A Comparison of Slow and High Speed Engines for Oil Fields

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INTRODUCTION

As far as the writer knows, no paper has been prepared which makes a comparison of slow and high speed engines such as are used in the oil fields. Many times a certain prime mover is selected because that particular make and size is known to the purchaser. Little or no consideration is given to the various types of engines available, one of which may be the best for the particular installation.

To make an intelligent comparison of slow and high speed engines and be able to make a proper selection of a prime mover for a particular installation it is necessary to understand the definition, the principle of operation, the mechanical construction, and the advantages and disadvantages of each type of engine.

Slow and high speed engines, as the terms are applied today, take a very different meaning from that used a number of years ago. Normally, when a person mentions high speed engines he thinks of the present motor car with its engine turning above 4000 RPM; in oil field practice he thinks of the multiple cylinder engine as being a high speed machine. Here he is only partially right. Some of the so called slow speed engines really fall into the classification of high speed engines.

In order to get a basis of comparison of high and low speed engines, the author prefers to define them as:

Slow speed engines are those of one or more cylinders and having a crankshaft speed of less than 750 RPM and with a piston speed not to exceed 900 ft. per minute.

High speed engines are those of one or more cylinders having a crankshaft speed of more than 750 RPM and a piston speed of 1000 ft. or more per minute.

Piston speed, as referred to above, is the number of feet each piston travels per minute moving back and forth in its bore. For example, a 9 in. stroke engine makes 2 strokes per revolution of the crankshaft or 1.5 ft. per revolution. This times the number of revolutions per minute results in the piston speed.

It is pointed out by the above definitions that neither the number of cylinders, type of engine cycle, nor the position of the cylinders enter into the classification.

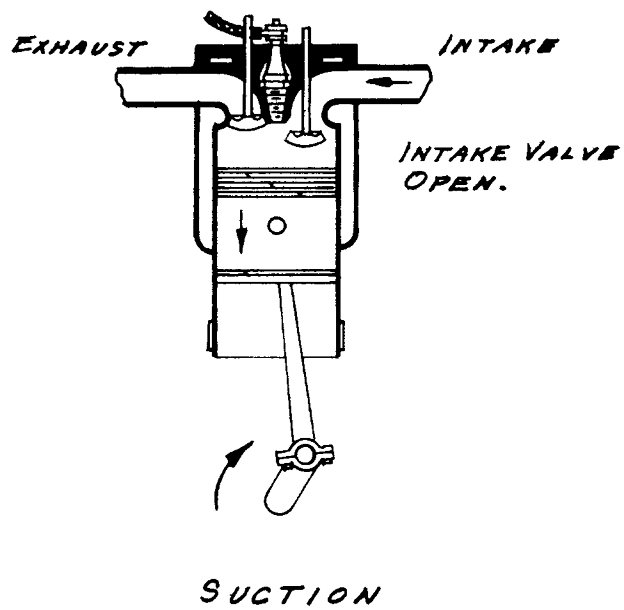
TYPES OF CYCLES

There are two types of cycles of gas engines used in the oil fields. The Diesel engine is not considered in this discussion. The difference between the type of cycles is the method of filling the cylinder with a fresh charge and removing the burned gases from the cylinder. The two types of cycles are four stroke cycle and two stroke cycle.

The four-stroke cycle, normally called four cycle, completes its work cycle in four strokes of the piston or each two revolutions of the crankshaft regardless of the number of cylinders. The four strokes are:

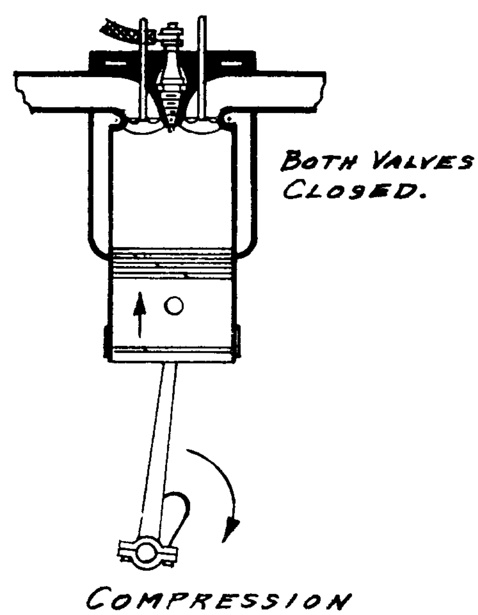
- Suction
- Compression
- Power (Expansion)
- Exhaust

The piston moves away from the head (the intake valve being open and the exhaust valve closed) creating a vacuum in the cylinder and causing the air and gas mixture supplied



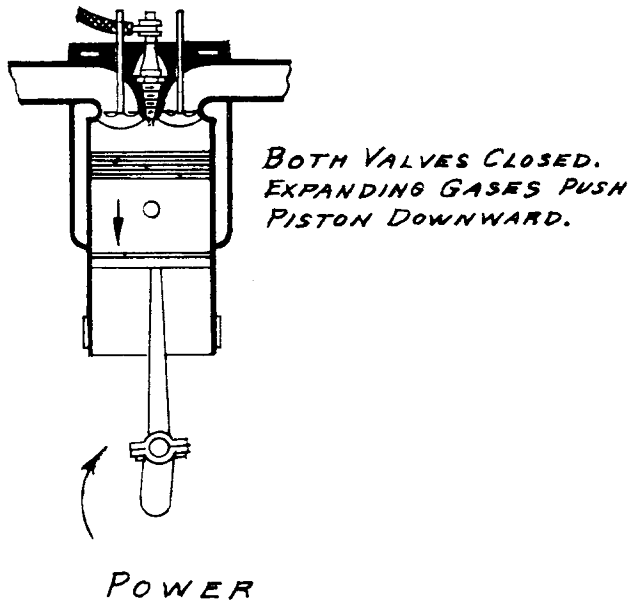
Suction Stroke (Fig. 1a)

by the mixer or the carburetor to enter and fill the cylinder with an unburned charge. The filling occupies the entire suction stroke.



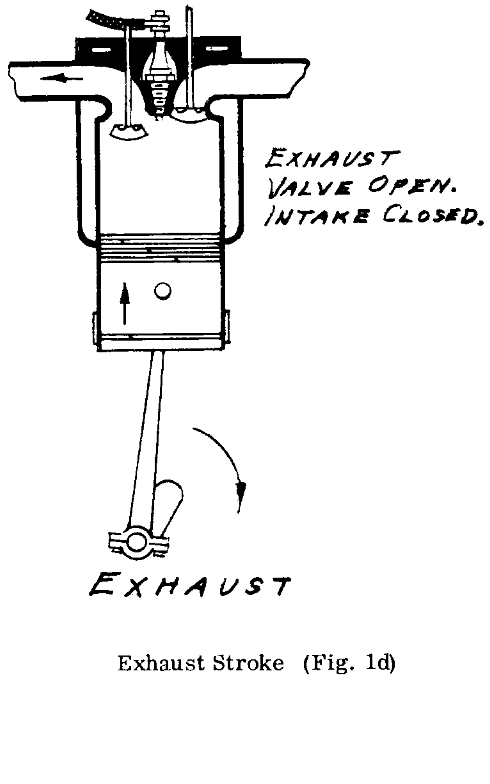
Compression Stroke (Fig. 1b)

At the bottom of the suction stroke the intake valve is closed (the exhaust valve is already closed) and the piston moves toward the head compressing the fresh charge of air and gas to approximately 100 lbs. per square inch. When the piston reaches the end of the compression stroke, ignition occurs which is caused by the magneto sending a high voltage current into the spark plug, then jumps the spark plug gap, and ignites the compressed charge.



