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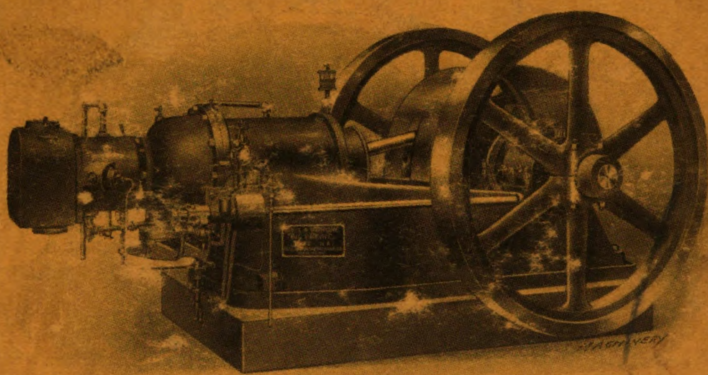
# CARE AND REPAIR
OF
# GAS AND OIL ENGINES



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# MACHINERY'S REFERENCE SERIES

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NUMBER 129

# CARE AND REPAIR OF GAS AND OIL ENGINES

CONTENTS

# PREFACE

This Reference Book has been prepared mainly from a series of notes compiled by J. L. Hobbs, who has had a long and varied experience with the care and repair of gas and oil engines. Much valuable information has also been abstracted from the publications of various manufacturers of gas and oil engines, especially from material obtained through the courtesy of the International Harvester Company of America, the De La Vergne Machine Company, and the Westinghouse Machine Company.

# INTRODUCTION

## INTERNAL COMBUSTION ENGINES

While there are a great many books dealing with the theory and design of gas engines, as well as their operation, there has been a great lack of information relating to the care and repair of gas engines. Those that have devoted themselves to the work of gas engine repair have largely obtained their knowledge of the subject by practical experience. The author of this treatise on gas engine repairs has been forced to obtain his knowledge in this way, which, after all, is the best, although it is often a slow, expensive and difficult one. In order to make it easier for others who are engaged in this work or who intend to enter into this field, the most important points relative to the care and repair of gas engines have been put down in the following chapters, thereby providing a means by which others may find it easier to become familiar with this subject.

There has always been an air of mystery surrounding the gas engine. Often everything seems to be in the best condition and yet the engine may refuse to start or may not develop its rated power. The fact is, however, that, as a rule, the troubles likely to arise are easily detected, providing one has the knowledge to look for the causes of the difficulties at such points where they may arise. Under the four heads of "Compression," "Carburetion," "Ignition" and "Lubrication," practically all of the ordinary difficulties that arise in gas engine operation are dealt with; special chapters on cooling systems and on installation have been added, the latter giving information to owners and others to whom the installation of a gas engine plant may be entrusted.

It may be said, in a general way, that any gas engine which has proper compression and receives the proper mixture of fuel and air from its carburetor, and, in addition, ignites this mixture at the proper time, and the moving parts of which, including the inside of the cylinder and the outside of the piston, are properly lubricated, will run and will develop the power it is intended to develop. When anything goes wrong with any of these conditions, the engine will give trouble, and it is the purpose of the following chapters to explain how these troubles may be avoided or remedied.

### Principles of the Internal Combustion Engine

The gas engine and oil engine are practically identical as far as the principles of their power producing qualities are concerned, both being internal combustion engines, that is, engines which derive their power from an expansion of gases caused by burning a mixture of gas, or a gasified liquid fuel, and air in their cylinders. Of the various fuels that can be used to produce the explosive mixture, gas, gasoline, kerosene and alcohol are the most commonly used.

It may be well at the outset to explain the difference between the so-called two-cycle and the four-cycle engine. In the four-cycle engine, which is most commonly used, there are four distinct movements or cycles necessary for one power impulse to the crankshaft. The first of these strokes is the intake stroke, which is made with the piston moving towards the crankshaft and with the intake valve open; the cylinder is now being filled with the explosive mixture. The second or the compression stroke is made when the piston is forced back against the mixture which has just been drawn in during the intake stroke. During the second stroke all the valves are closed and the proper compression of the mixture secured. Then, just as the piston starts back towards the crankshaft on its third stroke, all the valves still being closed, the charge is ignited, the explosion occurs and the power of the explosion is conducted to the crankshaft. As the piston now reaches the end of this stroke the exhaust valve is opened and remains open while the piston returns for the fourth stroke, thus expelling the exhaust gases in the cylinder. This completes the four cycles and requires two full revolutions of the crankshaft. The flywheel is depended upon to store enough energy to keep the engine moving at a fairly uniform rate of speed during the complete cycle. A camshaft is provided to operate the valves in such a manner that they will open and close at the proper moments during the forward and backward strokes of the piston.

In the two-cycle engine a power impulse is transmitted to the crankshaft for each revolution. There are two models of this type of engine. In the one an auxiliary cylinder is used to compress the gas and force it into the main cylinder at the proper time. In the other type an air-tight crankcase is used for this purpose. When an auxiliary cylinder is used, it is operated in the reverse order from the power cylinder, so that a charge is entered into the main cylinder just when the exhaust port in this cylinder is closed, and in this way the intake and exhaust strokes are eliminated, giving a power stroke for every revolution. The incoming charge is necessarily mixed to some extent with the exhaust gases not yet thoroughly driven out, and for this reason it is generally conceded that the two-stroke engine is neither as economical nor as reliable as the four-stroke or four-cycle engine. Its advantages, however, are light weight and a more uniform application of the power, and because of these features it is extensively used, especially for marine engines.

### Principal Parts of Gas and Oil Engines

The principal parts of an internal combustion engine are the cylinder, piston, connecting-rod, crankshaft, flywheel, valve gearing, inlet and exhaust valves, mixer or carbureter, igniter, and governor, with a base on which the various parts are mounted. The cylinder, with its head, is either provided with a water jacket through which the cooling water is circulated for keeping down the temperature of

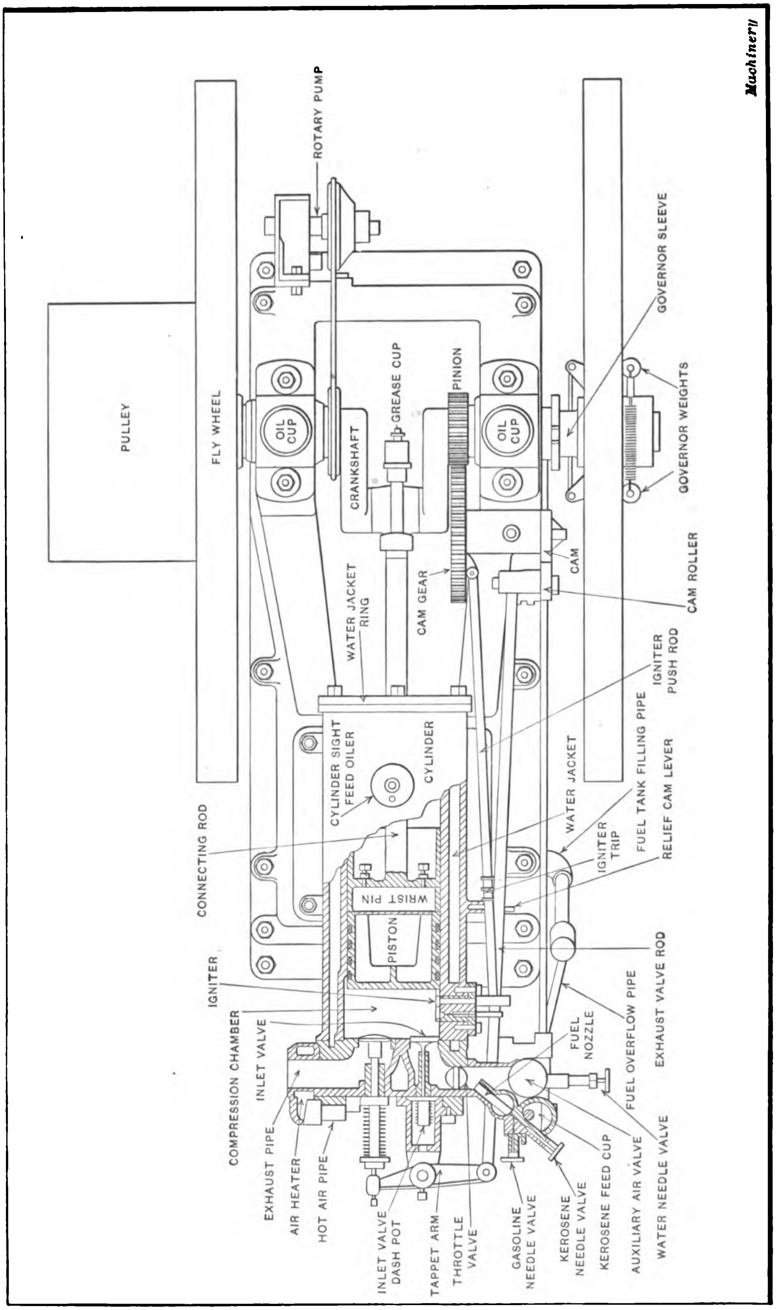


**Fig. 1. Section and Plan View of International Harvester Co. Horizontal Oil Engine**

the cylinder walls, or it may consist of a single shell with projecting ribs for radiating the heat to the air. The piston is provided with packing rings to prevent the combustion gases from leaking past it. The inlet and exhaust valves serve the purpose of admitting and discharging the combustible gases at the proper moments, the valve gearing governing and timing their action. The mixer or carbureter is used for vaporizing or gasifying liquid fuels and mixing them with the proper amount of air to obtain the explosive mixture of right proportions. The igniter is timed to ignite the compressed explosive charge at the given moment, and the governor is designed to make the speed of the engine uniform within certain predetermined limits. It may regulate the speed either by regulating the amount of mixture for each charge, as in the case of the throttling governor, or by preventing ignition and explosion of power charges in cases when the speed is above normal, as in the case of the "hit-and-miss" type of governor.

The governor of a gas engine must be in perfect working order. The type generally used is some form of fly-ball governor, the same as is almost universally employed on steam engines. This governor is operated by the action of the centrifugal force pulling against springs which tend to hold the fly-balls near each other. On the "hit-and-miss" type of engine, when the governor runs above a certain speed, it forcibly prevents the exhaust valve from closing, thus allowing the engine to run without an explosion or to miss an explosion or two until the speed decreases enough for the governor to release the exhaust valve, when the explosions begin again. In some engines, the governor also controls the sparking device and eliminates the spark, except when it is needed to ignite a charge. This saves the batteries materially. Some engines are provided with a device which locks the intake valve when the exhaust valve is held open by the governor. This is a valuable feature as it saves fuel.

When the throttling governor is used, a device is provided in the intake pipe to regulate the amount of gas passing to the cylinder, only enough being allowed to enter the cylinder to retain the speed. The instant the load is put onto the engine it will slow up slightly, and then the throttle will open just enough to maintain the speed. This governor is superior to the one of the "hit-and-miss" type as far as steadiness of power and speed is concerned, but it is claimed that the "hit-and-miss" governor is more economical, providing the intake valve is closed when the exhaust valve is held open by the governor, and for burning gasoline, the "hit-and-miss" type is probably the best. When using other fuels, the throttling governor seems to be preferable, because the less volatile fuels require the increase of heat made possible by the operation of this type of governor, where combustion takes place for every cycle.

The exhaust valve is operated mechanically by some form of eccentric or cam on the camshaft, the valve being opened at the end of the power stroke by means of this cam. A spring is used for closing the valve, but some positive means must be provided to open it.

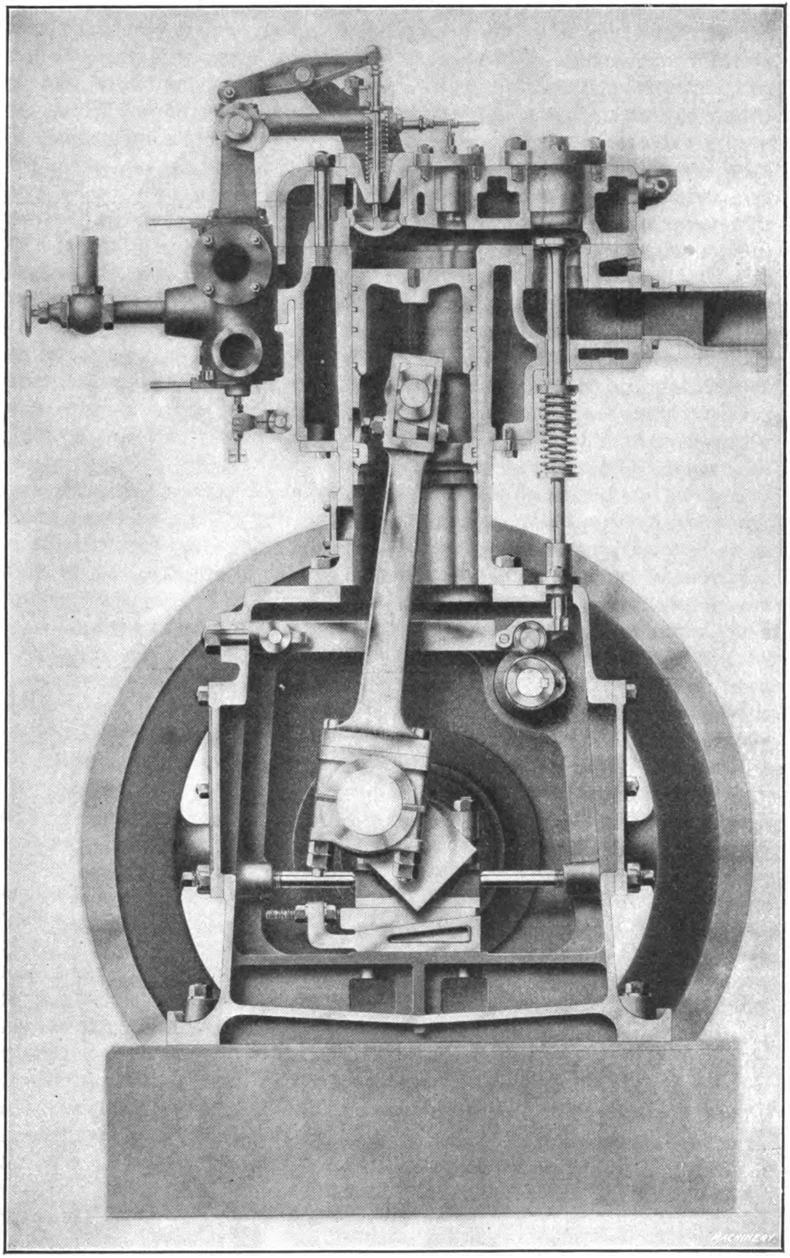

Fig. 2. Section through a Westinghouse Vertical Gas Engine

On some engines the intake valve is operated in a similar manner, except that it opens at the beginning of the suction stroke and closes at the beginning of the compression stroke. When this valve is not mechanically operated, it is allowed to open automatically and is closed by the spring which is provided for that purpose. When the intake valve is opened automatically, a spring just strong enough to keep the valve closed is used so that the suction of the piston on the suction stroke will open the valve to admit the charge. As long as this valve spring holds the proper tension, the arrangement will work to good satisfaction, but if the spring is too weak or too strong it will cause trouble. On new engines it is frequently found that the intake valve is stuck fast with paint. In that case, a little kerosene on the stem and a few movements of the valve by hand will loosen it.

