Operation and Maintenance of Mechanical Prime Movers

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Part 1

Introduction

This paper is divided into two sections—the first covering a discussion of the types of prime movers used in the oil fields, their cooling systems and ignition. The second part covers fuel systems, lubrication and general maintenance items.

Almost all types of prime movers have been used at one time or another in the oil fields. Some of these have proven satisfactory, but many others have been discarded in favor of more acceptable types of equipment. Before we can properly operate and maintain oil field prime movers it is necessary that we understand the basic operation of the engine or motor.

There are four basic types of prime movers used in the oil fields:

(1) Electric motors.

(2) Four cycle high speed multi-cylinder engines.

(3) Four cycle slow speed engines.

(4) Two cycle slow speed gas engines.

Electric Motors

Electric motors are entirely different from internal combustion engines. It is not within the scope of this paper to cover electric motors completely. Normally, 900 and 1200 RPM AC motors are used in oil fields. The motor operates at a constant speed and its speed cannot be changed. Voltage required for operating these motors is usually 220 or 440 volts alternating current. There are both single and three phase motors. However, the single phase motor is usually applied to small jobs up to approximately 7½ HP and are used on REA lines where three phase current is not available. Starting of electric motors is usually directly across the line, i.e., the switch is thrown and the starting current is high but the motor obtains its speed very quickly and the current returns to normal for the motor.

Maintenance on electric motors is very simple. They should be kept clean and free from oil on and around the windings. The bearings may be either grease packed or oil lubricated. These should be checked according to the manufacturer's recommendation. All terminals should be made tight and breaker points on starters kept in good condition. Heaters are used as an overload device whereby if the load on the motor is too great a small bi-metal strip is heated until it trips and opens the line switch. This is protection for the motor. The heater should be installed large enough to accommodate the expected load of the motor, but not too much greater so as to provide protection of the motor and the pumping equipment.

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Engine Cycles

To understand the operation of an internal combustion engine we must first understand what takes place to turn the air and gas fuel into power. There are two types of cycles used on engines. We will discuss the four stroke cycle and then the two stroke cycele in order to understand the difference in the types of engines.

A four stroke cycle engine, normally called a four cycle engine, requires a piston connection to the crankshaft. Push rods are used to push the intake and exhaust valves open at the proper time. A spark must occur at the spark plug at the exact time to develop power.

Let us follow through the four strokes of a four cycle engine and see what takes place. The strokes of a four stroke cycle engine are:

(1) Suction

(2) Compression.

(3) Power (Expansion)

(4) Exhaust

Now looking at Figure (1a) we note that the piston is moving away from the cylinder head and that the intake valve is open. This movement of the piston pulls into the cylinder through the mixer, or carburetor, an air and gas mixture. In Figure (1B) we notice the piston has reached the bottom of its travel and is moving toward the cylinder head; you will note that the intake valve is closed. This piston moving up compresses the air and gas mixture until it reaches the end of the stroke nearest the head where the magneto causes a spark to jump the plug gap and ignite the compressed mixture. The third stroke (1C) is away from the head and is called the expansion, or power stroke, because the pressure of the burning and expanding gases push the piston downward. As the piston reaches the end of this stroke (1D) the exhaust valve is opened and the momentum of the engine pushes the piston back toward the head, forcing the burned charge out through the exhaust valve, thus completing one cycle of the four stroke cycle engine.

Now we see that four strokes are necessary to complete the cycle and that the crankshaft has made made two complete revolutions for one power stroke.

A two stroke cycle engine, normally called a two cycle engine does not have valves in the cylinder head, but ports cast in the cylinder walls. The piston passing over these open and close the openings. The intake ports carry the fresh fuel charge into the cylinder and the exhaust ports carry the burned charge away. It is necessary that a magneto deliver a spark through the spark plug at the exact moment required when the piston reaches the head end.

Now let us follow through the events of the two stroke cycle. The strokes of a two stroke cycle engine are:

(1) Compression and suction.

(2) Power and exhaust

Referring to Figure 2a, we find that the piston is moving toward the cylinder head, thus compressing the charge in the cylinder.

At the same time, a vacuum is created on the under side of the piston which pulls in through lightly loaded strip valves the fresh charge. This area into which the fresh charge is pulled is known as the scavenging chamber. The scavenging valves are away from the heat of combustion and operate by a difference of pressure inside and outside the scavenging chamber.

As the piston reaches the end of its stroke nearest the cylinder head, the compressed charge is ignited by the spark plug.

The piston then moves downward on the power stroke caused by the burning and expanding of the charge just ignited by the spark plug. This is shown in Figure