Power Stroke (Fig. 1c)

Both valves are now closed and the piston is forced away from the head by the burning and expanding gases which build up a pressure of approximately 400 lbs. per square inch, thus turning the crankshaft and producing power. Actually, the burning starts just before the piston reaches the head end and builds up pressure very fast making an explosion of the gases so that the greatest push on the piston occurs a few degrees past top center.



Exhaust Stroke (Fig. 1d)

As the piston reaches the end of the power stroke the exhaust valve opens (the inlet is closed) and the momentum of the crankshaft pushes the piston back toward the head forcing the burned charge out of the cylinder through the exhaust valve.

This completes the cycle of the four stroke engine. This sequence is followed in all of the cylinders that the engine may have. Thus, for a single cylinder four cycle engine we only get one power impulse for each two revolutions of the crankshaft.

The two stroke cycle, normally called two cycle, completes its work cycle in only two strokes of the piston, or one revolution of the crankshaft, regardless of the number of cylinders. This type of engine does not have valves as in the four cycle but has intake and exhaust ports in the cylinder wall. The piston passing over these ports acts as a slide valve to open and close the ports at the proper time. In four cycle engines the filling of the cylinder with a fresh charge and the removal of the burned gases occupies the entire suction and exhaust strokes. In two cycle engines these two operations are performed through ports near the bottom of the stroke by means of the scavenging system.

Cylinder Filling and Compression

The modern two cycle engine is of crosshead construction in which the piston is fastened to the crosshead by a smooth round piston rod. (Fig. 2a) Between the piston and crosshead, metallic packing around the piston rod separates the cylinder from the crankcase and forms a scavenging chamber around part of the cylinder bore. The back side of the piston is used to pull the mixture into the scavenger chamber and compress it so that it will enter the cylinder at the proper time. As the piston moves from the bottom of the stroke toward the head, it covers first the inlet and then the exhaust ports. The charge in the cylinder is thus trapped and compression starts. At the same time the gas in the cylinder is being compressed the back side of the piston is creating a vacuum in the scavenging chamber which causes the gas and air mixture to enter through the carburetor or mixer and fill the scavenging chamber. Light scavenging (feather) valves which operate on differential pressure act to hold the charge in the scavenging chamber on the power stroke. When the piston reaches the end of its travel toward the head, the compressed charge (approximately 100 lbs. per square inch) is ignited by the magneto sending a high voltage current into the spark plug, jumping the spark

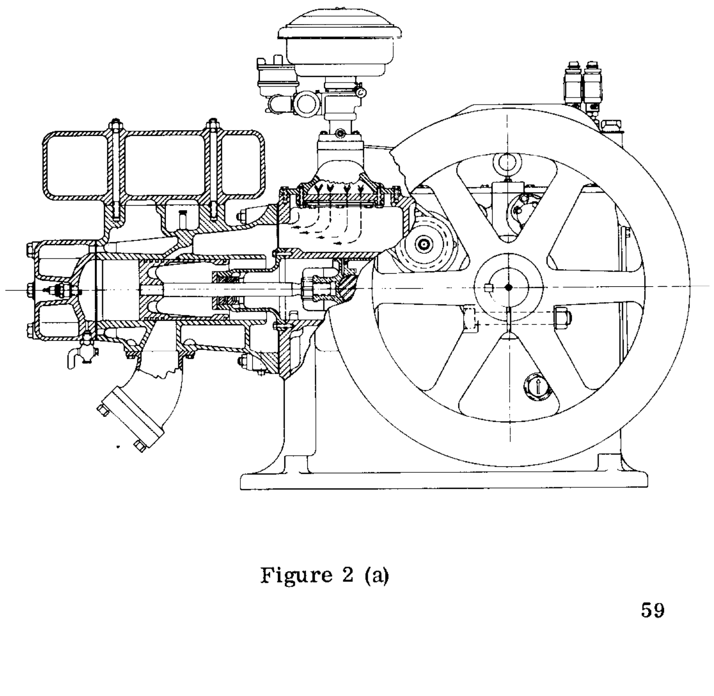


Figure 2 (a)

gap, and igniting the compressed charge in the head of the engine.