On some engines a compression relief is provided to assist in starting the engine. This opens the exhaust valve slightly during the compression stroke and allows the spring to close it again, giving compression enough to start the engine, but not enough to interfere with the turning of the engine over the dead center.

In most engines all the principal bearings are made in halves and separated by thin shims which may be removed as the bearings wear, so as to always insure a snug fit for the parts to fit in them. All bearings should be kept as tight as is permissible and yet let the engine run freely. A knocking noise which is caused by a loose bearing should never be permitted, as it will soon destroy the bearing.

### Starting an Engine

It is always best to have some regular way in which to start an engine. The following method is recommended by The International Harvester Company:

1. See that the fuel supply is ample.

2. Oil the engine thoroughly with gas-engine oil, filling every oil cup and noting carefully its adjustment.

3. See that all nuts are tight and that all parts are secure.

4. Close the battery switch and see that the ignition system is in good order. It is best to remove the wire from the stationary electrode and try for a spark by brushing this wire against the circuit breaker on the engine, or test as follows: If batteries are used, test the battery current by closing the switch, disconnecting the end of one of the wires and brushing it against the binding post to which the other wire is attached. If a bright spark does not show every time the wire is snapped or slipped off the binding post, there is something wrong with the current or the conductors. It may be a disconnected switch, loose wires, or exhausted batteries. If there is a good spark on the end of the wires, and a weak one or none at all at the point of contact of the electrodes, there is something wrong in the sparking mechanism of the engine—the mechanism is either corroded, gummed up, short circuited, or out of adjustment.

5. Try the valves to see if they operate freely.

6. Turn on the cooling water, if a water-cooled engine.

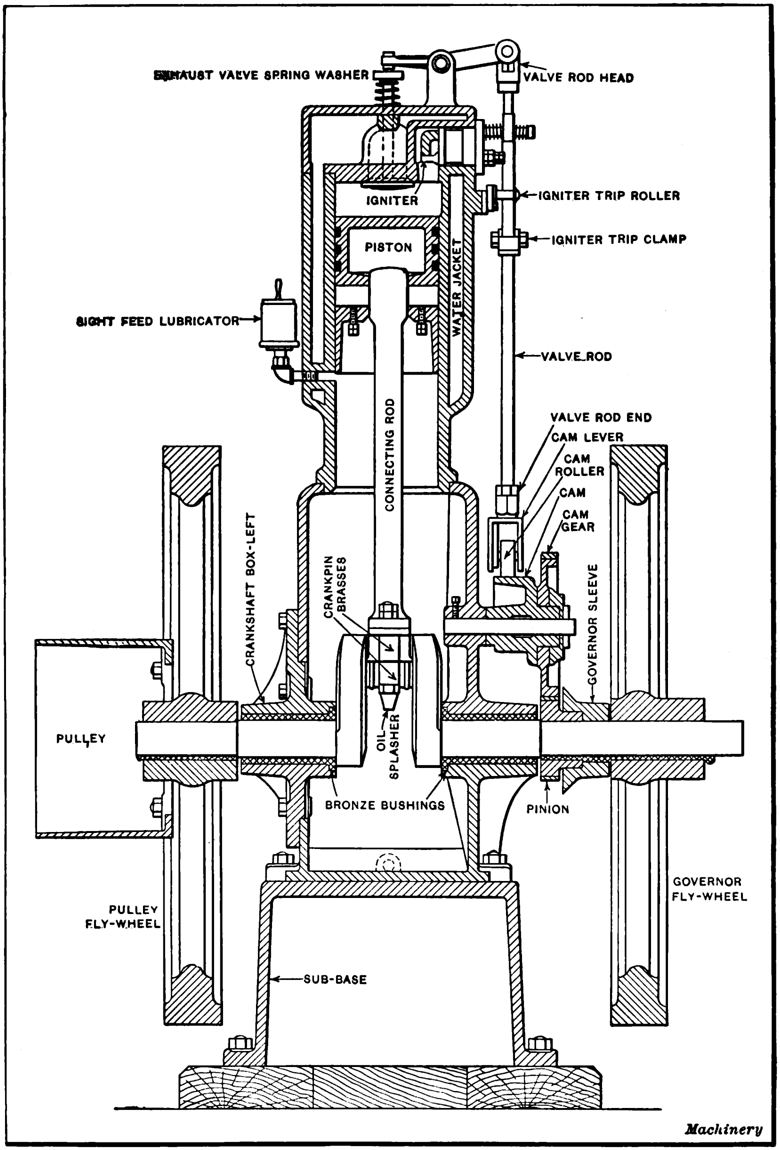


**Fig. 3. Section through an International Harvester Co. Vertical Engine**

When properly set, the engine should start with two or three turns of the flywheel. It is not necessary to turn the engine for a long time. If it does not start readily, it is time to begin to examine the parts systematically in an effort to find what is wrong.

### Troubles that Prevent Starting

The troubles which may prevent starting an engine may be due either to lost compression, faulty ignition, slow vaporization of the fuel in cold weather, not enough fuel, too much fuel, or water in the cylinder. These various difficulties will be referred to in the following chapters under the headings of "Compression," "Carburetion" and "Ignition."

### Stopping an Engine

After stopping the engine, close all oil cups and all needle valves, and drain the water from the cylinder jacket and from the cooling tank. If the engine is to be shut down for a short time only, and there is no danger from freezing, the cooling tank need not be emptied each time. See that the exhaust valves are left closed to prevent corroding of the valve seats and injury to the inside of the cylinders, and be sure that the battery switch is left open. If an oil engine, the kerosene and water should be shut off before stopping, and the engine run on gasoline for a minute to clean the water and oil from the cylinder and valves.

Every time the engine is stopped the operator should take a wrench or a set of wrenches and go over every nut on the engine to make sure it is tight. A few minutes spent this way each day will greatly increase the life of the engine. Any part that shows wear should be taken care of at once, for if it is allowed to wear on it will cause some other parts to begin to wear also, and the life of the engine, as a whole, will be shortened. There is no reason why an engine properly taken care of should not look as good as new after having been running for five years, and it probably does not require, under ordinary conditions, more than about ten minutes a day to give an engine enough attention to preserve it in good condition. At the same time as the nuts are tightened, all parts of the engine are wiped dry and cleaned, as in doing so the engine is also given an inspection that all parts are in good condition. The cost for repairs will be greatly minimized if this care is given to gas engines.

### Care of the Engine

It is advised that as far as possible one man only should be held responsible for the care of an engine. Two advantages are gained in this way: the operator will get a thorough knowledge of the engine, and failure of the engine to operate will not be due to errors on the part of others who are incompetent or not familiar with the working of the mechanism.

It is very important that the engine be kept clean. When an engine is run regularly every day, the piston and valves should be removed from the cylinder and these parts and the cylinder itself should be washed with kerosene or gasoline at frequent intervals. When the engine is used only intermittently, the number of times it is necessary to clean the engine will depend upon the conditions, but in order that it may work properly it should in no case be allowed to stand

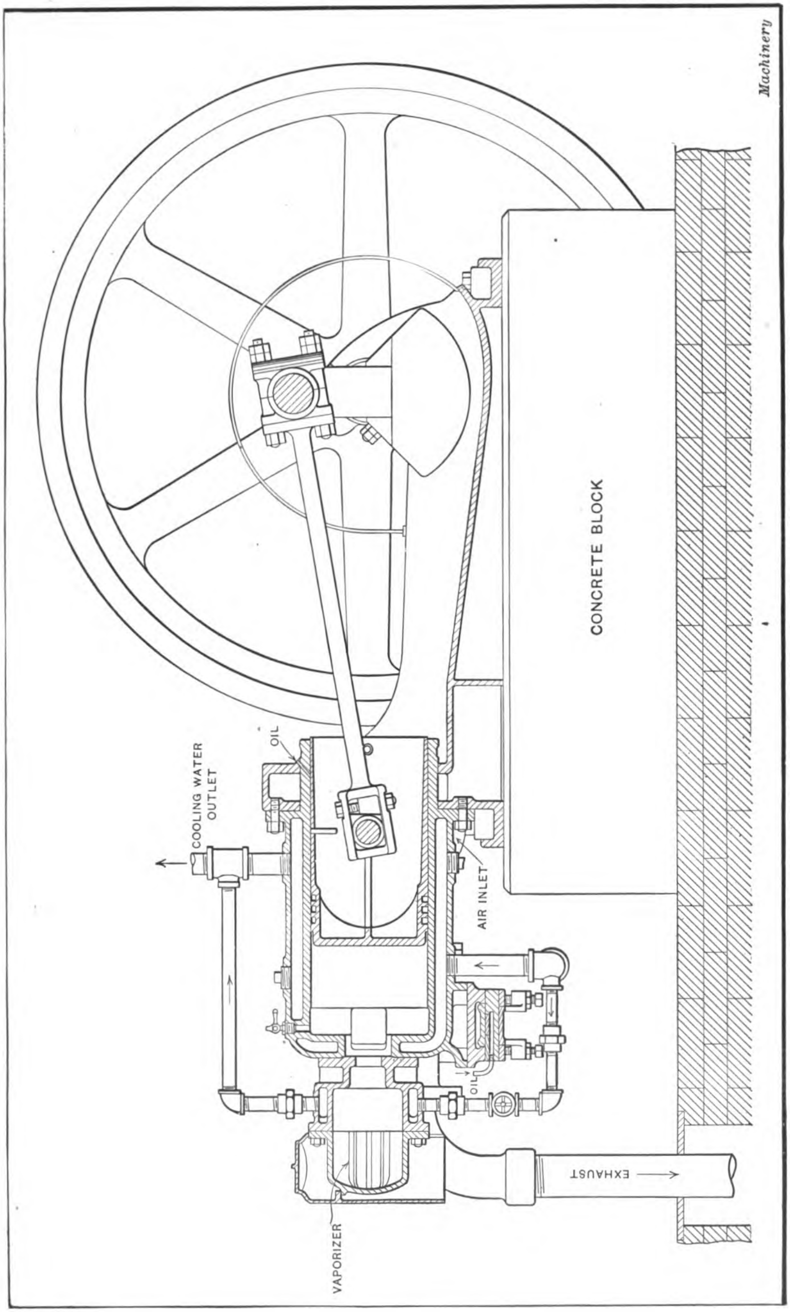


Fig. 4. Longitudinal Section of De La Vergne Machine Co. Oil Engine

more than six months without being dismantled and thoroughly cleaned. The igniter should be removed about once a week and the points of the electrodes cleaned with sand paper or with a fine file. The elements of a wet battery should be removed about every six months.

### Replacing a Worn Babbitt Bearing

A worn babbitt bearing can be replaced by anybody, even if he has had no previous experience with this work. To babbitt a one-piece bearing, cover the shaft with ordinary laundry soap and place it in the bearing in the position it will have when it is to run, and fasten it securely. Pour in the babbitt at the highest point of the bearing. The shaft and box must be heated previously, so that the hands cannot touch it and the babbitt must be hot enough to burn a stick of wood when inserted into it. Both ends of the bearing must be stopped off, except for a small hole into which the babbitt is poured. A piece of wood should be driven into the oil hole until it touches the shaft. After having poured the babbitt into the bearing, allow it to cool thoroughly before making any attempt to turn the shaft. The shaft may turn a trifle hard at first, and, in some cases, it may even be necessary to drive out the shaft and to ream the babbitt to get a good fit.

A two-piece bearing is handled in practically the same way, except that only one-half of it is babbitted at a time. The outer half of the bearing is first removed and laid to one side, the shaft is fastened in exactly the same position it will have when running, the bearing should be perfectly level while pouring, the end of the bearing is stopped off with any heat-resisting material, and enough babbitt is poured to run around the shaft and fill the box halfway around it. The babbitt is then dressed down smoothly after it cools, even with the top of the lower half of the bearing box. Cardboard is now fitted entirely over the lower half of the bearing, tightly up against the shaft. The top half of the bearing is now placed in position, fastened securely and the ends stopped off with heat-resisting material, and the babbitt poured into the oil hole until the bearing is full. The oil hole is drilled out after the top half is removed, and the bearing is complete and ready to run after cooling.