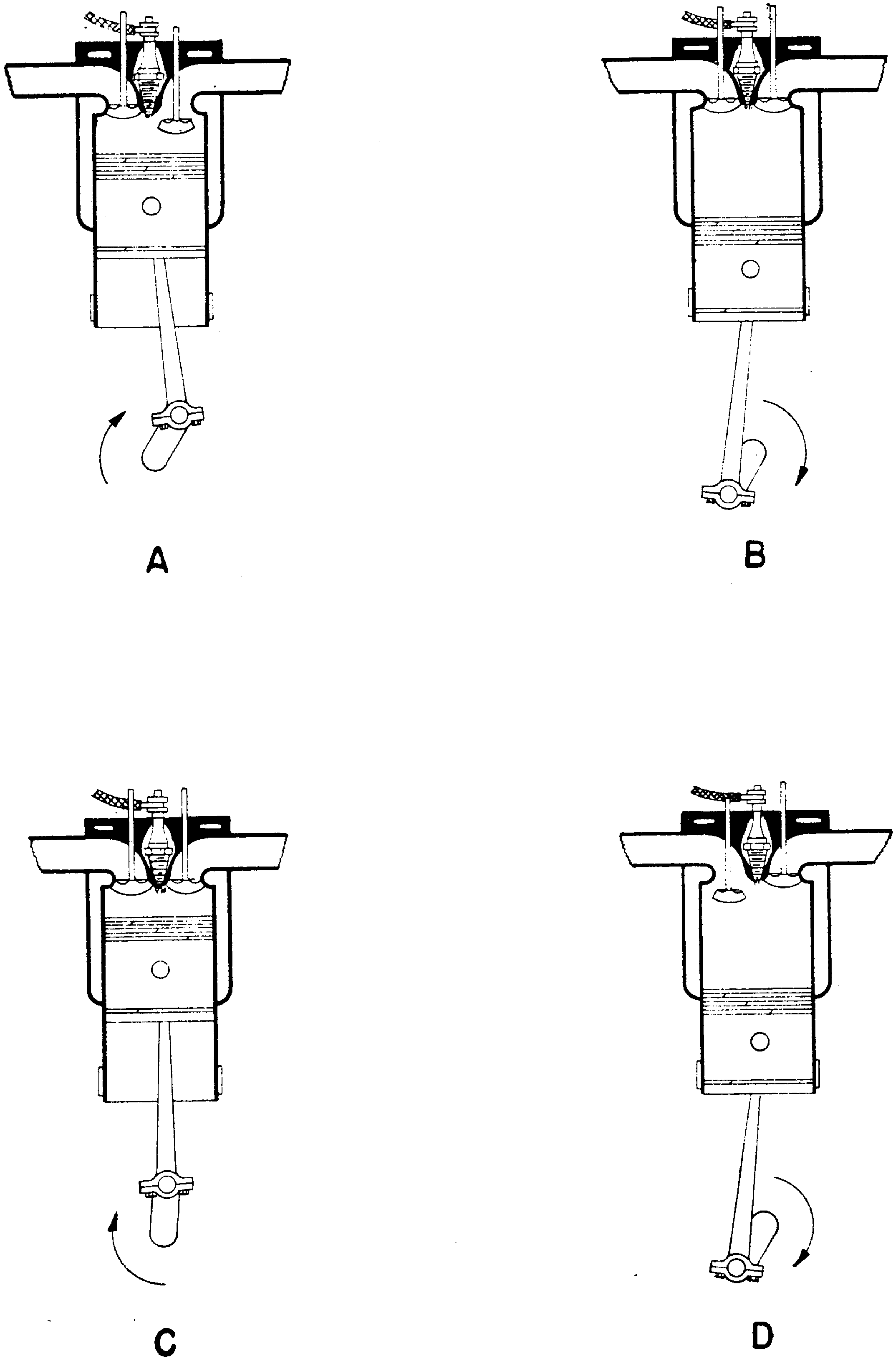

FIG. 1

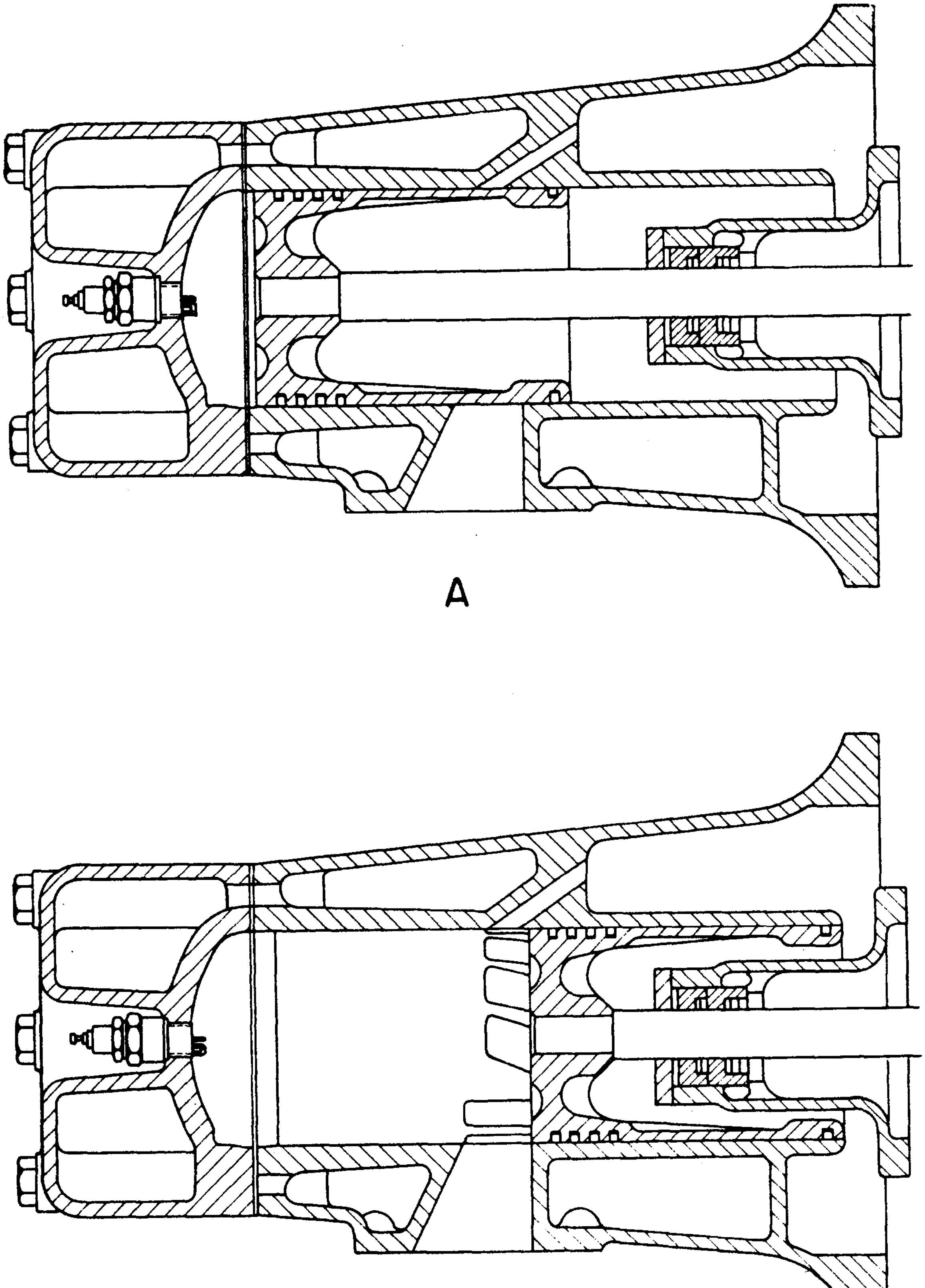

FIG. 2

(2B). While the piston is moving downward on the power stroke, the under side of the piston is compressing the fresh charge of gas to a low pressure of 2 to 5 pounds.

