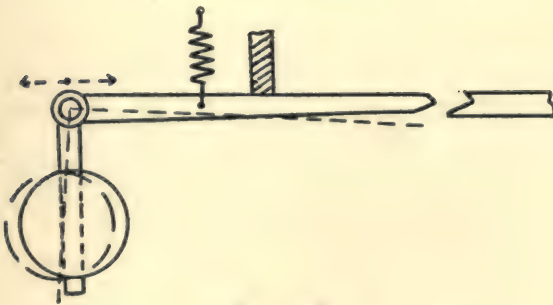


FIG. 14-8.

Fig. 14-8 shows the simplest kind of inertia governor for a horizontal valve stem. This may be used with or without the spring. Its action is sufficiently plain.

There are many modifications of these fundamental types.*

* See Güldner, *Entwerfen & Berechnen der Verbrennungsmotoren*, p. 354.

These will readily suggest themselves to suit any particular case. The following are some examples from actual practice.

Fig. 14-9 shows a modification of the vertical pick blade governor that has been used on Crossley engines.* The lever, *a*, is

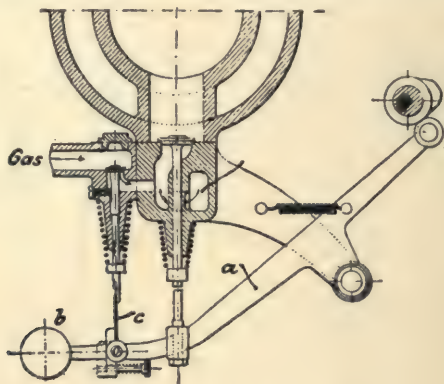


FIG. 14-9.

actuated by the cam, and as long as the speed is normal the spiral spring on one arm of the bell crank is strong enough to make the

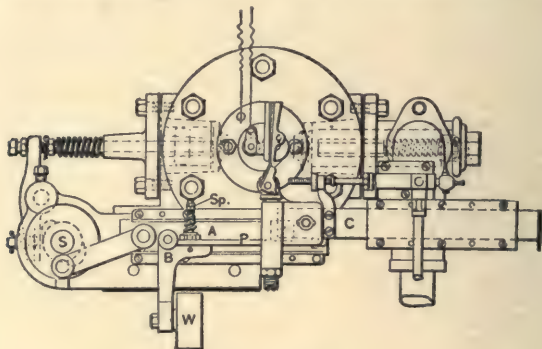


FIG. 14-10.

weight, *b*, attain its normal position in the time available. The blade, *c*, then opens the gas valve. If the speed rises above normal, the inertia of the weight, *b*, throws it down so far that it cannot reach its normal position in time and *c* misses the valve stem.

* Güldner, Entwerfen & Berechnen der Verbrennungsmotoren.

speed, however, rise above normal, the upward throw given to the blade due to the inclined surface, 6, sliding against the roller, 7, becomes excessive, and blade 4 fails to assume its normal position by the time the lever 8 is reached. The gas valve then fails to open.

An ingenious modification of the above types of hit-and-miss governors used by Delamare* is shown in Fig. 14-12. The stem

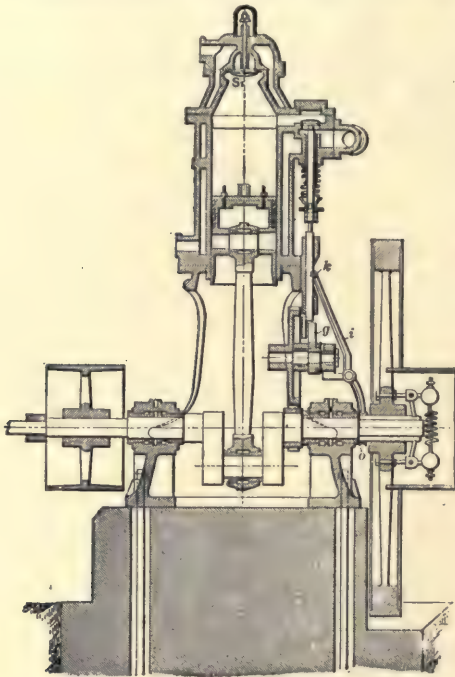


FIG. 14-13.

of the inlet slide valve carries a small cylinder, *a*, into which is fitted a stationary piston, *b*, air-tight. The needle valve, *c*, serves to adjust the velocity of air escape from behind the piston, *b*. With the cylinder, *a*, in the extreme right-hand position, air is admitted behind *b* through the groove, *d*. As *a* travels to the left at the proper speed, the air is compressed, but it escapes through the needle valve, *c*, just fast enough to prevent its pushing outward the plunger, *f*, in the branch cylinder, *e*, against the spring. In this position the blade, *g*,

hits the gas valve stem, *h*. For an excess in engine speed, cylinder *a* travels to the left so fast that the air cannot escape at the proper rate, the pressure generated forces the plunger, *f*, outward, and *g* misses the valve stem as shown in the dotted position.

(b) CENTRIFUGAL GOVERNORS FOR HIT-AND-MISS REGULATION. — A hit-and-miss governor of this type is used in the French engine shown in Fig. 14-13.† The centrifugal governor

* Schöttler, Die Gasmaschine.

† Power Quarterly, Oct. 15, 1900.