# CHAPTER I

## COMPRESSION

The power developed by an engine is largely determined by the compression in the cylinder. "If the engine is not developing its power," says Leslie in the *Engine Operator's Guide*, "look for loss of compression."

The compression space is usually about one-fourth of the entire cylinder space, the compression space being that part of the cylinder space between the piston and the cylinder-head when the piston is at its extreme inner end of the stroke, and the cylinder space the complete space behind the piston when the latter is at the extreme outer end of its stroke. In a four-cycle engine the cylinder space is entirely filled with a mixture of air and combustible gas on the intake stroke. Then on the compression stroke this amount of combustible mixture is compressed so that it occupies about one-fourth of the space formerly occupied. It is the degree of the compression that determines the power the engine will produce when the compressed charge is ignited.

### Importance of Good Compression

The object of compression in an internal combustion engine cylinder is to insure rapid ignition of the gases to be consumed, thus insuring the highest degree of heat and the greatest expansion of the gases, thereby giving more powerful impulse to the piston. The slower the process of burning in the cylinder is, the less vigorous is the expansion. Hence, if the compression is good, the particles of the combustible mixture are closely crowded and will burn quickly, and a higher degree of heat and a more powerful impulse to the crankshaft is insured.

The compression of a gas engine thus takes place in the air-tight chamber at the closed end of the cylinder, in which the mixture from the carbureter is compressed to from 60 to 75 pounds per square inch. There are a number of difficulties met with which prevent good compression. We will suppose that we have to do with an engine where the compression is found to be defective. The first thing to do in a case of this kind is to take hold of the flywheel and move the engine forward, listening for any hissing sound which might aid in finding where the leak is that prevents the proper compression from being obtained.

### Carbon Deposits on the Piston

If the leak is not located directly by this means, release the connecting-rod from the crankshaft. As a rule, the connecting-rod is attached to the crankshaft by means of two bolts. Then remove the piston from the cylinder by pulling the piston out towards the crank-shaft. After having pulled out the piston, examine its head carefully. It will be found that the end of the piston head is covered with a black coating of carbon; this coating will vary in thickness from a thin film to as much as one-half inch. If carbon has accumulated to a depth above one-eighth inch, it will, in a properly designed compression chamber, raise the number of pounds pressure of the compression to such a point that the vapor will be filed before the proper time, which interferes with the running of the engine. This firing ahead of time, or "pre-ignition," will be explained in Chapter III, under the head of "Ignition."

The carbon on the piston head must all be scraped off until a clean surface is obtained, and the carbon in the compression chamber of the cylinder must also be removed in order that the engine may be restored to its original condition. The square end of a flat file can generally be used for this work, although if the carbon deposit is baked on in the form of a hard crust, it is sometimes necessary to use a cold-chisel and hammer. When the latter method is used, care must be taken not to pound hard enough to break the parts from which the carbon deposit is removed. After the removal of all the carbon, the piston must be further inspected to find the cause of the leak.

### Cracks or Sand-holes in Piston

Examine the head of the piston for a crack or a sand-hole. A very small hole will cause a serious leak at this point. If a crack is found which cannot be sealed with some good iron cement or welded by the oxy-acetylene process, it will be necessary to replace the piston with a new one. If a sand-hole should be found, the trouble can be easily remedied by drilling out the hole with an ordinary drill and countersinking the hole a little on each side, and then putting a piece of iron into the hole, this piece being about one-eighth inch longer than the length of the hole. Then, with a light hammer, rivet one end of the piece of iron, the other end, meanwhile, resting upon some solid support; then turn around and rivet the other end, and the leak will be stopped up permanently.

### Influence of Poor Lubrication

Poor lubrication of the cylinder will cause a loss of compression. This difficulty is indicated by a peculiar blowing noise in the cylinder at each impulse, being due to the fact that the lack of lubrication permits part of the compressed gases to pass by the rings. The trouble is overcome by adjusting the lubricator means in such a way that a freer flow of oil is allowed. If the cylinder has been running dry for some time, the piston should be taken out and the rings, piston and inside of the cylinder walls cleaned and inspected.

### Removing the Piston Rings

For a thorough examination of the piston, remove the rings by using thin pieces of metal under them to prevent them from slipping back into the grooves. The rings can then be slid over these pieces in order to take them off the piston. After the rings are out of the way, attention must first be directed to the grooves in which the rings fit. First examine these for carbon deposits. If any foreign matter is found there, remove it, leaving the bottom and sides of the grooves smooth and bright. Then take one of the rings and, without putting it onto the piston, fit it into the groove to which it belongs and see that it fits closely, but at the same time works freely all the way around the piston; continue this test with all the rings, fitting them into their respective grooves. If a ring fits loosely, it must be replaced with a new one which fills the space.

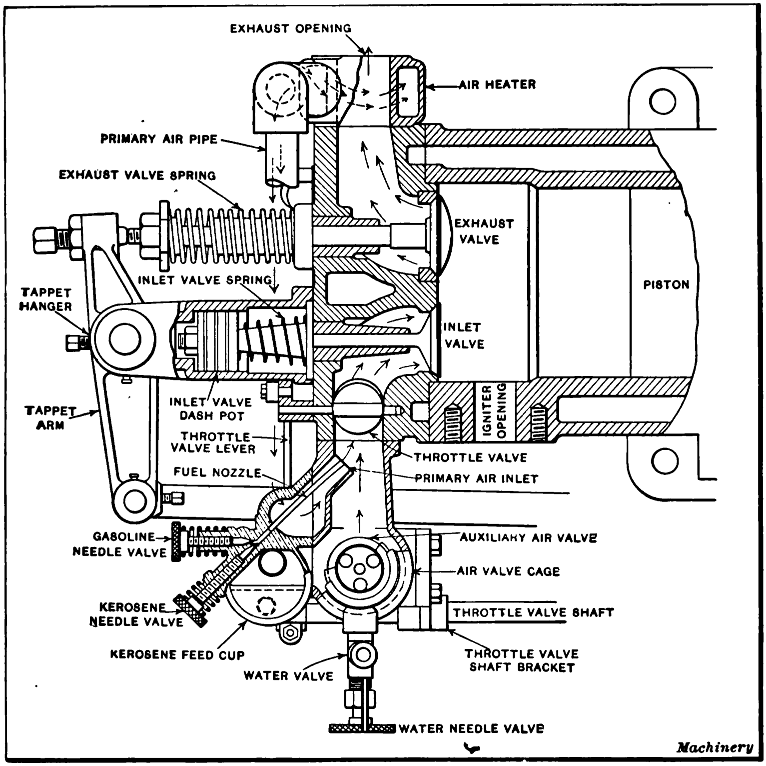


**Fig. 5. Sectional View of Oil Engine Cylinder-head**

Before replacing the rings, slip the piston back into the cylinder and move it from side to side and up and down, watching all the time for defects in the fit between the piston and cylinder. There should be just room enough for the piston to work freely and there should be the same space on all sides. With a horizontal engine, there is a strong tendency for the piston to wear on the top and bottom. If this wear is noticed, the same defect must be looked out for on the inside walls of the cylinder. This matter will be considered later.

While continuing the examination of the piston, remove the piston pin which passes through the piston and the end of the connecting-rod. If there is any wear in this pin, it will cause a knocking sound in the cylinder when the engine is running. In some engines means are provided for taking up this wear, but when no means are provided, it may be necessary to put a new bushing into the end of the connecting-rod. If this does not remedy the trouble, a new piston pin will also have to be provided. In all engines means are provided for fastening the piston pin rigidly to the piston.

The piston is now ready for replacing the rings, which may be done in the same manner in which they were removed. Care should be taken in replacing old rings, because when they have been exposed to the intense heat on the cylinder for some time, they become very brittle and will break easily. The same care should be exercised with new rings, as there is danger of springing them out of round, which will prevent them from fitting the piston properly. Do not replace the piston before a careful examination of the inside of the cylinder has been made while the piston is out of the way. The inside of the cylinder should be perfectly smooth, round, and bright with a coat of oil. The piston should also be covered with a fine coating of oil when removed.

### Defects on the Inside Walls of the Cylinder

We will assume that instead of finding the cylinder perfectly smooth and bright on the inside, we have discovered some brown streaks on the top or bottom of the bore. These brown streaks are caused by the fire from the explosion escaping past the space between the rings and the cylinder. This may have been caused by worn rings, and if we have already renewed the rings, this will probably remedy the trouble. However, it may not be caused by worn rings, but by irregularities in the diameter of the cylinder at various points. In order to make sure of this, take an ordinary caliper and fit it to any part of the inside of the cylinder. Then pass it back and forth from one end of the cylinder to the other, turning it a little each time until the entire surface of the inside of the cylinder has been tested. If this test does not reveal any irregularities, the cylinder is in good condition and the trouble must have been with the rings. If this test reveals irregularities in the inside dimensions of the cylinder, it must either be rebored and the new piston and rings fitted, or it must be replaced with a new cylinder.

Defects in the inside walls of a cylinder which was perfect when new, may be caused in two ways, either by overheating or by scratching or scoring. Overheating has the same effect in water-cooled engines as in air-cooled. It is caused by the failure of the cooling system. In the air-cooled system, it is generally caused by the fan belt being too loose or entirely off. In the water-cooled cylinder, it may be caused by a clog in the water-cooling system, which prevents the water from circulating, or it may be caused by the failure of the operator to supply the circulation system with water. The effect of this failure of the cooling system causes the metal in the cylinder to expand unduly because of overheating. As the inside of the cylinder is subjected to a considerably more severe heat than the outside, the metal on the inside must expand more than that on the outside, and this expanding metal must find a place somewhere. It generally buckles or warps back into the cooling jacket, leaving a space between the cylinder and piston. If it does not do this, it is forced in against the piston, causing a binding on the piston which generally is the reason for scratches or scores on the inside of the walls of the cylinder. In either case, there will be a loss of compression and the engine will give less favorable service than if the cylinder were perfectly round. If the cooling system is at fault, this trouble must, of course, be remedied as explained in Chapter V, on "Cooling Systems."

Having the internal parts removed, it is advisable to look into the compression end of the cylinder to see whether there are any cracks or sand-holes or any other defects which would allow the compressed gases to escape. If anything is found defective, it must be remedied before going further. The more nearly air-tight the compression chamber is the better service the engine will give.

We will now assume that we have remedied every known trouble which may affect the compression in what we might call the piston end of the cylinder. We may, therefore, replace the piston and connect the connecting-rod to the crankshaft, care being taken to leave no lost motion at either end of the connecting-rod in doing so. There are generally thin shims provided in the bearings at the crankshaft end, which may be removed when the bearing is too loose, to allow the bearing to be clamped a little tighter around the crankshaft. These bearings should be just as tight as possible (while yet running freely) so that no movement can be observed between the parts. A properly tightened bearing will run much longer without giving trouble than one having a little play.

### Valve Troubles

Attention is now directed to causes for lost compression at the other end of the cylinder. The valves are a frequent cause of loss of compression, especially the exhaust valve, because all the hot gases from the cylinder must escape through this valve. The intense heat has a tendency to warp the metal of the valve out of shape, as well as to make the valve surfaces rough or pitted. A slightly pitted valve may be put into shape again by removing the valve stem, and placing a small amount of valve grinding compound, or emery flour and oil, between the valve surfaces; after this is done the valve is placed again in its seat and turned back and forth until a perfectly smooth seat is obtained. When the valve is warped it must be replaced by a new one, which should be ground into its seat in the same way as a pitted valve.

Valves are placed in the cylinder by two methods. In one case the valve is seated directly on the inside of the cylinder head, in which case sometimes a small removable ring is fitted into the head and the seat made in this ring, or the valves have seats machined directly in the head. The object of removable seats is to save the expense of a new cylinder head when the valve seat becomes worn. The other method is to seat the valve into a valve cage and then fasten this cage to the cylinder from the outside. Both of these methods have their objections. In the first case, it is necessary to remove the cylinder head when grinding-in the valve seats. In the latter case, the cage can be removed for grinding-in purposes, but an extra joint, which must be kept air-tight, enters in the design. When the cage is set in the cylinder from the outside, an air-tight, fireproof gasket is generally used to prevent a leakage of compression. When this is not provided, the cage must be mounted on the cylinder by means of a ground joint, the same as the valves.

The intake valve is continually admitting cool charges of gas to the cylinder. This keeps the valve comparatively cool and as a result there is very little trouble with the intake valves, although it is good policy when grinding-in an exhaust valve to examine the intake valve also. The same method is used for the grinding-in of all valves.

### Other Defects and Troubles Likely to be Met With

Besides the defects in the gas engine, which are noticed by the eye and the sense of touch, many defects can be detected by the sense of smell and hearing. The sense of smell will tell when a bearing is running hot, and will also aid in determining when the combustible mixture is about right. An odor of gasoline in the exhaust is evidence that too much fuel is being fed into the carbureter or mixer. By the ear, a number of gas engine troubles may be determined, as any knocking sound is easily detected and located by the practiced ear. A hissing sound is an indication that some of the compressed gases are escaping. A squeaking sound indicates that a bearing needs lubrication. A coughing sound through the intake pipe indicates that the mixture is too weak. A smothered exhaust indicates that the mixture is too rich. An expert becomes trained to these different sounds so as to be able to detect quickly the seat of many gas engine troubles.