Now as the piston moves down far enough there is a series of quick happening events. The exhaust ports are uncovered by the piston, which allows the high pressure gases to blow out into the exhaust pipe. Further downward motion of the piston uncovers the intake ports, allowing the fresh charge to flow into the cylinder. This is directed toward the cylinder head where it sweeps the cylinder completely and pushes out the remaining burned charge of gas, thus completing the cycle of operation in two strokes, or one revolution of the engine crankshaft.

Four Cycle High Speed Multi-Cylinder Engines

Four cycle multi-cylinder engines had their beginning as an engine built for automotive, truck or tractor service. Adaptation of radiator, clutches and weather covers over the engine made it a light, compact engine for the oil fields. These engines normally are classed as high speed multi-cylinder type and operate on the four stroke cycle principle. Their piston speed is high since they were designed for higher speed service than is desired in the oil field. They normally have a small capacity oil pan and require rather frequent oil changes. Their life is reasonably short, and when this type of engine needs repairs they should be put into the hands of a first class engine mechanic.

Four Cycle Slow Speed Engines

Four cycle slow speed engines are usually of a single horizontal cylinder. They have been made for a great many years for the oil fields, the earliest of these being the old Superior 200 RPM heavy duty engine. Today the same principle holds true. However, the engines have been much improved and are made in smaller, more compact jobs. Actually, this type of engine has the same working parts that you will find in one cylinder of a multi-cylinder engine, i.e., they have both intake and exhaust valves, trunk piston, and are usually splash lubricated from the crank case. Their speeds run from approximately 300 RPM to 600 RPM. Their parts are large and simple and can usually be repaired at the well location. Most of these engines now use steam condensing type radiators which eliminates the need for a water pump and other equipment. Representative engines of this class are Fairbank-Morse, CSCO, Witte, and Le Roi A288.

Two Cycle Slow Speed Gas Engines

The earliest heavy duty engines used in the oil fields were single cylinder, two cycle, crosshead type engines. Likewise, they have been much improved and today are produced as single and two cylinder horizontal engines.

These engines are very simple in construction and are easy to maintain. They have few moving parts. In order to service the cylinder block assembly it is not necessary to disturb the crank case assembly as it is with a four cycle engine. The two cycle engine operates at speeds of 300 to 600 RPM. The engines are either splash or pressure lubricated. A force feed lubricator furnishes a fixed amount of oil to the cylinder at all times, thus the oil system is under the control of the operator.

Cooling systems on two cycle gas engines may be radiator, condenser, or thermo-syphon.

The two cycle gas engine built today is the only type in which the products of combustion do not get into the crank cases and destroy crankshafts, etc., because of acids. Therefore, the two cycle engine has given a good account of itself in the sour gas fields.

In two cycle gas engines it is very necessary that the exhaust pipe be of proper size and length as given you by the manufacturer as a two cycle engine gets most of its scavenging effect through the exhaust pipe.

This engine, like all other engines, has certain drawbacks which you men, as operators, are very quick to point out. One of the most common complaints with the two cycle crosshead engine is it tends to misfire or run very irregularly unless fully loaded. Some men feel that the engine is not operating properly under such conditions. The fact remains that this is the nature of the two cycle engine, that it does not have sufficient charge in the cylinder at light load to fire regularly, or "around the clock." Many old-times thought a two cycle engine would burn up and was heavily overloaded if it was firing regularly. This, of course, is not true and any time that you hear a two cylinder engine running and not hitting evenly you can assure yourself the engine is not hurting itself, or is it anywhere near loaded.

Ignition System

Almost universally in the oil fields, engines depend upon magnetos for setting off the electric charge that fires the air-gas fuel mixture in the cylinder. Magnetos generally give considerable difficulty; however, after all, considering the abuse they take, they are very dependable mechanisms. The ignition system of a gas engine compresses a magneto, which is properly timed in relation to the engine, ignition cables and spark plugs to fire the compressed charge. Also, miscellaneous wiring necessary to connect the various safety devices to the ground side of the magneto in order to shut the engine down in case of failure of some part.

Magnetos

Magnetos generally are of two types—rotary brushes and jump spark. By this we mean, with the brush type magneto, the high tension current is passed to the spark plug terminals through a carbon brush, which is spring loaded, rubbing over a brass contact point; whereas the jump spark type, the high tension current jumps from a distributor rotary to the distributor cap at the proper interval. Magnetos may either be base mounted or flange mounted. Practically all oil field magnetos are equipped with an impulse coupling to provide a hot spark when cranking the engine slowly by hand. The spark automatically advances to a proper running degrees as soon as the engine speeds up enough to centrifugally disengage the impulse coupling.

The proper timing of a magneto is highly important and performance of the engine is seriously affected by an improperly timed magneto. It is necessary that the spark be delivered to the spark plug at the exact interval that it is needed by the engine to burn the mixture within the cylinder. This varies with types of engines, and, of course, with speed. Normally, the running spark of a magneto is set for 15 degrees BTC, which means that the magneto delivers its spark to the spark plug when the piston of the engine is 15 degrees, as measured on the crankshaft, before it reaches the top and starts on its downward stroke. This is necessary because of "combustion lag." With a timing such as this, the rotative speed of the engine is such that the piston has passed top center and is starting down before the full force of the burned charge is exerted.

Normally there are two ways of timing a magneto to the engine. Some men use impulse release, others set by actual breaker point opening. By the first, we mean that the impulse coupling on the magneto releases, giving off a spark just after (0 to 5 degrees ATC). If the magneto is properly constructed for the particular engine, the running spark will then likewise be correct. The impulse lag of a magneto varies with the engine. On most two cycle engines the magneto runs at twice engine speed and the impulse lag is set at approximately 35 degrees, which means 17½ degrees advance. Therefore, if the impulse released 2 degrees ATC, then the running spark would be 15½ degrees.

The second method is to remove the distributor cap, turn the engine to where the magneto distributor contact is at the position of the number one cylinder. With the impulse release, the magneto is then rotated slightly until the breaker points just break with the engine flywheel set in a running spark poistion.