Power Stroke and Scavenging

The piston is forced away from the cylinder head by the rapidly burning and expanding gas, (approximately 400 lbs. per square inch) thus turning the crankshaft and producing power. At the same time the piston moves away from the head, the back side of the piston acts as a pump to compress to a low pressure (3 to 7 lbs.) the fresh charge (drawn in on the up stroke) in the scavenging chamber. As the piston nears the end of the power stroke, two vital functions rapidly take place. First, the piston uncovers the exhaust ports allowing the hot expanded gases to escape, and second, as the piston moves away from the head slightly more, the intake ports are uncovered and the fresh charge, now in the scavenging chamber, is directed into the cylinder through the intake ports so that the burned gases are pushed ahead and out the exhaust ports, thus filling the cylinder with a fresh charge of air and gas mixture for the next compression stroke.

We see from the above that each stroke of the piston toward the head is a compression stroke, and each stroke away from the head is a power stroke. Thus, in a two cycle engine we have one power impulse for each revolution of the crankshaft.

The two cycle engine with a power impulse, each revolution of the crankshaft, usually develops for the same bore, stroke, and speed approximately 1.6 times the power that the four cycle engine develops. The reason it does not develop twice the power is the loss of effective stroke length required for exhaust and scavenging.

OPERATION

From the above description of operation of cycles we see there is considerable difference in the principle of operation in two and four cycle engines. There is also a large difference in the mechanism of the two types.

To make a comparison we must discuss the design, construction, advantages, and disadvantages of each type. The four cycle engine will be discussed in two categories. First, high speed multi-cylinder engines and second slow speed single cylinder engines. The two cycle engine will be discussed separately, due to the difference in operation of the cycle and mechanism.

The four cycle engine is made with trunk piston design, whether high speed or slow speed type. That is, the piston is fitted to a bore which opens on the side away from the cylinder head directly into the crankcase. The connecting rod is fastened at one end to the crankshaft and to the piston at the other. The products of combustion escape the piston rings and find their way into the crankcase where the lubricating oil is quickly contaminated, requiring frequent oil changes.

Usually, lease gases are wet, have high carbon forming properties, dirt, etc., and form corrosive compounds in the crankcase. Gas containing sulphur forms sulfuric acid to contaminate the crankcase oil and results in short life to polished surfaces and bearing metals.

Even with good clean gas the products of combustion cause varnish, sludge, etc., with resulting stuck, worn, and burned parts of the mechanism. These products cause wear, increased oil consumption, increased deposits, and blow by in the crankcase. This is a vicious circle which results in a complete overhaul of the engine in a very short time if proper fuel and maintenance is not provided.

Four cycle engines are usually equipped with combination gas-gasoline carburetors allowing them to operate on either fuel. LPG gases such as butane and propane can also be used successfully.

High Speed Four Cycle Engines

Basic engines in the high speed category are designed for one specific service such as for tractors, trucks, or industrial applications. With modifications such as mounting the radiator, clutch, and weather covers, the basic engine is converted into a power unit for the oil fields. The basic engine is designed to give high horsepower and flexibility of speed in a light compact package. It is designed for intermittent service and with a wide speed range. In order to accomplish this, many small delicate parts and adjustments are used. Little or no consideration is given in the basic engine design to the continuous heavy pulsating loads such as are encountered in oil well pumping. Consequently, its life is short and proper maintenance requires shop equipment, usually not available without removal of the engine from the installation.