If there are any openings into the cylinder from the outside, such as pet cocks, drain cocks, priming cocks, peep holes, or any other openings, it is necessary to make sure that they are air-tight, as a very small leak will seriously interfere with the power obtained from the gas engine.

The place where the igniter is attached to the cylinder is a frequent cause of compression troubles and the igniter itself may sometimes leak. Provision is generally made for a fireproof, air-tight gasket between the igniter and the cylinder, and it is well to examine this joint. The igniter is provided with a movable electrode necessary to produce the spark at the right time. This electrode should be kept well oiled so as to prevent wear, and thus assist in retaining the full amount of compression.

The bearing through which the stem of the intake valve moves as the valve opens and closes, often becomes slightly worn. There is a strong suction in this intake pipe just as the charge passes into the cylinder, and if a small amount of air is admitted here it weakens the mixture in proportion to the size of the air space. A leak here will make it difficult to start the engine and will even cause it to fail to run.

The place where the intake valve is joined to the cylinder is also provided with a fireproof, air-tight gasket. If this gasket leaks it will have the same effect as a leak caused by a worn valve stem, as mentioned in the previous paragraph. Leaks of this character may be easily detected. Take an ordinary oil can, fill it with gasoline and squirt a small amount of the gasoline in every place to be tested. If there is a leak, there will be an immediate effect in the running of the engine. If there is no leak, no difference will be noticed.

Another important matter to be investigated is whether there is a leak in the cylinder-head gasket. Such a leak is very difficult to locate. Often, in taking off the cylinder head to grind the valve seats, the gasket is injured in such a way that it will not provide a tight joint. In such a case, some sharp instrument should be used to remove every particle of the old gasket and to clean out the small grooves generally found there. A new gasket is then put in its place, care being taken not to allow any hard substance to get onto the gasket, such as a grain of sand or a small metal chip, as this might keep the cylinder head away from the cylinder and prevent the gasket from forming a perfectly tight joint. When the new gasket has been properly put in place, replace the cylinder head and tighten each nut a little at a time until they are all properly tightened. Then start the engine and after it has run a few minutes go over the nuts again and tighten them a trifle more.

In the jump-spark system of ignition, there is a spark plug instead of an igniter which must be tested for leaks just the same as other parts of the engine. Spark plugs, as a general rule, are air-tight but sometimes one is found that is not. Some spark plugs are made to screw into the cylinder with a straight thread, a shoulder and a copper or other gasket being employed to make the joint air-tight. Some spark plugs are screwed in with a taper thread and depend upon the tightness of the threads to make them air-tight. In every case, they should be screwed in tightly.

In looking for gas engine troubles, do not overlook little things. Never take anything for granted and never take the word of anyone for any condition, for the giver of the information may be mistaken. Investigate every individual feature personally to make sure that everything is in perfect order, taking one step at a time as indicated in the preceding paragraphs.

# CHAPTER II

## CARBURETION

Carburetion is the process of atomizing the fuel for the engine, thus mixing the proper amount of fuel in the form of vapor with the proper amount of air. There are two general devices used for this purpose, the carbureter and the mixer.

The carbureter consists of a float, float valve, needle valve, fuel bowl, air inlet and fuel inlet. The float is made in a manner to obtain the most buoyancy or lifting power in the fuel chamber in which it is used. Floats are made either of cork covered with a coating of shellac or of some light sheet metal, forming an air-tight bulb.

### The Float

Troubles are sometimes experienced with floats. If the coating of shellac of a cork float is in some way injured, it will allow the gasoline or other fuel to soak into the cork and make it too heavy to close the float valve properly. When a sheet-metal float is used, it is liable to spring a small leak, and when filling up with the liquid fuel it will lose its buoyancy and fail to work. The remedy for the cork float is to remove it from the chamber, dry it thoroughly either in the sun or in a warm oven, taking care to leave the oven door open to prevent an explosion. After it is thoroughly dry, it is given one or two coats of shellac and allowed to dry until the coatings are thoroughly hard. In the case of metal floats, the fuel must be removed from the inside and the hole soldered.

The float is used to keep the liquid fuel at the same level in the bowl of the carbureter at all times. This is accomplished by the use of the float valve and the lever connecting the two. The mechanism is so arranged that when the fuel rises to a given height, the float which remains at the top will operate automatically and close the fuel supply or float valve. When some of the fuel has been used, the float will settle down, allow the valve to open again, and cause the bowl to be filled up to the desired point.

### The Float Valve

The float valve generally consists of a cone-shaped valve suspended at one end of the lever connecting the float with the float valve. This lever is hinged in the middle in such a way that it will open and close the float valve as the float moves up and down with the surface of the fuel. This valve sometimes causes trouble. Occasionally a small grain of sand or other substance will lodge between the valve and its seat, holding it open and allowing the fuel to waste when the engine is not running. If this is the trouble, it can generally be remedied by a light tap on the side of the carbureter, near the float valve, which will dislodge the foreign substance and allow the valve to work freely. Sometimes a valve or its seat may be slightly worn so as to allow the fuel to waste when an engine is not running. This does not generally interfere with the working of the engine, but should be remedied by grinding in the valve with emery flour and oil or some grinding-in compound specially prepared for the purpose.

### The Fuel Bowl

The fuel bowl is, as its name implies, a bowl for holding the fuel in the carbureter preparatory to its vaporization and entrance into the mixture to be carried to the cylinder. This bowl is generally spherical and the needle valve is placed in the center of it so that tipping the carbureter in any direction will have no effect upon the action. For a stationary engine a fuel bowl of any desired shape may be used, but for a tractor or any movable engine, it should be spherical and have the needle valve in the center.

### The Needle Valve

The needle valve regulates the amount of liquid fuel which passes into the mixture of vapor and air. The gasoline or other liquid passes through the needle valve in the form of a spray and is immediately taken up by the air in the form of gas; this gas passes into the cylinder and forms the explosive charge. It is important to see that there is no obstruction of any kind in the needle valve, as very little is required at this point to upset the working of the engine. A small speck of dust, too large to pass through the needle valve, may obstruct the passage of gasoline and prevent the proper running of the engine. The adjustment of the needle valve will be explained under the heading "Carbureter Adjustments."

### The Fuel Tank

It is important that there is a proper connection between the carbureter and a suitable fuel tank, as a great deal depends upon this tank and its connections. If gravity is to be depended upon to feed the carbureter, the tank must be so placed that at all times it is at least eight inches above the fuel level of the fuel bowl of the carbureter. This arrangement will allow the gasoline to flow to the carbureter by its own weight. Great care should be taken to prevent water or any other foreign substance from entering the tank. When filling the tank, the gasoline should be strained through a chamois skin to prevent foreign substances entering the tank. The cap on the top of the tank must be provided with a suitable air vent to allow the air to enter as soon as the fuel is drawn out of the tank, otherwise the gasoline would not leave the tank on account of the vacuum that would be produced at the top. The bottom of the tank should be provided with some kind of a trap which will stop any foreign substance from entering the carbureter. There should also be a shut-off valve between the carbureter and the tank so that if the float valve should fail, the supply of gasoline could be shut off. When it is desired to place the tank in some particular place, without regard to the height of the carbureter, the top of the air tank may be made air-tight and an air pump used to produce sufficient pressure in the tank to cause the gasoline to feed to the carbureter. Any pressure from 5 to 50 pounds per square inch will work, as the float valve will be able to resist that pressure.

It is important to take care that the air hole in the top of the tank does not fill up with dirt, as in certain cases it has happened that, due to this cause, engines have run for a short time and then failed to run for want of fuel. In one case it was found that the hole in the top of the tank had become filled with paint used in painting parts of the engine, and this prevented the air from entering in sufficient quantity to admit a steady flow of gasoline.

### Carbureter Adjustments

The carbureter adjustment is one of the most important features in connection with the running of a gas engine. It is important that every man having anything to do with gas engines should be able to make all the required adjustments, because if he is unable to do so he invites trouble. Assume, as an example, that the carbureter is to be adjusted on a new engine which has never been run. After making sure that there is plenty of gasoline in the carbureter, close the needle valve entirely, then open it again about three-fourths of a turn, which, as a rule, will permit the engine to start. After it has run a short while, turn off the gasoline very slowly by closing the needle valve until the engine commences to miss, then open it slowly again until smothered explosions are noticed, which is an indication that the engine gets too much gasoline. Now the correct position is between these two, and a little moving back and forth of the needle valve will soon indicate which is the adjustment at which the engine runs the best. When this position has been obtained, fasten the needle valve with a lock-nut so that it will not jar out of position by the vibration of the engine. If the engine is of the variable-speed type, there will probably be a compensating air valve which will require adjustment. In this case, speed up the engine to about 300 revolutions per minute and open the air valve until the engine begins to miss fire, then close it until it runs steadily and fasten this valve with a lock-nut also.

### The Mixer

On heavier engines, a mixer which is more simple than the carbureter is used. The same remarks with regard to the fuel tank apply in the case of the mixer, with the exception that in most cases mixers are supplied with a pump so that the tank is generally buried in some convenient place outside of the building and suitable pipes run from the tank to the pump, and from the mixer back to the tank, as an overflow.

Some mixers on the smaller types of engines employ the suction of the piston as a means to bring the gasoline to the needle valve. In this class of engines, the tank and mixer are generally attached with very short connections at the bottom of the cylinder. There should be a trap and drain in the bottom of the tank for dispensing of any water which might accumulate in the tank.

The mixers on the heavy type of engines are supplied by some kind of pump. Generally a plunger pump with two check valves, one between the pump and tank and the other between the pump and mixer, is used. The check valves are generally of the steel-ball type. Engines using one kind of fuel are provided with a simple kind of mixer, while there are also more complicated double mixers intended for the use of two kinds of fuel, one for starting and one for running conditions.

The simple or single mixer intended for one kind of fuel at a time consists of a fuel bowl and needle valve and an overflow pipe to maintain the fuel level at the proper point. As mentioned, it is generally supplied with a plunger pump and generally gives little trouble. The piping from the pump to the tank must, however, be air-tight, and the plunger must fit snugly and have suitable packing to make it air-tight. This packing must be kept properly lubricated to prevent undue wear. The valves seldom give any trouble. Occasionally a small piece of foreign substance will enter between the valve and its seat and cause the pump to fail in its action, but this difficulty is generally removed by a light tap with a small hammer or wrench. The valves sometimes become worn and require reseating. When the ball valve is used, all that is necessary is to remove the top of the valve, place a small piece of wood on the ball and tap it gently until it will hold gasoline poured into the valve. If the valve is of such a type that it needs to be reground, emery flour and oil or some grinding-in compound is used in the well-known manner employed with all valves of this type.

Cases have been known where a plunger pump with ball check valves has given trouble on account of too large balls being used in the check valves. If the balls are too large for the seat and project up rather high, the vibration of the engine will cause them to leave their seat so that the gasoline can return to the tank. In that case, they may be replaced by smaller balls and no difficulty will be experienced afterwards.

A mixing valve which serves to properly proportion the gas and air and which also controls the quantity admitted to the cylinders, is shown in Fig. 6. The construction there shown is used on a Westinghouse gas engine employing natural or illuminating gas. A vertical and free-moving cylindrical valve *A* with suitable ports is surrounded by two independent sleeves *B* and *C*, provided with ports and arranged to be rotated or adjusted by handles *N* and *N′* through a small arc. The gas enters at *P* and the air enters through an opening at the side, not shown in this illustration. This arrangement of ports insures a thorough mixing of the air and gas before entering the combustion space. Pointers *T* and *T′* move over graduated scales and indicate the size of the openings in the ports. Hence, the ratio of these two readings gives the proportions of gas and air. By rotating the sleeves when the engine is running, the correct mixture can be easily regulated, after which the mixing valve acting under the control of the governor, admits the proper amount of gas and air into the cylinders. In producer gas engines a poppet type valve is used, because of the presence of small quantities of dirt and dust. Mixing valves of this type can only be used for gaseous fuels. When gasoline or other liquid fuels are used a carbureter is, of course, necessary to gasify the liquid fuel.

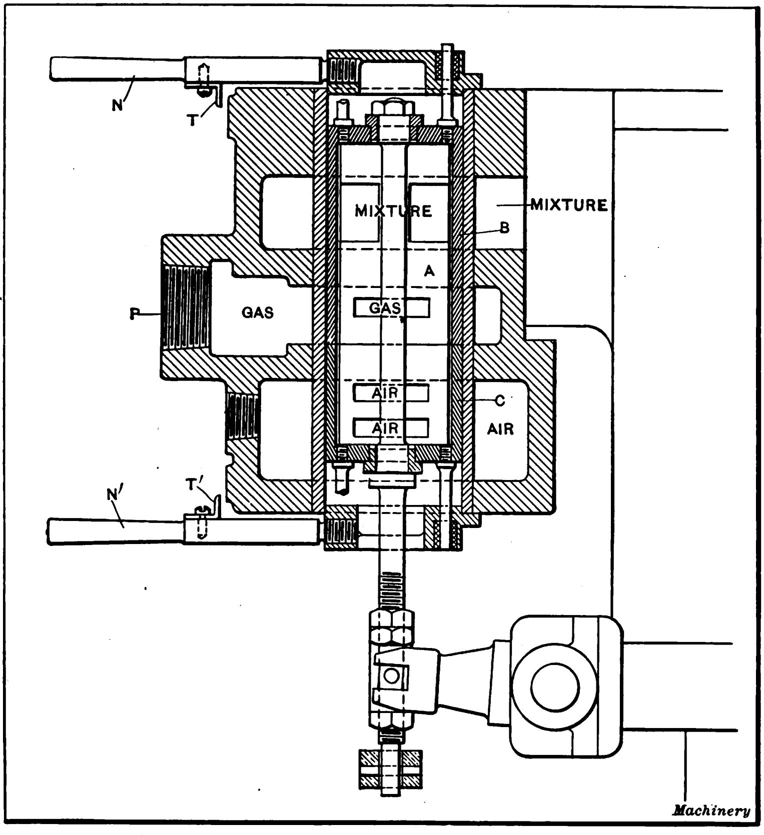


**Fig. 6. Mixing Valve used on Westinghouse Gas Engine**

### Needle Valve Adjustment

The needle valve of gas engines using a mixer is generally provided with marks to enable the operator to get somewhat near to the position where the proper mixture will start the engine, but after the engine is running, the operator should depend upon the sound of the exhaust for the final proper adjustment of the needle valve, and should not depend upon the manufacturer to tell him the position of the needle valve for the operating condition. The best method for accomplishing this adjustment is to shut off the gasoline entirely until there are indications of absence of sufficient gas and then open the needle valve a little at a time until the exhaust is steady.