Magneto Care

The magneto is a highly developed electrical mechanism delivering a very high voltage. If it is not kept clean, dirt will form an electrical short circuit and prevent the magneto from delivering a hot spark to the spark plug. All dirt and oil should be kept wiped off the magneto, particularly that of the distributor cap.

The breaker points must be kept properly adjusted, normally .015". These points must be absolutely free of oil and smooth so that they will make as large a contact as possible. The breaker points are adjusted by loosening a locking screw and turning the second screw holding the fixed breaker point. The magneto is then rotated so that the cam moves the movable point. At the highest point of its movement, set the points to be open .015" and securely lock in place.

The condenser, which is a small tubular device with one wire leading to the breaker points, is a very vital and necessary part of the magneto. This condenser acts as an absorber for the rush of the electric current at the time the breaker points open and prevents arcing and burning of the breaker points. If the points are burning it is usually an indication that the condenser is bad. Each time it is necessary to renew breaker points, the condenser should also be renewed. The only lubrication required by the magneto is a small amount of petroleum jelly on the felt cam wiper. If this felt is lubricated each time an adjustment or replacement of points is made, considerably longer life will be secured from breaker points.

The impulse coupling on an engine is only in use when the engine is being started. This device, usually considered a part of the magneto, is centrifugally operated. At slow speed, driving lugs engage a spring and stops rotation of the magneto rotor and winds the spring up until a certain point is reached in the rotation of the magneto where the driving lugs release the rotor of the magneto and causes it to rotate very fast, giving a hot starting spark. As soon as the engine has started and speeds up, centrifugal force causes the driving lugs to align outward and not catch the rotor of the magneto. As soon as this happens, the magneto is automatically advanced to the running spark position, which is normally 15 degrees BTC.

Ocassionally the impulse coupling will become gummed with heavy oil and will fail to operate properly. Do not, under any circumstances, hammer on the magneto as this will certainly do damage. The magneto should be removed from the engine and the impulse coupling washed out with kerosene or solvent to remove the gummy deposit. If this does not correct the impulse coupling, it should then be serviced as parts may be worn or the spring may be broken.

Spark Plugs

More good magnetos have been ruined by bad or improperly adjusted spark plugs than from any other reason. A magneto under atmospheric conditions may give off a spark as much as 3/4" long, but under the compression of the engine it is very difficult for a magneto to jump a spark gap of 1/16". Spark plugs normally are adjusted to approximately .020" and vary from .010" to as much as .040", depending upon the compression of the engine used. However, if your manufacturer tells you that a spark plug is to be set at .020", they should be maintained at this point as nearly as possible, as allowing this gap to increase to .030" doubles the load on your magneto. After all, electrical equipment will only stand so much and then insulation breaks down. Spark plugs should be checked certainly not less than each week. In sour gas areas checking of plugs more often is sometimes necessary.

The installation of a spark plug in the engine cylinder is important. New plugs are furnished with a new copper gasket. This gasket not only seals the combustion but has a great deal to do with dissipating heat from the spark plug to the cylinder head. It is therefore necessary that the spark plug can operate properly.

Spark plug manufacturers normally make two types of gas engine plugs. These are single and triple ignitors. Spark plugs are of three normal heat ranges, namely, hot, medium and cold. There are in addition plugs made particular for use with sour gas. Incidentally, the points of a sour gas plug will burn very rapidly if used in an engine operating on sweet gas.

The engine itself normally will tell you the heat range of a spark plug to use. If your engine comes equipped with a certain plug, this plug may be suitable only for average conditions. The plug may be entirely too cold if your engine is lightly loaded. This is evidenced by the porcelain of the plug having a carbon formation, or in extreme cases, filling up of the areas between the body and the porcelain with carbon. If this is your condition, then you need a hotter plug, one which runs hotter and burns up the carbon. If, on the other hand, you have an engine that is excessively hard on plugs, i.e., rapidly burns up the tips and the porcelain, then you need a colder plug because either your gas or your load conditions demands a cooler running plug.

Single ignitor plugs normally require more frequent adjustment than do triple ignitor plugs in that with the triple ignitor there are three ground terminals, all of which are set to begin with as near equal as possible. However, as one should burn, the other two in sequence take up and discharge the magneto current through the points. They cost more, however, it is the writer's experience that they are worth it.

In setting of spark plug points, all adjustments should be made on the ground electrode. You should not guess at the gap but use a round wire spark plug gauge. Keep the outside porcelain of the plug clean and free from dust and oil. Many times an engine will shut down in a light rain and the pumper blames it on many things other than the true cause of the shut-down, i.e., dirt on the porcelain which acted as a conductor of the magneto current.

A little trick after installing new spark plugs is that after they have run until thoroughly heated, it is well to shut down, remove the plugs and re-adjust the points. Very frequently under this first heating condition the setting of the plugs will change. They may close or may open, thus disturbing the setting which you thought you had.

Safety Controls

In the ignition system of an engine there are usually various safety controls put on the engine for your protection. We say your protection, because in a sense it is. It is, of course, for the final protection of the engine. The types of controls available for engines are:

(1) High water temperature control
(2) Low water level control
(3) Low oil pressure (low oil quantity)
(4) Miscellaneous, overspeed, beam switches, etc.

All of these ground the primary side of the magneto when the safety device gives a warning, thus shutting down the engine.

These controls can be broken into two categories—those which operate by means of a float, and those which operate by means of pressure exerted within a capillary tube, which is caused by higher temperatures or lower pressures than they are normally set for. All safety controls should be kept in working order, periodically checked to see that they are functioning properly, and replacement should be made any time that any of the safety devices fail to function properly.

Wiring should be kept in good condition and free from oil and dirt. It is just as important that the primary wiring be kept in good condition as it is that spark plug wires be kept clean. Broken or frayed wires should be replaced.

Cooling System

Every engine must have a means of dissipating the heat created by combustion. Normally, of the gas burned in an engine, one-third of its heat value is lost to cooling, one-third to exhaust, and one-third to actual power. Therefore, it is necessary to provide a cooling system that will properly cool the engine under extremes of temperature. There are two types of cooling—air and liquid. Air cooling is restricted to very small part-time operation engines. Liquid cooling is universally used on oil field engines. There are three types of cooling systems commonly used:

(1) Radiator with water pump temperatures 140-180 degrees F.

(2) Condenser (sometimes spoken of as vapor phase—operates at a constant 212 degrees F.