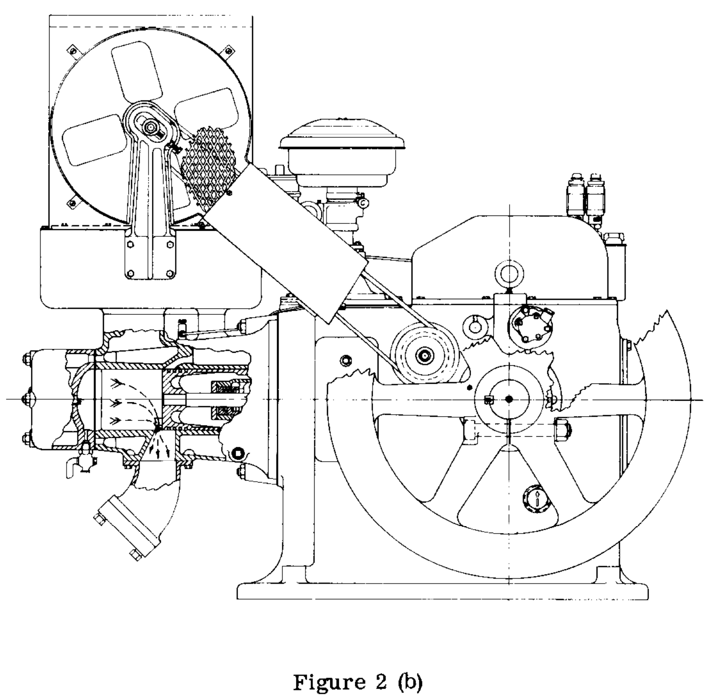


Figure 2 (b)

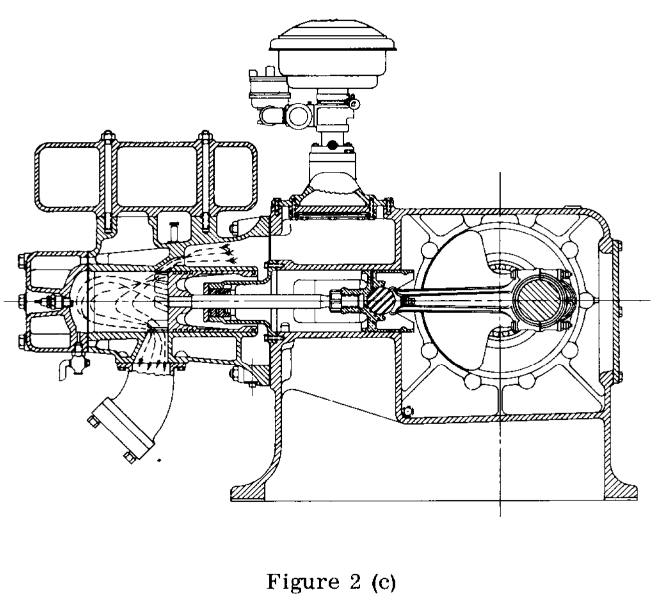


Figure 2 (c)

In the high speed engine a small light flywheel, having a small WR^2, is used to provide the flexibility of speed desired in services other than the oil field. When such an engine is used to pump an oil well there is considerable speed change in each pumping cycle in that there is insufficient WR^2 to maintain an even speed in the prime mover.

Furthermore, high speed engines are equipped with a governor which is set by the manufacturer at the maximum speed the engine is to operate. Thus, the governor acts only as an overspeed device. Pumping engines are usually run at speeds below the governed speed and are controlled by fixed throttles or hand settings. With a fixed throttle the engine tends to slow down excessively on periods of high load. To partly overcome this speed variation, the operator uses a larger engine to handle the pumping peaks.

For best results the high speed engine should be operated at a speed near the manufacturers governor setting so that the engine operates on the falling side of the torque curve; if operated on the rising side of the torque curve any change to increase the load results in slower engine speed and laboring with resulting wear and tear of the prime mover.

Multi-cylinder high speed engines are best when used for intermittent pumping and on short life wells or portable base installations. They must have a supply of good clean gas which is not wet or contains sulphur.

This type engine requires the smallest foundation and expense of installation. It is light, easily handled, and gives high horsepower per dollar on initial investment. It must be remembered that the initial cost may be low, but the maintenance expense is high and the useful life is short when applied to oil well pumping loads.