### Single Mixer for Two Kinds of Fuel

A single mixer is sometimes used to burn two kinds of fuel. This is accomplished by having a pump with a three-way valve which makes it possible to first draw fuel from one tank for the starting and by a movement of the valve switch to another tank for the running fuel. This is a simpler arrangement than a complete double mixer with double piping and two pumps, and works well with a load, but does not run well without a load. Of course, it is always necessary when using this kind of a mixer to switch back to gasoline for two or three minutes before starting the engine, in order to have the gasoline ready to start with the next time. If this is neglected, however, there is a provision by which the pump can be worked by hand to produce the same results. However, few drops of gasoline in the cylinder, after having run on some other fuel, is a splendid thing in order to clean out the cylinder, mixer, intake piping and valves. This system is used on some heavy tractors with good results under load.

By using a double system of mixers, pumps, piping, etc., it is possible to have an arrangement which will handle fuels which require a higher temperature before they will vaporize. While this system is a little more complicated, it gives the best results under all circumstances.

It may be mentioned that a piece of screen wire placed in the intake pipe between the needle valve and the cylinder often aids in mixing the vaporized liquid fuel properly with the air.

### Gas and Oil Engine Fuels

The following information relating to fuels is given by The International Harvester Co. The liquid fuels, with the exception of alcohol, used in the modern internal combustion engines are all products of petroleum oil or crude oil as it is usually called. This oil is a mineral liquid which is obtained usually at a great depth in the earth by drilling a well and pumping. The oil is seldom refined at the wells but is stored in large tanks or open reservoirs and pumped to the refineries, sometimes hundreds of miles distant through pipe lines as needed. The first fields found in America are in Pennsylvania. Today fields are being worked in Pennsylvania, Illinois, Indiana, Kansas, Oklahoma, Texas, California, and many other states. The oil fields in the East are gradually being exhausted, so that little Pennsylvania, Illinois, or Indiana oil is now refined.

### Methods of Testing Fuels

There are two general methods of testing fuels in common use. The usual way in the field is by comparing the weight of fuels with the weight of an equal bulk of water, although this test does not always distinguish the grade on account of the difference in composition of crude oils from the different oil fields, and the practice of mixing low-grade and high-grade distillates. This test is accomplished by means of a hydrometer, and supposed to be made at a temperature of 60 degrees F.

On the Beaumé scale for comparing the density of liquids lighter than water, water is rated 10 degrees. Heavy liquids run lower and oils run higher than water. Crude oil runs from 12 up to 50 degrees, mostly averaging from 22 to 40 degrees, distillate, about 39 degrees; kerosene, from 40 to 50 degrees; and common gasoline, from 50 to 80 degrees. In the larger cities gasoline is kept in stock with gravity of from 64 to 70 degrees, or even lighter for special purposes. Owing to the small amount of gasoline which can be produced, the tendency is to make it heavier by distilling off some of the heavier oils with it in order to supply the demand.

Kerosene as sold today varies between 42 degrees and 54 degrees, Beaumé test. It is the common belief that because gasoline is more easily evaporated and ignited than kerosene, that it gives more power, but the reverse is true. Kerosene and the lower grade oils, such as distillate, solar oil, fuel oil, etc., contain more heat units than an equal bulk of gasoline and in a properly designed engine will give proportionately more power. The reason for this is that in every pound of petroleum products there are about 20,000 heat units. Therefore, it is evident that there are more heat units in the heavier liquids than there are in an equal bulk of the lighter liquids. It is this that makes hard coal worth more per ton than soft coal. It has more heat units per pound and heat is power.

It is evident that the Beaumé method of testing does not in reality give the true value of the liquid tested; in fact, liquids of the same quality distilled from crude oil from the different fields vary in weight, the Eastern oils being lighter than those obtained from the West. It has been demonstrated that Pennsylvania crude oil of 66 Beaumé gave the same results as the refined gasoline testing 58 Beaumé from Kansas crude oil. The reason for this is that both oils, although differing, in gravity have the same points. The only accurate test to determine the quality of a distilled fuel is to determine the initial (lowest) and maximum (highest) boiling points. This is the method used by the refineries and it can only be determined by actually distilling the liquid. The refiner knows and distinguishes each product, not by gravity but by boiling points. He knows it would be impossible to make his goods uniform by using the fleeting standard of gravity, but knowing the boiling points, he can depend upon the quality.

It is not difficult to understand what boiling point means, for the expression explains itself. It is the point on the Fahrenheit thermometer at which a liquid will begin to boil. But the refiner does not stop here. He distills a given quality of gasoline, and while it is in the process of distillation, ascertains at what point each 10 per cent will boil until the entire quantity is evaporated or distilled. This is called fractional distillation. In this manner is determined what is known as the initial boiling point, as well as the maximum boiling point and all intervening boiing points. The rapidity with which a liquid will evaporate is determined by its boiling points. For instance, a liquid that has a low boiling point will evaporate quicker than one with a high boiling point—it takes less heat to boil it. that is, to cause it to go off in a vapor; consequently, it requires less heat and air to vaporize it.

Water boils at 212 degrees F.; consequently it will take it longer to evaporate than gasoline that has an initial boiling point of, say, 115 degrees F. But water will evaporate quicker than kerosene oil with an initial boiling point of 325 degrees F. From this we see that the lower the boiling point the quicker the liquid will evaporate under ordinary temperature. Of course, any liquid will begin evaporating long before it boils.

### The Distillation of Fuels

To understand thoroughly the action of fuels in an internal combustion engine, one must know something of the process of distillation. The crude oil is pumped into a huge steel boiler or still and gradually heated. A pipe leads from the still to a condenser, and as the gas rising from the crude oil seeks to escape, it runs through the condenser and is condensed again into a liquid. The temperature at the still is constantly watched and recorded and the liquid from the condenser is also tested with a Beaumé hydrometer and recorded. By previous experiment the oil refineries know at just what temperature the different fuels are distilled off so that as the temperature rises in the still, the fuels are run into separate tanks according to their quality. The lighter liquids testing around 80 degrees Beaumé come off first and as the crude oil becomes hotter the liquids that are distilled off gradually become heavier. This process continues until nothing is left of the crude oil but a kind of coke.

In this manner the refineries obtain gasoline carrying in quality from 80 degrees down to 50 degrees, Beaumé tests; kerosene from 50 degrees down to 40 degrees Beaumé; distillate from 40 degrees down to 29 degrees Beaumé; and below that, lubricating oils. The gasoline as sold now usually runs from 50 degrees to 62 degrees Beaumé test, but as the gasoline obtained from the crude oil varies from 50 degrees to 78 degrees or 80 degrees Beaumé, it is evident that the small proportion obtained at 56 degrees to 62 degrees Beaumé would not be enough to supply the trade. In order to get a product that will have a uniform weight, and to use up the very high and low grade gasoline, they are mixed in such a proportion as to produce the desired results. For example, if equal parts of gasoline testing at 55 degrees and 65 degrees Beaumé, were mixed, the result would be a gasoline testing at 60 degrees Beaumé.

The big oil companies now realize that the heavy fuels give trouble in starting when used in internal combustion engines, and are now putting out a winter gasoline and a summer gasoline. The winter gasoline, being a little higher grade, contains more of the lighter grades of gasoline, having a low boiling point, which are more easily evaporated in cold weather.

### Motor Spirit

Within the last two years the rapid increase in the use of gasoline has shown the oil companies that the time would come and that very soon when the production of gasoline would not meet the demand. The Standard Oil Company has for some time been experimenting with substitutes and now announces that they are equipping their distilleries for the manufacture of a new product of crude oil called Motor Spirit which has all the characteristics of gasoline and which will sell for three cents a gallon lower. This product is obtained by redistilling under pressure the distillates that range from 29 degrees to 40 degrees Beaumé. This will practically double the output of oils in the gasoline class as soon as the distilleries are equipped for manufacture.

The distillation process is practically the same as with the original crude oil except that it is done under pressure which produces an entirely new product with new boiling points and gravity. The original distillate having a boiling point of about 400 degrees and a gravity of from 29 degrees to 40 degrees Beaumé is turned into motor spirit with a boiling point of 95 and a gravity of 59.2 Beaumé.

The Standard Oil Company makes many claims for this new fuel, among them are 20 per cent greater power than gasoline and easier starting. The one point which might be brought against it is its disagreeable odor.

# CHAPTER III

## IGNITION

There are two general systems of ignition; the "make-and-break" system and the "jump-spark" system. The make-and-break system is used extensively on stationary, portable and traction engines running below 500 revolutions per minute. The "jump-spark" system is almost entirely confined to small high-speed engines used on automobiles and motor trucks.

### The "Make-and-break" Ignition System

The make-and-break system consists of an igniter, a coil, a switch and batteries, and may also use a magneto. It operates by breaking an electrical current inside of the cylinder. The igniter generally consists of a cast frame, a stationary electrode, a movable electrode, and means for making and breaking the circuit, by having its parts connected with the camshaft by a push-rod, bevel gear and shaft, or chain drive. The movable electrode is made to move through about one-tenth of the circumference of a circle. It must fit snugly into the igniter frame and must be properly oiled to prevent the compressed gases from escaping. The stationary electrode must be insulated from the igniter, this being easily done by mica washers, but porcelain or glass may also be used, if the exposure to the heat is not too great. The electrodes are each provided with a small point on the inside of the cylinder. These points are separated except when a spark is desired, when they are pushed together and allowed to separate to produce a spark.

### Wiring the Batteries

The wiring for the make-and-break system and the jump-spark system is, in general, the same. Before starting to wire the batteries, it

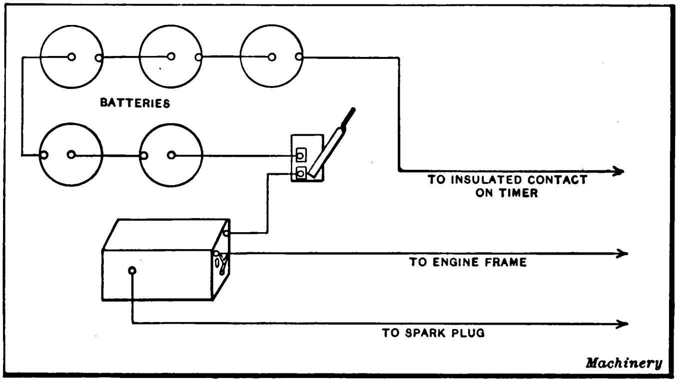


**Fig. 7. Wiring for "Jump Spark" with Batteries**

is necessary to choose a good place for the location of the battery box, coil and switch. The battery box should be located in a clean, dry place where it will not be affected by the vibration from the engine. If so placed it will last much longer and the absence of vibration will tend to eliminate loose connections. The switch can be placed on the outside of the battery box or at any other convenient point. The coil box may be placed inside of the battery box or it may be placed on a small shelf near the switch. The nearer the coil is to the battery box and switch, the less wiring will be required.

There is generally a so-called "ground-post" provided on the frame of the engine to receive the ground wire from the batteries, but if this is not the case, a wire can be run from any metal part of the engine frame to the zinc or outside electrode of the first battery, assuming that the engine uses the ordinary dry cells for ignition, which can be procured in almost any locality. Then from the center or carbon electrode of this battery run the wire to the zinc of the next, and so on until all are connected. When the wires are all connected together, there will be one vacant carbon electrode. Run a wire from this carbon electrode to one side of the switch, a three-point switch being used, and from the center of this switch run another wire to one terminal of the coil. Then from the other terminal of the coil run a wire to the stationary electrode of the igniter and the battery circuit is complete. Insulated wire is generally furnished with the engine for the wiring.