(3) Thermosyphon — operating with normal outlet water temperatures of 160 to 225 degrees F.

The first method mentioned, i.e., Radiator and Water Pump Installations, are most frequently found on multi-cylinder engines. They have been used on slow speed engines. However, for the oil field pumping engines there has been a great desire to eliminate the water pump as it is a source of continuous difficulty. Thermostats are frequently used in the water line from the cylinder head to the radiator, often with a by-pass arrangement which allows the water pump to circulate the water through the block without passing it through the radiator. These are used to attempt to hold a constant temperature of the cooling fluid.

Condenser cooling is used quite extensively on small oil field pumping engines. This system maintains water at 212 degrees, or the boiling point, irrespective of engine load or outside temperatures. There is water surrounding the cylinder walls and head. A reservoir or steam chest is provided above the cylinder for the steam coming off the water to expand into. A small fan cooled condenser is then mounted on top of this expansion chamber. The pressure created by the steam coming off the rapidly boiling water forces the steam up into the tubes of the condenser where it is cooled by the fan and reduced back to liquid form, returning to the block. This type of cooling does not function until the water reaches 212 degrees at sea level and starts giving off steam It is very efficient and requires a much smaller radiator than conventional radiator and water pump installtions. It is highly important that the water level not be greater than that which is shown by the manufacturer, usually by means of a sight level or a test cock on the side of the steam reservoir. If filled too full, the safety controls will shut the engine down, or water and steam will be blown out of the engine until its operating level is reached. It is necessary that the filler plug be tight in its place. It is also necessary that the small vent hole usually found in the center tube of the system be kept open. Closure of this small vent hole can cause steam pressure to burst the radiator, or to cause the radiator to collapse from vacuum when the engine is shut down.

Thermosyphon cooling today is highly improved and pressure caps carrying the pressure up to 7 lbs. make it a very desirable cooling system for oil field engines. The principle is that of the Model T Ford. It has the advantages of having a radiator, cylinder block and head completely filled with the cooling medium. If leaks occur, they can be detected by seeing where the water drips. This system works entirely without a water pump. It is necessary that both inlet and outlet hose and piping be large and free of sharp bends. The water heated in the cylinder becomes lighter and flows up the pipe leading from the cylinder head to the top of the radiator, this lighter water being displaced by cooler water in the block, causing a constant uniform circulation. This system lends itself very well to variation of atmospheric temperatures. Normal outlet water temperatures vary with the load and speed of the engine. With light loads the water temperatures are lower. In extreme cold weather it is desirable to cover a portion of the radiator in order that the incoming water into the cylinder block is not too cold.

The maintenance of cooling systems generally is very simple. It is necessary that the radiator core be kept free of dirt, oil, bugs, etc. as the fan pulls or pushes the air across the fins, taking out of the radiator the excess heat. A dirty radiator becomes very inefficient and causes extremely high temperatures, cracking of heads, etc. Externally it is a matter of housekeeping. The inside of the cooling system also must be kept clean and free from scale and oil. This is best accomplished by using pure water in the initial and subsequent fillings. Rust inhibitors may be added. It is well at least once each year that the cooling system be given a good purge of radiator cleaning solutions to remove sludge, scale, etc.

Fans are usually driven by V-belts from some moving part of the engine. They are usually mounted on ball or roller bearings in a housing packed with grease or filled with oil. If oil is used, make sure you follow your manufacturer's recommendations. If grease is used, make sure that it is a high temperature, long fibre, ball bearing grease so that under operating temperatures it does not thin out and soon sling itself out of the fan hub. Under no circumstances should you use chassis lubricant as it is entirely too light for the heat encountered.

Fan drive belts should be kept snug, but no tighter than necessary to drive the fan without slipping. Belts too tight will cause excessive wear of bearings in addition to early replacement of drive belts. Water pumps should be greased according to manufacturer's recommendations, or kept in good order. If there is a leak at this point, it will usually show up by the engine boiling over or heating and throwing the water out of the radiator. This is usually caused by a suction leak either in the pump or on the suction side of the pump.

Since we are subject to varying temperatures from summer 100 degree heat to winter 0 degree cold, it is necessary in the winter that engine cooling system be protected from freezing by the addition of antifreeze solutions to the cooling water. The cooling system should be thoroughly re-conditioned, all weak or bad hose and connections replaced, and hose clamps tightened before filling with anti-freeze. Ethyl Glycol, or permanent type anti-freezes, we believe, are the best investment as one filling will last an entire winter. However, alcohol base solutions may be used. The basic idea of adding anti-freeze is to raise the freezing point of the water. At the same time you do this, you also raise the boiling point, and on condensing types of engines it is highly important that not more than 50 percent of the cooling solution be that of the anti-freeze. This will normally give protection down to minus 40 degrees F. One-third the cooling system capacity gives normal protection down to 0 degrees F.

Part II

Fuel System

Oil field prime movers are primarily operated on natural gas, either taken from the separator on the lease, or from residue lines. Where the gas is taken from the casing head directly to the engine, usually considerable difficulty soon arises. Gasoline is used for starting, mainly of multi-cylinder and single cylinder four cycle engines. It should never be used except in emergencies with two cycle engines. Engines which can operate on gasoline are usually furnished by the manufacturer with a combination gas-gasoline carburetor. When using gasoline, it is necessary that this fuel be converted into vapor before it can be utilized by the engine. Therefore, natural gas should provide a better starting mixture than does gasoline, provided the air to fuel ratio is correct. Normally, to have an explosive mixture, we have 14 parts of air to one part of gas vapor. To obtain this correct mixture it is necessary to have proper mixing equipment, which is in the form of a carburetor or gas mixer. This is usually mounted on the intake manifold of the engine.