### The Magneto

An ordinary friction-drive magneto is often used to run the engine after it has been started by the use of a battery. A suitable place for the magneto is provided so that the magneto drive pulley will be in contact with the flywheel, the pressure being great enough to drive the magneto. The place selected should be as free as possible from vibra-

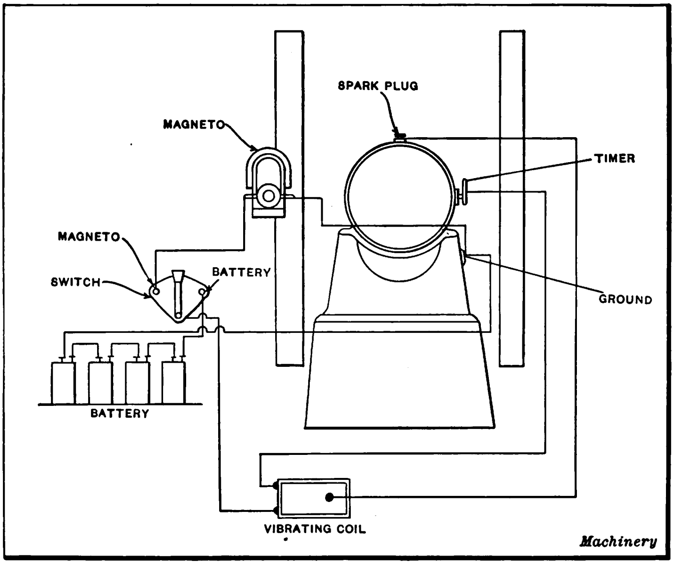


**Fig. 8. Wiring for "Jump Spark" with Batteries and Magneto**

tion and the magneto mounted as firmly as possible. Run a wire from one terminal of the magneto to the vacant terminal on the switch. The other terminal of the magneto may be connected by a wire to the ground wire which runs from the engine frame to the zinc of the first battery, or it may be connected directly with any metal part of the engine frame. This wiring applies to a magneto depending upon its permanent magnets for its magnetism, but if a magneto uses small coils in connection with the magnets to increase the magnetism, these field wires are connected together, and the wire is run from each end of this small circuit to each of the brushes of the magneto. In this style of magneto, it is necessary that the direction in which the magneto will run when placed on the engine is determined upon when it is manufactured, because this determines the method for attaching the field wires. If a magneto is attached in such a way that results are not obtained, all that is necessary is to change about the connections at the terminal posts.

If the magneto furnished with the engine is connected to the camshaft or crankshaft with gear wheels, and runs at the same speed as the crankshaft, it is likely that a coil is not necessary, but a small change in the wiring outlined in the previous paragraphs will be necessary with this style of magneto. The wire which runs from the carbon electrode of the battery to the switch and the wire which runs from the coil to the igniter should be interchanged. Upon examination of the wiring it will now be seen that the battery current passes through the coil but the current from the magneto passes directly to the igniter.

All friction-drive magnetos are provided with a governor of some kind, which, when the armature of the magneto attains a certain speed, usually about 1800 revolutions per minute, will release the pulley wheel from the flywheel or allow it to slip, so that the speed will not

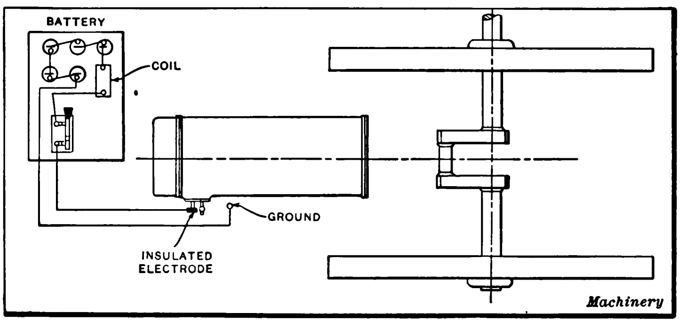


**Fig. 9. Wiring for Horizontal Engine with Batteries**

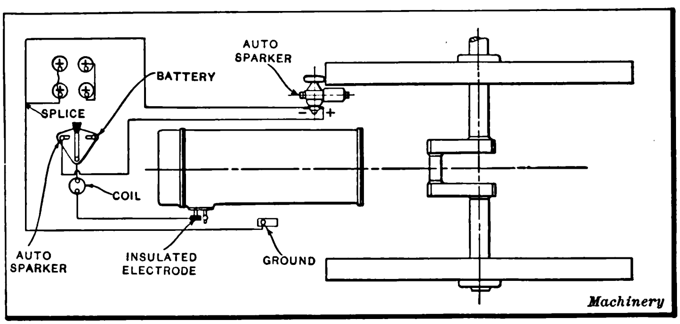


**Fig. 10. Wiring for Horizontal Engine with Batteries and Auto Sparker**

exceed that given. Care should be taken to adjust this governor so that it will do its work properly. With some magnetos the adjusting spring is arranged to work in two ways, one way being used when the magneto drive pulley touches the upper side of the flywheel, and the other when it is touching the bottom side of the flywheel. If the spring allows the drive-pulley to be lifted from the flywheel and returns it to its place when released, it is in the proper position, but if it refuses to leave the flywheel, the adjustment is not ccrrect and must be changed.

### High-tension Magnetos

High-tension magnetos are beginning to be used on stationary and traction engines. These magnetos are self-contained and require neither coils, timer or switch. They are generally provided with a breaker box at one end of the armature, which acts as a timer and also advances or retards the spark. These magnetos are gear-driven and run at engine speed.

In all gear-driven magnetos the gears should be marked so that if it should become necessary to remove the magneto, or if it should be removed by some accident, it could be replaced without the services of an expert. If these gears are so marked, the replacing can be done by anybody. If the gears are not marked and the magneto has to be replaced, it is necessary to set the engine at the firing point, about 10 degrees ahead of the center on the compression stroke, that is, when

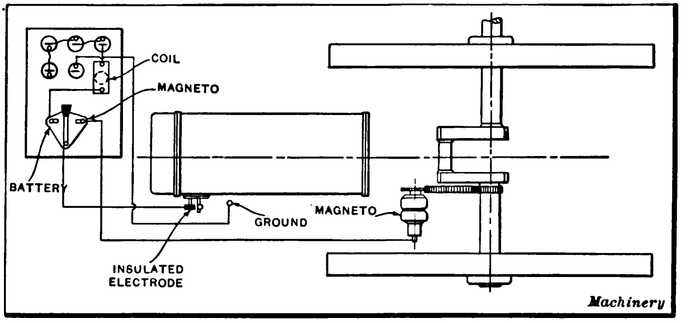


Fig. 11. Wiring for Horizontal Engine with Batteries and Gear-driven Magneto

the piston ordinarily would be within about, say, one-half inch of the end of the compression stroke. Now place the magneto in mesh with the gears so that the points in the breaker box on the end of the magneto, which are separated once and sometimes twice during each revolution, are just ready to separate. In this position the gears should mesh.

### Gear-driven Magneto with Coil Box

In a gear-driven magneto, which is used with a coil box or with an igniter only, the process is a little different. Hold the magneto in the hand and take hold of the gear with the other hand and turn it in either direction. It will then be discovered that at two points in each revolution the armature turns harder than in other positions. These points are called points of resistance and are the points of the rotation at which the spark is made. Set the engine so that the igniter has just tripped, turn the magneto until one of these points of resistance is found, and place the gears in mesh at this point. Then connect up the wires as usual.

### The Oscillating Magneto

There is still another type of magneto known as the oscillating magneto which only requires that the igniter push-rod should trip the magneto rotor at the proper time. The spark in this magneto is made by the rotor which is used instead of the armature in other magnetos, and which rocks back and forth between the magnetic fields. The igniter pushes the rotor in one direction and it is tripped and returned to its normal position by springs supplied for this purpose. This style of magneto has been in use for several years and has proved very satisfactory.

### Care of Magnetos

Magnetos must not be oiled too freely. Generally they are provided with ball bearings which require but little oil. If more oil is used than the magneto requires, it will get onto the armature and a short circuit may be formed. In case of trouble on this account, wash off

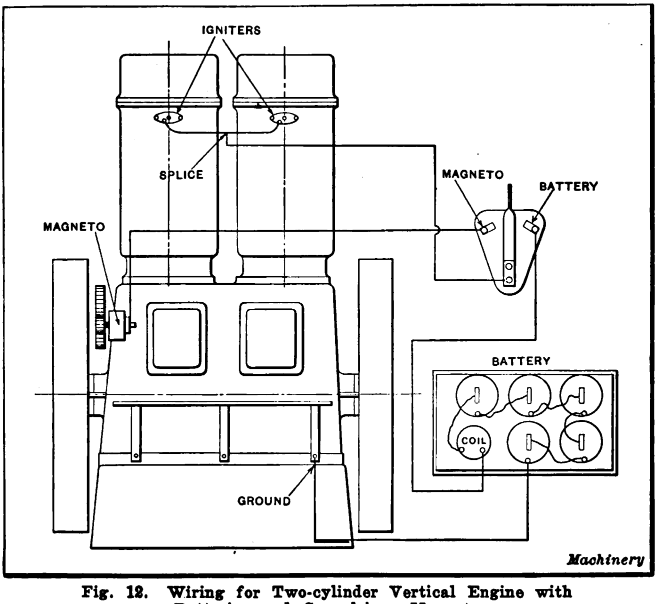


Fig. 12. Wiring for Two-cylinder Vertical Engine with Batteries and Gear-driven Magneto

the magneto with gasoline, removing every particle of dirt and grease; then let it dry out. It is then usually ready to run again without trouble. In nine times out of ten this simple remedy will take care of the difficulty.

### Other Means for Obtaining Electricity

Storage batteries are used for ignition purposes and give good results when a suitable plant for re-charging them is accessible. They should be handled by a electrician, except for the wiring connections into the circuit, which may be made by anybody. Once in a while one will find a man who wants to use electricity from the regular electric light circuit, but this is dangerous and hard on the igniters on account of the voltage being excessively high for this purpose. From six to ten volts is all that is necessary for ignition purposes.

### The Jump-spark System

The jump-spark system differs from the make-and-break system only in the means of igniting and in the kind of coils used. In the make-and-break system a so-called "silent" coil, or one without a vibrator is employed, but in the case of the jump-spark system a vibrating coil is necessary. The silent coil needs no adjustment or other attention as long as it works, and when it fails it must either be attended to by an

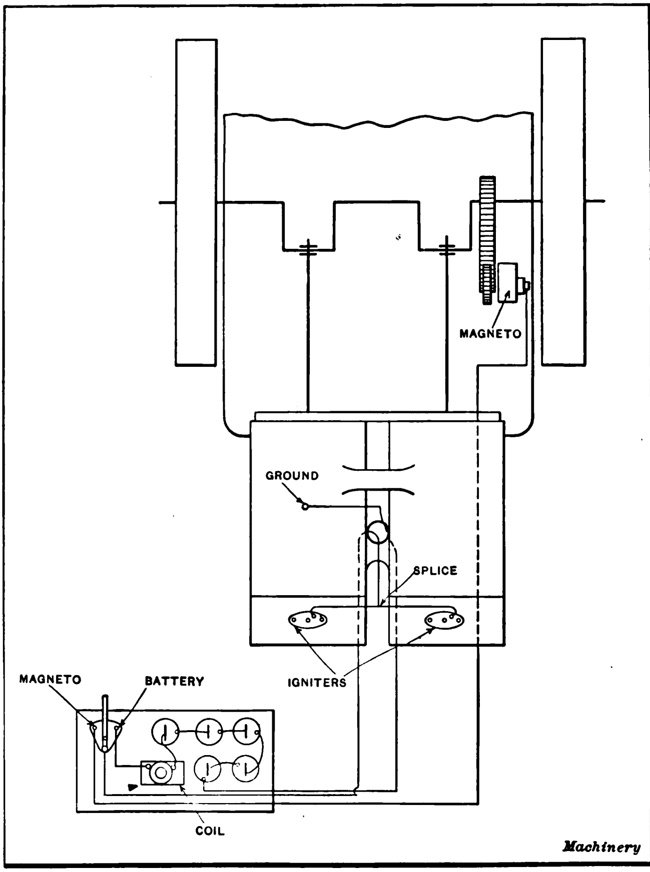


**Fig. 13. Wiring for Two-cylinder Horizontal Engine with Batteries and Gear-driven Magneto**

electrician or be replaced by a new coil. As a rule, it is about as cheap to replace it as to undertake to repair the old coil. An ordinary spark plug, such as is used in the regular automobile engine, will prove satisfactory.

The vibrating coil must be adjusted and the adjustment is simple, when understood. The coil should be so adjusted that the points will touch each other during the vibrations as lightly as possible, as this lengthens the life of both the coil and batteries. The best way in which to accomplish this adjustment is to turn the adjusting screw until one can see the light between the points, and then turn it back until the points just touch each other.

### Ignition Troubles

The ignition trouble most frequently met with is perhaps unsuitable or run-down batteries. It seems as if the average engine operator

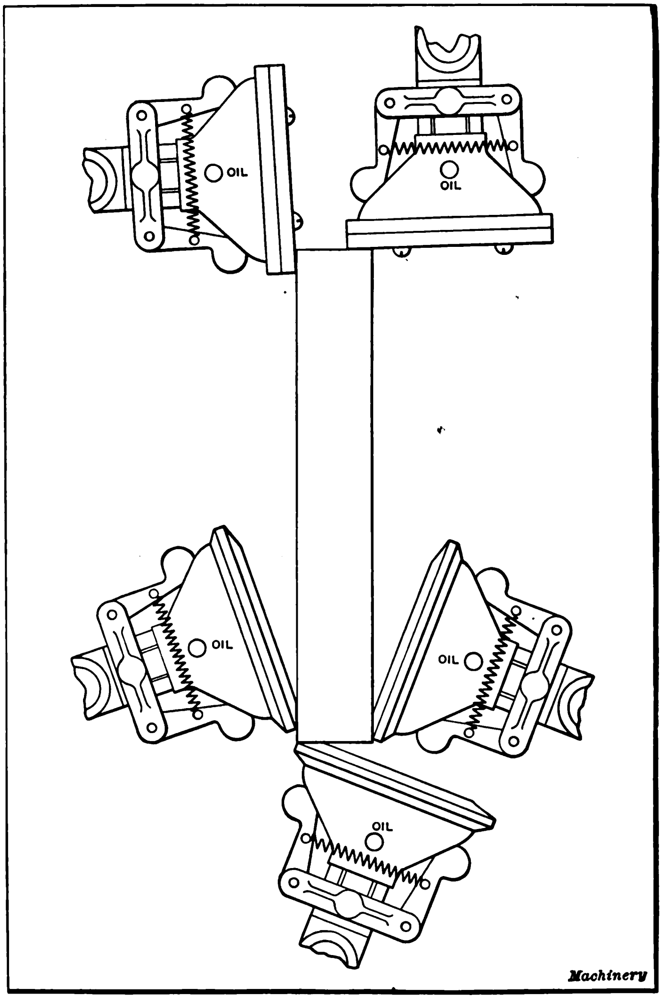


**Fig. 14. Diagrammatical View showing the Different Positions that may be used for Driving a Rotary Magneto**

could not realize that a set of batteries must necessarily give out some day. The average operator seems to think that because a set of batteries did its work properly the day before or last week, it should go on indefinitely performing the same task. A good battery tester is, therefore, suitable to have around where batteries are used. It will instantly indicate how much power is left in the batteries and often save a great deal of useless work in cranking a gas engine with run-down batteries.

Another common fault with batteries is the loosening of the connections. When the batteries are subjected to vibrations the connections are very apt to work loose. The only way to locate a loose connection is, as a general rule, by examining each connection in turn. All the connections should be kept as tight as possible. Broken wires are also likely to cause loss of time and must be located. Assume that an engine has been running smoothly and that it then without warning stops suddenly as if the switch had been turned off to the ignition system. If the carbureter and fuel supply system seem to be all right, it may be taken for granted that the fault is with the ignition system. First test the igniter by allowing a piece of metal to come in contact with both electrodes and then removing it quickly to see whether it causes a spark. If a wire is broken or a connection is loose, the spark will not be there. Then test the wires which run from the engine to the battery box to see if they are in good condition. Examine the switch, take out the coil of the circuit and test it by passing a current through it to see if it works properly. Then test the batteries one by one to see if they are in good condition. If no defect has been detected so far, the only thing left to do is to test the batteries as a complete circuit by placing the wire of the battery tester on the carbon at one end of the set of batteries and connecting the other terminal of the tester with the zinc at the other end. Assume that when this is done no current is indicated. It is then clear that there is a broken connection between two batteries and if these are tested in order, the broken connection will be found. Broken wires are sometimes caused by allowing the batteries to be placed so loosely in the box that the vibrations of the engine keep bending the wire constantly until it breaks. The igniters should be kept clean and free from carbon deposits.

# CHAPTER IV

## LUBRICATION

In the present chapter attention will be given to different types of oilers and the different kinds of oils to be used. The lubrication of a gas engine is accomplished in a great many different ways. It may be said, in general, that there are four principal methods: force-feed oilers, gravity oilers, grease cups, and lubrication by means of the ordinary squirt oil-can.

There are several different methods in use for driving force-feed oilers, the most common being by means of gears, belts, chains or the ratchet and pawl. Some manufacturers provide oilers with sight-feed attachment, while others do not. The sight-feed oiler is valuable, in many respects, but there is nothing to prevent this oiler from failing to do its work just after the operator has looked to see if it is feeding, so that it does not present an absolute guarantee against ruined bearings.

Early engines were generally provided with large oil cups in which a quantity of waste or felt was packed to prevent the oil from feeding too fast and be wasted. This method was quite satisfactory at that time because better methods were not known. It was necessary, however, with this method, to fill the oil cups several times a day in order to insure that the engine would be properly lubricated, and, as a matter of fact, on engines provided with these oil cups there were not many bearings ruined from running dry. The operator knew that he had to watch them in order to prevent trouble and they were generally attended to. This kind of oil cup was gradually improved with many modifications until the gravity-feed oiler in general use today was developed.

When grease cups are used care should be taken to provide a good grade of grease, neither too thin nor too heavy, otherwise good results cannot be expected. The oil-can used for oiling various moving parts around the engine should always be kept filled with clean oil ready for immediate use, as it is sometimes possible to save a bearing after it has been discovered that it is running warm, by giving it a generous dose of oil with the hand can. Every time before the engine is started it should be gone over with the hand oil-can in the one hand and a piece of waste or an old rag in the other. All the old grease and grit should be removed with the waste and fresh oil applied.

It is sometimes desirable to lubricate the crank bearing with lubricating oil instead of with grease, and this may be done easily and with little extra expense. To accomplish this, it is necessary to provide some method to support a gravity-feed oiler or a pipe from a force-feed oiler directly above the highest point that the crank reaches during its revolution. To the bottom of this support is attached a small piece of ordinary lamp wicking in such a position that the oil from the oiler may be dripped onto it. A small cup is provided on the top of the crank bearing which passes close enough to this wicking to wipe the oil off it without touching the wick. If it touches the wick the latter will soon be worn out, and as it wears particles from it are likely to fall into the cup and clog up the oil supply. The oiler can now be set to feed any number of drops per minute to the wick and the cup on the crank bearing will wipe off this oil, and from the cup it will flow directly into the bearing. When gravity oilers are used, it is necessary in most cases to provide an oiler for each bearing, although appliances are on the market by means of which both the main bearings and the crank bearing can be supplied with one oiler by providing a three-way feed.

### Force-feed Oilers

Force-feed oilers may be divided into direct-feed and sight-feed oilers. The sight-feed oiler brings the oil into plain sight as it is fed into the bearing, while with the direct-feed oiler the lubricant generally passes from the bottom of the oiler directly into the bearing. The connecting pipe is then generally provided with small screws, generally called "bleeders," which may be loosened in order to tell whether the oil is feeding as it should or not. The force-feed oiler is provided with one or more small pumps, generally of the plunger type. These pumps are placed in the bottom of the oil tank. A pipe is run from each of the pumps to the bearing to be lubricated. The supply of oil may be increased or decreased as desired. When these oilers are kept filled with clean oil and the driving mechanism is kept in good condition, they generally work very satisfactorily, but a little dirt in the tank or a loose belt in the driving mechanism is apt to cause trouble. As an example may be mentioned a 20-horsepower traction engine fitted with a six-pump force-feed oiler. The customer assumed, and in fact had been told by the salesman from whom he had bought the engine, that this type of oiler was absolutely automatic and would never require any attention except to put oil into the tank. The engine was running nicely for six weeks when at times it began to show loss of power. A gas-engine expert was sent to investigate the trouble. This man began his work by putting in a new set of piston rings, and when putting them in used a very liberal supply of oil. The engine was started and ran nicely for a few minutes, long enough, in fact, for the gas-engine expert to get time to disappear, after which the old trouble again developed. Finally, trouble in the oiling mechanism was suspected, and it was found that the oil pumps were feeding only about half of the time on account of the wear in the driving mechanism, which did not admit the pawl and ratchet to do their work properly. This experience shows, in the first place, how necessary it is that the oiler should work properly in order to lubricate the engine, and also that unless the engine is properly lubricated it will not develop its rated power. New engines are generally adjusted to use considerably more oil than is necessary after they have been in service for some time.

### Lubricants to Use

For lubricating the inside of the cylinder, the piston and the rings, which are all exposed to high temperatures, on account of the combustion of the gases, it is necessary to have an oil with a high fire test and at the same time with good lubricating qualities. If proper oil is used, the piston, upon removal from the cylinder, will be found to be oiled properly and the inside of the cylinder to be coated with an even coat of oil. The piston will also be comparatively free from carbon deposits. If the high fire-test oil used for the cylinder has good lubricating qualities in general, it can also be used for all other lubrication about the engine.

What has been said in the previous paragraph applies especially when gasoline is used as a fuel, but when kerosene or any of the other less volatile fuels are used, it is necessary to have the cylinder much hotter than with gasoline, in order to get the best results, and, hence, an oil which will work well with gasoline may be absolutely unfit for an engine using kerosene as a fuel. When kerosene is used, therefore, it is necessary to use an oil with the very highest fire test obtainable, and this oil is not of a quality which could be used for other parts of the engine, except those which are exposed to exceptionally high heat. In the case of a kerosene engine anything except a very high fire-test oil is likely to ruin the cylinder and piston in a few weeks.

Too much oil in the cylinder will be indicated by a blue smoke in the exhaust. Too much fuel in the cylinder is indicated by a black smoke coming from the exhaust. Either of these troubles should be remedied at once. The exhaust of an engine which is working to its full load should be practically free from color or odor.

The manufacturers of most engines have made extensive tests with different oils on the market and will, as a rule, give all users of their engines information as to the best brand of oil to be used for any particular make of engine. It is, therefore, well for any user of engines to write the manufacturers and ask them what brand of oil ought to be used for the lubrication.

# CHAPTER V

## COOLING SYSTEMS

There are two general methods for cooling the cylinder of the gas engine, either by means of water or air. Water-cooled systems may be divided into two classes; those which use some kind of a pump, and the thermo-siphon systems. The thermo-siphon system is a simple, effective method of cooling, although it requires considerably more water than when a pump is used and some screen or radiator employed as an aid in cooling the water. In the thermo-siphon system the water is moved in its circuit simply by means of the heat and the apparatus necessary consists merely of a tank and necessary piping. The tank is set with the bottom about on a level with the bottom of the water jacket of the cylinder. A pipe is run from the lower part of the tank to the bottom of the water jacket of the cylinder. Another pipe is run from the top of the cylinder to a point near the top of the water tank. The tank must be kept filled with water to a height above the opening of the pipe from the top of the cylinder. When the engine is started and the water begins to heat around the cylinder, it rises into the upper pipe and passes into the tank. As the water in the water jacket rises, cold water from the tank passes into the bottom of the cylinder jacket to take its place, and when this water is heated it rises in turn to the top of the tank, thus keeping the water constantly in circulation.

### Water Cooling Systems Using Pumps

Cooling systems operated by a pump may be classified into three divisions according to the kind of pump used, the pumps being either plunger, rotary or centrifugal, and gear operated pumps. With a plunger pump, at least two check valves are necessary, one between the tank and the pump and one between the pump and the cylinder, these being either ball-check valves or of the regular valve type. The plunger of this type of pump is generally operated by a cam or crank attached to either the crankshaft or the camshaft of the engine. It is fitted with suitable packing to make it air-tight. This packing should be kept well oiled to prevent wear. The parts to be especially taken care of in this style of pump are the check valves and the connection to the propelling shaft. Undue wear in this connection will shorten the stroke of the pump and interfere with its efficiency. The valves sometimes wear and need reseating, which is done in the same manner as explained in previous chapters.

The rotary or centrifugal pump may be operated either by chain, belt or gear drive. All three have their advantages and drawbacks. With the belt drive the pulley is likely to slip and insufficient water will be circulated for proper cooling purposes; but in case the water should be frozen in the pump on a cold morning, or if something else should go wrong, tbe belt will slip and not break the inside parts of the pump. The chain and gear drives will always deliver a uniform amount of water to the cylinder when in working order, but have the disadvantage that they will not slip under any circumstances, and breakages are often due to this condition. In this style of pump the body of the pump must be below the level of the water in the tank so that the water will flow naturally to the pump. The rotary pump is probably the most satisfactory pump for the circulation of cooling water. It must be watched, however, to see that it is performing its work properly and should be drained carefully when the engine is used in cold weather.

A gear-operated pump is one in which the movement of a pair of gears causes the water to pass through with the meshing gears, between the gear teeth and the walls of the pump. This pump must also be placed below the level of the water in the tank and will, when in proper condition, work in a satisfactory manner. These pumps should also be carefully drained in cold weather.

### Purpose of Cooling Water

The cooling water is not intended to keep the cylinder cold, but only to keep it cool enough to prevent the lubricating oil from burning. The hotter the cylinder walls and the parts within it can be kept without interfering with the lubrication, the better the engine will run and the more power it will develop. After the water has passed through the water jacket, its temperature should be about 180 degrees F. If water from a well or a hydrant is forced around the cylinder there will usually be a decrease of power, because the heat from the ignited charge is cooled down so quickly by the water that the expansion force is greatly reduced.

### Air-cooled Systems

The air-cooled system is the simplest cooling system and works satisfactorily as long as the parts are kept in good working order. The cylinder, instead of having a water jacket, is provided with a series of ribs for the radiation of the heat. A blast of air is blown upon this cooling surface in order to dissipate the heat. This blast of air is generally produced by some kind of fan. There are different methods of driving the fan. Some manufacturers place the fan on the flywheel which gives a positive drive, and the fan runs when the engine runs. Others drive the fan with some kinds of gears or a chain. Either of these methods is positive, and when the engine is running the fan will run at the proper speed. The belt-driven fan is the one that is most likely to give trouble. If the belt is too tight, it will place unnecessary strain upon the bearings. If it is too loose, the fan will not drive fast enough and the cylinder will become injured if not entirely ruined by the excess of heat. An overheated cylinder may be detected either by the heat itself or by the sluggish action of the engine. The engine will act as if it was receiving too much fuel, and yet no black smoke will be visible at the exhaust. No gas engine should be run more than a few minutes without ascertaining if the cooling system is in working order. A cylinder can be ruined in a few minutes in this way.

### Cooling Systems for Engines Using Kerosene and Other Less Volatile Fuels

What has been said in the previous paragraph refers to engines using gasoline or natural gas as a fuel. If the less volatile fuels are used, such as kerosene, distillate, or alcohol, a slight change must be made in the cooling system. A piece of pipe of the same size as the pipe connecting the pump to the bottom of the cylinder jacket must be attached to this pipe between the pump and the cylinder; this pipe should extend up until the top end of it will join the pipe coming down from the top of the cylinder just where it enters the tank or cooling system above the tank. A valve is placed in this pipe so that by opening or closing it we may admit just enough water to the cylinder to produce the degree of heat needed to cause this less volatile fluid to vaporize, in order that it may mix properly with the air to form the explosive charge.