For our discussion here we will consider natural gas only. The gas comes from the separator or the gas line under pressure where a 1" reducing regulator reduces the line pressure down to approximately 4 to 6 oz. of pressure on the outlet side of the regulator. This regulator is usually mounted on what is known as a volume tank. This tank should have at least five times the displacement in cubic inches of the engine. Some volume tanks are of two compartments, the first one acting as a scrubber in which the gas is bubbled thru water or light oil to remove dirt and other impurities from which it then goes into the volume tank. The volume tank has been thought to be a necessity in order to prevent uneven running of an engine due to pulsation within the engine. It has now been proven, and although a number of engines are running without a volume tank, we still strongly recommend the use of a proper scrubber to prevent dirt, water and oil from finding its way into the engine. We find that it is necessary that the regulator be placed very close to the engine if no volume tank is used. The gas is admitted from the volume tank to the engine through a dial cock, or a shut-off cock, or an Ensign "B" regulator. On some of the simpler gas mixers the dial cock is used to regulate the amount of gas going to the engine. Each speed and load has its own setting. This is determined by experience. When using Ensign carburetion a shut-off cock is all that is necessary as the Ensign "B" regulator is a sensitive fuel regulator admitting gas to the engine in the amount that it is actually required by the engine. When the engine is at rest, the fuel is automatically shut off.

The gas comes to the engine mixer where it is mixed through a Venturi or orifice with the proper amount of air. A load screw is usually provided to adjust the amount of gas that is going to the engine for a given air intake requirement. A butterfly valve on the mixer closes the entrance to the engine. This butterfly is actuated by the engine governor which sets the speed at which the engine is to operate.

After the air-gas fuel mixture leaves the mixer, it enters the engine through scavenging valves described before in the case of two cycle engines and through the intake valves of four cycle engines.

Air Filters

Practically all oil field engines are equipped with oil bath type air filters. The filter is placed on the engine to cleanse as near as practical the air of dust and abrasive matters. It is therefore highly important that the air filter be kept in good operating condition, the dirt accumulating in the oil chamber removed, and the filter filled to its proper operating level with oil. Gaskets or hose connections between air filter and the engine proper must be maintained so that they are air tight, causing all of the cleaned air to enter the engine through the filter.

In very dusty areas such as West Texas, it is vitally important that after each dust storm the air filter be removed and thoroughly cleaned and serviced.

Governors

The proper speed control of an engine as mentioned above depends upon the governor. The governor operates by centrifugal force resisted by a spring. Most oil field slow speed engines operate directly on the governor, whereas multi-cylinder high speed engines usually have a speed limiting governor with a hand throttle control for all speeds below the maximum governed speed. It is very necessary that the linkage between governor and the mixer, including all ball joints, shafts, etc., be kept properly lubricated so that there is the least possible friction, as governors are not made to operate against any appreciable friction.

Clutches

Clutches used on oil field engines are usually dry friction type. The pressure exerted by pressure plates upon friction discs provide positive non-slipping engagement, long life, and trouble-free operation provided they are properly adjusted and maintained. The pressure exerted upon the pressure plate is by means of a hand lever for engaging and disengaging. Adjustment should be made of the adjusting yoke so that a decided pressure and snap is required when the clutch is engaged. Running an engine with the clutch adjusted so loose that you do not hear a distinct snap when engaged very frequently is the cause of worn out and burned up friction discs. If a clutch similar to the Twin Discs is dismantled, the shaft bearings should be properly adjusted to where there is some slack or movement of the shaft. On Twin Disc clutches this is accomplished by a threaded bearing adj. nut which is screwed down until the bearings are snug, then backed off from this position three to five notches, allowing some looseness of the shaft within the housing.

The clutch pilot bearing forms the other supporting end of the clutch shaft and take some of the radial load imposed by the V-belt drive. Normally, this bearing does not rotate except when the engine is running and the clutch is disengaged.

Lubrication of the clutch is very important if you, as an operator, expect to get trouble-free service. Normally, there are three points of lubrication, these being provided on the clutch in the form of grease fittings. The grease fitting in the end of the power take-off shaft lubricates the clutch pilot bearing. The other two fittings are located on the housing of the clutch. One of these supplies grease to the main drive bearings, the other one to the bronze throwout collar, which is sliding on the clutch throwout. This bearing should be greased with a small amount of grease each 24 hours. Normally, greasing the other two bearings once each week is sufficient.

We would like to add a word of warning to those who like to run their drive belts from the clutch to the unit very snugly. Many a clutch bearing and clutch shaft, as well as the bearings of the input shaft of the pumping unit, have been damaged because of excessively tight belts. The nature of the V-belt is that it does not require fiddle-string tightness in order to transmit its power. The belts should be adjusted only tight enough that they do not slip. Do not try to adjust them to where whip or slap is taken out of them. This whip or slap is usually due to unbalanced conditions and you are only aggravating the situation by trying to tighten the belts.

Starters

In the early days, all oil field engines were started by tromping the flywheel. Many men have been hurt by this process. Manufacturers have done their share to eliminate this hazard by providing starters. Some of the open flywheel types of engines are still started by kicking. There are available the following types of starters:

(1) Electric
(2) Air-gas motor
(3) Friction wheel
(4) High pressure air
(5) Hydraulic motor

(1) Electric starters are either of 6 or 12 volts and require a battery for starting. Engines can be provided with generators for recharging the battery or plug and cable can be provided where one battery is used for several engines.

(2) Air gas motor starters take from 30 to 60 lbs. of air or gas available at the engine. They are small gas turbines which turn the engine over through a Bendix or over-running clutch.

(3) Friction wheel starters are adapted only for open flywheel engines. They are usually driven by a small air cooled gasoline engine through a reduction gear to a friction coated wheel which is pressed in contact with the rim of the flywheel when starting is needed.

(4) High pressure air (150 ib.) supplied by a small compressor and storage tank is used on some engines. A cam on the engine admits air through a check valve to one cylinder of the engine, and is timed to shut off the air when the piston reaches the end of its stroke. Thus the engine is caused to rotate until it fires.

(5) Hydraulic starters have been adapted in a few instances. This consists of a high pressure (3,000 lbs.) hydraulic pump which forces oil into an accumulator receiver. At the moment of starting a valve is released which causes the hydraulic motor to operate at a very high rate of speed. This in turn drives through a Bendix or over-running clutch to a ring gear on the crankshaft of the engine. So far, these have not become universally used in the oil fields, but do offer a system of starting that does not rely upon batteries or hard to start small gasoline engines.

Starters of all types require servicing. Proper cleanliness of fuel, checking of air filters and changing of lubricating oil is necessary in air cooled gasoline driven type. Proper lubrication and filtering of the incoming gas is necessary in the air-gas motor turbine type. Batteries must be maintained in fully charged condition for proper operation of electric starters.