It is sometimes necessary and always advisable to be able to admit warm air from around the exhaust pipe to the intake pipe in order to aid the mixture. It is also necessary when kerosene or distillate are used as fuels to admit a small quantity of water in vapor form with the charge to the cylinder, the reason for this being to prevent premature ignition. A water valve is generally provided on the mixer for this purpose and only enough water to prevent premature ignition should be used. Premature ignition is detected by a metallic sound inside the cylinder at the time of explosion. This sound will not be heard until the cylinder becomes very warm, and when noticed, water should be turned on in the water valve until this metallic sound stops. Water is only necessary when pulling a load. When the engine is running empty on kerosene it is rarely necessary to turn on the water valve, which should never be turned on until this signal of premature explosion begins to be heard. Water must not be used with gasoline or natural gas as in either case it is detrimental to the charge. The water should always be drained from the mixer when the engine is stopped.

### Anti-freezing Mixture

The International Harvester Co. recommends the use of an anti-freezing mixture in the cooling water in the winter. Calcium-chloride is commonly used in the following proportions: one pound of calcium-chloride to one gallon of water for temperatures down to 27 degrees F.; two pounds of calcium-chloride to one gallon of water for temperatures down to 18 degrees F.; three pounds of calcium-chloride to one gallon of water for temperatures down to 1 degree F.; four pounds of calcium-chloride to one gallon of water for temperatures down to 17 degrees F. below zero; five pounds of calcium-chloride to one gallon of water for temperatures down to 39 degrees F. below zero.

**Cracked Water Jackets**

Freezing of the water in the water jacket of an engine cylinder and thus cracking the cylinder is a common occurrence in winter. In fact, the jacket water will often freeze, when the temperature is barely down to freezing. The reason for this is as follows: iron gives off heat very rapidly, consequently it quickly returns to the temperature of the surrounding atmosphere. Now, as the sheet of water around the cylinder in the water jacket is very thin, it is evident that if the water is not taken out of the cylinder at night, it will freeze if the temperature drops below freezing. Water in bulk retains heat much longer than a thin sheet of water, consequently the thin sheet in the water jacket will freeze on some nights when a pail of water standing near the engine will not have even a crust of ice on its surface.

When water in the cylinder jacket freezes it rarely causes the cylinder itself to crack, so that there is no damage to the interior of the cylinder, but it will frequently cause the outer wall to crack. A crack of this nature can be repaired by the operator if he is handy with tools. A small size drill for drilling a row of little holes on each side of the crack, about an inch from it, a tap to thread these holes, some screws to fit a sheet of iron plate, a screw-driver, asbestos, a cold chisel, and a little white lead are necessary to do the work. The following directions for carrying out the work are given by the International Harvester Company.

The first thing to do is to cut with the cold chisel a V-shaped crease along the crack from one end to the other, then cut the sheet iron plate so that it will cover the crack and extend one inch on each side, and the same distance beyond each end, lay it over the surface of the cylinder and shape it so that it fits closely; next drill a row of small holes around the edge of the plate, about one inch apart, large enough to admit the screws. Then place this plate directly over the crack in proper position and drill corresponding holes in the jacket, a size smaller than those in the plate and thread them with a tap. Now put some white lead paste in the V-shaped crease over the crack, saturate some of the asbestos wick with white lead and place it directly over the crease the entire length and a little beyond the ends of the crack; then cut out a sheet of asbestos about the size of the plate inside the holes which have been drilled around the edge; soak this in water, place it over the wick and crease and then fasten the plate down securely over all by means of the screws.

In making a patch of this description be sure that all the paint has been scraped off the cylinder where the patch is being made. After the patch has been put in place it can be smoothed down by a file, and then the engine should be allowed to stand for several days before using. A patch of this description will be found adequate in most cases.

# CHAPTER VI

## INSTALLATION OF A GAS ENGINE

There are a number of points which should be considered before purchasing a gas engine, one of which is the amount of power required for the work to be done. It is generally advisable, no matter what style of engine is to be purchased, to buy a unit somewhat larger than what at first may seem necessary. It is always well to have some power in reserve, because an engine working under an excessive load is inefficient and involves a money loss to the owner, because of the wear and tear on the engine.

The style of engine to be selected is determined by the location and the nature of the work to be performed. If the engine is used in a fixed location a stationary type should be selected, whereas the portable type and the traction engine must be selected when the engine is for use at various points and when loads are to be hauled. The selection of the right type of engine is fully as important as the selection of tne right make; also, while attractive paint and a high polish are desirable, these tell very little of the real value of the engine.

When repairs are necessary, the importance of having an engine which has been standardized is fully realized by the purchaser. Repair parts should be obtainable at convenient points within a few hours of the place where the engine is installed, because delays in waiting for repair parts usually prove expensive.

It is important to bear in mind that the rated horsepower of an engine is not always a reliable basis for comparison with the actual power that the engine will deliver. There are many gas engines on the market rated at five horsepower, for example, which will hardly have a maximum output of as much as five horsepower under regular operating conditions. Again, there are engines built by reputable manufacturers which deliver continually an overload of as much as 20 per cent above their rating. If there is any doubt in the mind of the purchaser as to the power possible to be obtained from an engine, he should insist upon proofs of the actual brake horsepower.

When the engine has been purchased, the next thing to consider is where it is to be placed. In selecting the position for the engine, note that it ought to be placed in the cleanest, driest and lightest place obtainable for it. If it is to be belted to machinery which is already in place, it is necessary to decide where the flywheel of the engine will be located and the foundation should be made with this in mind. If the machinery is to be installed later, suitable position for it must be determined at the time the engine is installed in order to insure that no difficulties will be met with in transmitting the power. If the engine is installed in a large room, a small room or space should be partitioned off around it in order to keep out dust and dirt. Under all circumstances, never allow a gas engine, or any other engine, for that matter, to run in the same room where there are emery or polishing wheels.

Assuming the engine to be of the stationary type, the purchaser should obtain a templet and anchor bolts, generally furnished with each engine. The templet is a wooden frame of the size of the bottom of the base of the engine, having holes in it to match the holes in the base of the engine frame.

### The Foundation

The dimensions of the foundation at the bottom should be at least twice the length of the engine base and not less than two and one-half times the width, and the depth of the foundation should be equal to its length. The shape of the foundation is then made in the form of a frustum of a pyramid, sloping up towards the top, where it is only about three inches larger on all sides than the base of the engine. When the hole has been dug in the ground, a form for the concrete must be made and then the concrete is mixed as follows: one sack of good cement, two wheelbarrows of sand, and three wheelbarrows of crushed rock or small gravel, well mixed with plenty of water to make it easy to handle. When putting the concrete into the form it is advisable to use old scrap iron of all kinds, chains, wire, etc., to reinforce the concrete and keep it from cracking. Put in the concrete and scrap iron together, tamping it tightly into the form. Before putting in the concrete, however, place the anchor bolts in the bottom of the hole, with large heavy washers on their heads, and use the templet to locate them properly at the bottom; then run the nuts down on the anchor bolts far enough to allow the templet to rest upon them while locating the bolts at the top at about the level where the engine will be set on the foundation. Then fasten the bolts in some way so that they will not move while the concrete is being put in place. The wooden templet is left on the top of the foundation, the nuts, of course, having been removed when the foundation reaches to them, and the engine is set on the top of the templet, as it is advisable to use a thin strip of wood between the concrete and the cast iron of the base. The foundation should be left to set at least four days before the engine is placed upon it.

### Removing an Engine from a Railroad Car

The foundation now being ready, we will assume that the engine has arrived in a railroad car to the station, and that it is to be removed from there by the purchaser. A few points relating to this operation will prove of value to all prospective buyers of engines. The engine has been delivered to the transportation company by the manufacturer or dealer, properly packed for shipment. The responsibility of the manufacturer or agent stops at this point, and the transportation company is supposed to deliver it to the purchaser in perfect condition. The engine, if of a heavy type, has been transported in a separate car, and is left on a side track accessible for teams. The first thing to do is to have the local station agent make an inspection of the engine in the presence of the purchaser or his representative, to see if it is in good condition and that no damage has been done to it in transportation. Should any damage be revealed at this inspection, the station agent should be required to make a notation of the damage upon the expense bill before the freight is paid. After this is done the transportation company is liable for the damage, if any, and the buyer is safe in unloading and taking charge of the engine.

If any timbers or assistance are needed in unloading the engine from the car, the transportation company, through its agent, is supposed to furnish them. If the transportation company furnishes bad timbers for this purpose and an accident is caused thereby, the mere acceptance by the purchaser of the bad timbers does not place the responsibility upon him. The engine should preferably be moved onto a flat top dray wagon without springs. In moving the engine, take care to see that it is properly supported at all times, and look out for where each step in the moving is going to leave it. If any accident happens to the engine before it is clear of the car or before it is taken off the skids conveying it from the car to the wagon, the transportation company is liable for the damage, because being a local shipment, the company is supposed to remove it from the car and the purchaser is merely acting for the company when taking the engine from the car. After the engine is placed on the wagon, the purchaser is entirely responsible for it.

As an example of what may be encountered in unloading an engine, the following experience may be mentioned. An engine arrived at its destination in good condition and the car was set on a siding near a pile of ties which were to be used in unloading. Some other timbers were also necessary which the agent of the railroad company furnished, but these were not as strong as the man unloading the engine required; however, the station agent informed him that he would have to use them. He went on with the operations, taking extra precautions to brace the weak timbers, but just as the engine was about half way between the car and the wagon, one of them gave way and the engine went into a ditch upside down. The man in charge of the unloading went to the long-distance telephone and called up the general agent of the manufacturing company, stating the circumstances and asking for instructions. He was told to inform the station agent that the engine could not be used, and that it would be left on the railroad company's hands. A new engine was loaded at the factory the same day and shipped, and in that case ample assistance was rendered in unloading the new engine. The first engine was loaded by the railroad company onto a car and returned to the factory free of charge, and the bill for repairs necessary to restore it into satisfactory working condition was rendered to the railroad company, which paid it without a damage suit.

After the engine is safely placed on the wagon it should be conveyed by the safest and easiest road to the place of installation. Avoid uneven ground and bad street crossings; take plenty of time and be sure of every move. Always release the team from the wagon while loading and unloading the engine. In unloading the matter is greatly simplified if two trenches are dug for the wheels of the wagon so that the axles almost touch the ground. In this case, the timbers on which the engine is handled will be more nearly level. If they are entirely level, rollers may be used under the skids to which the engine is fastened. If, however, the timbers slope at all, rollers should not be used. The main thing is to avoid being in a hurry, and not to permit anything else to interfere until the engine has been placed on the foundation.

### Installation of Auxiliaries

The next thing is to select a suitable place for the battery box. This place should be dry and free from vibration. Then connect the wiring as has already been explained in Chapter III. If natural gas is to be used as a fuel, it is necessary to have a special mixer which will be furnished by the manufacturer of the engine. All that is necessary is a gas bag or tank, together with the necessary piping, to allow the charge to be thrown quickly into the cylinder. Some engines use gasoline for a start and then switch onto the natural gas, while others start directly on the gas. If the engine *will* start directly on the gas, there is no good reason for using gasoline.

If liquid fuel is to be used, it is advisable to place the fuel tank outside of the building and it is still better to bury it in the ground. After the tank has been buried in a suitable place, it is an easy matter to arrange the piping to the fuel pump on the engine. As far as possible, this piping should be underground, as it is out of the way. A pipe for the fuel, passing from the pump to the mixer, and a pipe for the overflow to return from the mixer bowl to the tank, must be provided as already explained in Chapter II. If the overflow pipe stops at the top of the fuel tank, it will not be necessary to have a vent hole at the top of the tank, as the air will flow into the tank from the overhead pipe which will not always be full of gasoline. The pump pipe should pass to the bottom of the tank and should be provided with a fine screen to prevent foreign substances from passing into the mixer.

### Starting a New Engine

After the engine is properly installed, the first thing is to start it running. This is done by turning on the battery switch, setting the needle valve in the starting position, turning off the air damper, releasing the compression, and giving the flywheel a few turns, which will put it in motion. After the engine has made a few revolutions, open the air damper, close the needle valve to the running position, put the relief cam back into place, and let the engine run, watching for developments. It is, of course, presumed that all the oilers and grease cups have been filled, and that all movable parts have been oiled with the oil-can. Now see that water enters into the cylinder cooling jacket within five minutes, or stop the engine, as it is not safe to allow the engine to run without cooling water in the jacket. It is best to allow the engine to run an hour or so without any load, and to watch the bearings to see that they do not overheat or get warm. In case of doubt on any point, stop the engine and make an examination.

In cold weather, a gasoline engine is more difficult to start than in warm weather, the reason being that gasoline, in changing from a liquid to a vapor, reduces its temperature about 30 degrees F. If the air is cold on the outside of the cylinder and the mixer has taken in vapor 30 degrees colder, it is easy to understand that this would interfere with the proper vaporization. Hence, it will be difficult to start the engine. There are several methods to overcome this difficulty, either by warming the gasoline, warming the air, or by using one part ether and four parts gasoline for a start; this will make a liquid which will vaporize readily several degrees below zero. To warm the gasoline is a process which is dangerous and should only be attempted as a last resort. It can be done safely only by using hot water or a hot cloth. The air may be warmed by heating a piece of iron red-hot and holding it at the mouth of the intake pipe, allowing the air to pass over the hot iron as it passes into the intake pipe, after which it joins the gasoline vapor and raises its temperature.