Lubrication

Every internal combustion engine has close fitting parts that are under extremes of pressure and temperature. If these parts are not properly lubricated, excessive wear and short life are the results. The manufacturer of your engine has spent years in determining the proper fits for parts of your engine. He knows what lubricant is best and so advises you in your instruction manual. All oil companies are in position to furnish lubricants that are suitable for this equipment. Their dealers are supplied with recommendations for the proper weight and type of oil for your engine. You should rely upon them in the absence of experience with a given engine and its lubrication.

Oil Viscosity and Types

The viscosity of an oil is a measure of the resistance to flow. Oils have become standardized by the Society of Automotive Engineers (SAE) into certain classes where their viscosity range is known. The lower the SAE number, i. e. SAE 10, the lower the viscosity or the thinner the oil is made, and consequently the more readily it flows at low temperatures.

All lubricating oils change their viscosity with changes of temperature. It is necessary that an oil be used which will readily flow at the lowest temperatures expected yet must be heavy enough to give protection to engine parts when heated to normal engine temperatures. Normal oil field engines use SAE 20 or SAE 30 oils. The heavier oil should be used in Summer heat in order to have a sufficient film of lubrication on all moving parts.

Please bear in mind that the viscosity of an oil is no measure of the quality of an oil. Oils are classified as to grades according to the method of refining and the base crude stocks from which they are made. Lubricating oils are classified as napthenic or paraffinic depending from which base crudes they are derived.

The refining processes also vary with grades or qualities of oils. Straight run oils may be blended with several types of crudes and may be solvent extracted producing an entirely different oil than the base stocks from which they were made. The important thing to remember is that all oils are not alike and that different oils are made for specific purposes and are not suitable for all applications.

Detergents and additives have their places. Their purpose is to keep the solids of contamination suspended and to prevent formation of harmful acids, etc., from affecting the real purpose of the lubrication—that of forming a film of oil between all moving parts to reduce friction and wear at all heats and pressures encountered. HD oils are sometimes referred to as High Detegent or as Heavy Duty. Heavy Duty oils are compounded and blended to withstand higher temperatures and pressures. They may not necessarily be high detergent..

Lubricating Systems

Oil Field engines are lubricated by one or more of the following:

1. Splash Lubrication
2. Full Pressure Lubrication
3. Combination of Splash and Pressure

The splash system is very simple but is limited to low speed and low output engines. This system has an oil pan or sump into which the connecting rod dips and splashes oil to all working parts of the engine. A small dipper on the end of the rod picks up oil and carries it through a hole in the connecting rod in order to lubricate the crank pin bearing.

The oil level in a splash lubricated engine must be closely watched; a dip stick or visible oil level shows when oil must be added. Filling the crankcase too full of oil floods the engine and can cause excessive carbon and sludging to form. Likewise if the level is too low for the rod to dip into there is danger of ruining an engine from lack of proper lubrication.

Full pressure lubrication requires that the engine have a positively driven oil pump which picks up oil in the base and forces it through drilled passage to all working parts of the engine. This system is very dependable and is used in almost all engines built today.

Where a pump is used a pressure control or relief valve is mounted as a part of the pump or located somewhere in the oil lines. This is used to maintain a pressure set by the manufacturer. A pressure gage is a part of the system to show the operator the pressure in the system. Gages sometimes fail to function properly but oil pumps seldom need any attention.

On the suction side of the pump, located in the base or sump a strainer is mounted to strain the oil or sediment and coarse particles of carbon, etc. This strainer may be fixed or floating. Each time the crankcase oil is changed this screen or strainer should be cleaned. The oil sump of a pressure lubricated engine usually is larger and more oil is carried in the base, reducing the frequency of oil changes and provides a greater reserve of oil from low to full marks of the oil level gage.

Some engines are built with a combination of splash and force feed lubricating systems. When this method of lubrication is used a small oil pump puts oil into a trough where the connecting rod dips into the oil in the trough. Here splash lubrication takes over. In fact, all engines, whether full pressure or not depend upon splash and spray to lubricate many of the moving parts of an engine.

Lubrication of Four Cycle Engines

Normally four cycle engines operate on todays motor oils. Frequent oil changes are necessary in that some of the products of combustion find their way past the piston and rings into the crankcase. There is also a tendency for these engines to sludge. Sludge is caused by water vapor, dirt and oil being churned up together. No set time can be made for changing oil in the crankcase as this depends upon many factors beyond the control of the operator. An engine with worn rings allows more blowby and usually more frequent oil changes. Oil changes must be determined by the condition of the oil, or by a schedule based on past experience. A change of oil is needed when the oil looks black and feels that it has lost its body or is contaminated to an extent that acid forms. A sour smell sometimes indicates this condition.

Oil changes are made while the oil in the engine is warm and before the solids have had a chance to settle out into the bottom of the sump. Where cleanout covers are provided they should be removed and the base washed out thoroughly before putting in new oil.

The amount of oil consumed in a four cycle engine is controlled by the oil control rings on the skirt of the piston. With a proper fitting piston and rings the consumption is quite low, but as the engine becomes worn or the rings become filled with carbon more oil is allowed to pass the oil control rings and the consumption increases. This increases the carbon formation in the cylinder head and soon calls for an overhaul job.

On a four cycle engine there are other parts besides that of the crank case which must receive lubrication. On single cylinder horizontal engines it is sometimes necessary to lubricate the rocker arms and valve stems. Other parts to be lubricated are given in your instruction manuals.

Lubication of Two Cycle Engines

As for the crankcase, a two cycle engine is lubricated the same way that a four cycle engine is lubricated. However, beyond this its lubrication is entirely different. The cylinders are completely sealed from the crankcase and must receive their lubrication from a force feed lubricator. The crankcase is sealed from the scavenging system by means of metallic packing which is spring loaded and fits tightly around the piston rod. The lubrication within the crankcase may be splash or full pressure.

The force feed cylinder lubricator, positively driven by the engine has a reservoir of oil which is filled daily by the operator or is automatically filled by the oil pressure system from the sump of the engine. A separate pump unit connects to each cylinder by means of copper tubing and a check valve where the oil enters the cylinder. The quantity of oil delivered to the piston is regulated by the operator. Once set this will remain constant regardless of the mechanical condition of the engine. This is different from the four cycle engine as the amount of oil depends upon the oil control rings.

Lubricating oils for two cycle engines usually is that of an industrial type, usually napthenic base with certain additives to prevent oxidation. Regular motor oils can be used but usually an oil for two cycle engines requires that the carbon residue be very low. Some operators get the best results using what used to be known as "red engine oil." This is a straight run asphalt base oil which when consumed in the cylinder forms practically no carbon, and what carbon is formed is a soft sooty type and not hard and flaky as is with a paraffin base oil. The real reason for using such an oil in a two cycle gas engine is that one oil only is needed. The bearings and other moving parts in the crankcase are large enough that this type of oil is suitable for this use and an oil which will not cause carbon is required by the cylinder. The oil for a two cycle engine should be SAE 20 or SAE 30 or its equivalent in an industrial engine oil.

Frequent changes of oil are not required as the products of combustion do not come in contact with the crankcase. Normal changes of oil then can be set at a period of four to six months.

Since only the cylinder, that is the cylinder walls, pistons and rings are lubricated by the force feed lubricator a definite positive amount of oil must be fed regularly to the cylinder where it is entirely consumed. If the cylinder is fed too much oil the oil tends to burn and form carbon, stick rings and plug up intake and exhaust ports—too little oil causes extreme wear. The amount depends upon speed, load, gas conditions and type of oil that is used. Normally from one half pint to one quart of oil is required per cylinder per day. The manufacturer of your engine can give you more exact data as to how your lubrication should be handled.

The force feed lubricator pump units are in a reservoir which should contain only clean oil. The reservoir should be drained weekly to remove water that might have condensed in the reservoir. Also each six months it is a good idea to lift the cover off the reservoir and wash out the dirt and grime.

The pump units are precision pumps handling a very small amount of oil each stroke. The plunger is lapped to the bore and no packing is used to make a positive seal. Small ball check valves allow one plunger to form the suction and discharge work of the pump. Sight feeds are usually filled with water and glycerine using a 50-50 solution. This forms a liquid which will not freeze but allows the operator to see that the pump units are functioning. The drop of oil seen going up the sight feed is on its way to the cylinder. Other solutions such as windex, alcohol, etc. may be used, or in the summer time clear water is just as good. The sight feeds must be kept cleaned and all connections tight so that no oil discharged by the pump is lost before it reaches the cylinder.

It is important to always bleed or get the air out of the pump unit after cleaning or removing and replacing it in the lubricator. Air in the pump unit causes them to lock and they will not deliver the needed oil. The pump units are the heart of the two cycle engine; a little care and attention to their working condition and settings will reward the operator with long trouble free operation.

Oil Filters

A good oil filter is a good investment. Its purpose is to clean the oil in the crankcase of most harmful particals of dirt, metal carbon, etc. so that they will not scratch the highly polished working parts of your engine. They will not however remove the necessity of changing oil at regular intervals in that they do not remove acids, water and other things which get into an engine.

Most of today's filters have a removable element which can be renewed or a metal screen which can be cleaned. The disposable cartridge is probably the best as it is packed with Fullers earth, fibre or cotton waste which holds much of the abrasive elements of the oil.

Metal screen filters usually allow parts smaller than two or three thousands of an inch to pass.

Filters can be installed either as a full flow where all of the oil from the pump is passed through the filter, or as a bypass type where only a small part of the oil is filtered at one time. Most engines use the bypass arrangement. This provides filtering of all of the oil as it is constantly circulated through the filter. Some filters have a by pass valve so that should the filter become clogged the oil will bypass the filter and go directly to the bearings or parts to be lubricated.

Filter elements require changing or cleaning. No definite period can be stated as this depends upon the condition of the engine and the size of the filter as well as its capacity to absorb dirt. Inspection of the filter element will tell the operator when it is time to change. On two cycle engines using a filter it is suggested that the elements be changed at each oil change. A dirty filter can cause clean oil to become contaminated in a short time. Their cost is low but their protection is great.

Trouble Chart

The following chart is offered to assist in locating troubles in engines.

Hard Starting:

Engine Flooded
1. Excessive Priming
2. Regulator on Mixer not shutting off

Mechanical Trouble
1. Lack of Compression
   a. Worn or stuck piston rings
   b. Burned valves or not seating
2. Ignition Failure
   a. Weak magneto
   b. Bad or broken impulse on magneto
   c. Burned or dirty spark plugs
   d. Safety control grounding magneto
3. Lack of Gas
   a. Gas pressure too low
   b. Regulator not operating
   c. On 2 cycle engines Scavenging Valves may be stuck or not seating

Back Firing:
1. Ignition
   a. Improper timed magneto
   b. Weak magneto
   c. Faulty spark plug cable or plugs
   d. Reversed ignition wires
2. Compression
   a. Lack of compression due to valves or carboned up ports in two cycle engines
   b. Pistons set too low on two cycle engine
3. Gas Intake—Lean Mixture
   a. Low gas pressure
   b. Gas line too small
   c. Regulator with too small orifice
   d. Intake valve leaking

Poor Operation and Lack of Power:
1. Irregular ring
   a. Water in gas
   b. Water leaking into cylinder
   c. Irregular gas pressure
   d. Governor binding
2. Engine Slows Down
   a. Piston or rings too tight and sticking
   b. Overheating
   c. Governor binding
   d. Too much load

Heating:
1. Radiator
   a. Dirty radiator, inside or outside
   b. Slipping drive belt
   c. Stuck thermostat
2. Insufficient Air
   a. Dirty or clogged air filter
   b. Scavenging valves not seating
   c. Burned or stuck intake valves
3. Gas Mixer
   a. Mixture adjustment too rich
   b. Regulator or engine not functioning properly
4. Late Ignition Timing
5. Improper Lubrication or Low Oil Level
6. Tight Pistons or Rings—Not Properly Fit
7. Overload

Lubrication:
1. Low Oil Pressure
   a. Dirty oil intake screen
   b. Oil level low
   c. Oil too light
   d. Loose bearings
   e. Bad oil pressure gage
2. Ring or Cylinder Wear Excessive
   a. Improper amount or type of oil
   b. Wet gas
   c. Air filter not maintained and dirty
   d. Lubricator pump units not functioning properly

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