Slow Speed Four Cycle Engines

The second catagory of four cycle engines is designed primarily for oil well pumping. They are built in a single cylinder version with speeds from 225 to 750 RPM. The largest size built is 30 horsepower. They are manufactured with the bare essentials for operation of the engine. The parts are large, simply adjusted, and few, as compared with the multi-cylinder high speed engine. This engine is subject to the same troubles of stuck and burned valves and faults of mechanics as in the high speed four cycle engine. Safety devices are not usually placed on the engine by the manufacturer, but by the operator. Simplicity is the thought of the manufacturer.

Unlike the high speed engine, the slow speed engine is usually installed on a well for the life of that well. All repairs can normally be made in a short time, without special shop equipment and without removing the engine from its location.

Slow speed four cycle engines are equipped with flywheels of large WR^2 to smooth out the single heavy power impulse every other revolution of the crankshaft, and to provide enough inertia to carry the engine through the pumping cycle without a large speed variation. This type of engine operates directly on the governor to open or close the carburetor as the speed changes. The net result is that the combination of the heavy flywheels and the governing action of the engine makes a very steady running oil well pumping engine.

Slow speed four cycle engines require frequent oil changes because of their trunk piston design as explained above. Oil consumption is quite high after a few months of operation due to formation of sludge and gum on the oil control rings.

Starting of the slow speed four cycle engine has usually been by hand. The manufacturers have been slow to adopt starters due to the task involved with large flywheels. Now, however, the owner has one or more types of starting systems from which to choose. Most of these make use of a friction wheel driven by a small engine or an electric motor.

The heavy shock given out by the relatively large piston, once each two revolutions of the crankshaft, makes the slow speed engine undesirable from the unit and well standpoint. The heavy shock causes jerking of both the unit and the down well equipment. This shock effect is usually first noticed in difficulty with the engine clutch or short v-belt life on the pumping unit.

TWO CYCLE ENGINES

We have discussed the mechanism, advantages, and disadvantages of the four cycle high and low speed engines. In order to complete our comparison, we must discuss the two cycle engine and find its place with the internal combustion engines used in the oil fields.

Two cycle engines are manufactured in sizes from 10 to 100 horsepower. They are made in both single and two cylinder arrangements. Both fall into the classification of slow speed engines having a speed range from 300 to 750 RPM.

The oil industry grew up using two cycle engines; they are as old as the oil fields and have proven themselves to have very long life and are dependable power. From the old slow speed 150 RPM engines, today's engines have been much improved as to performance, life, maintenance, and installation.

The two cycle engine is very simple. There are no valves or push rods, valve linkage, etc. Cooling is no longer done with water pumps, but with thermosyphon or condenser systems which require very little maintenance. The few parts are heavily built, as two cycle engines follow heavy engine construction, and the life expectancy outlives the average oil field. The crankcase is sealed from the products of combustion and its bad effects by means of metallic packing sealing around the piston rod between the piston and the crankcase. A crosshead in the crankcase carries all side thrust of the connecting rod and allows the piston to float in its bore. This method of construction is much more expensive but results in a crankcase free of harmful effects of combustion gases resulting in long life with low maintenance. The lubricating oil is clean and requires not more than two changes per year.

Two cycle engines have one large flywheel with ample WR^2 to carry the engine through the pumping cycle with little variation of speed. The engine is equipped to operate on the governor at all times to open and close the throttle according to the demand for power. Since the two cycle engine gives one power stroke for each revolution of the crankshaft, its flow of power is much smoother than the four cycle single cylinder engine. One manufacturer uses two cylinders firing at 180 deg. and giving two power strokes per revolution of the crankshaft. This arrangement gives unusually smooth operation with very little shock transmitted to the pumping unit and down well equipment.

Maintenance is very simple as there are few moving parts. The two cycle engine is made to be installed at the well for the life of the well. Servicing can be done on any part without removing the engine from the well, and a complete overhaul can be done in less than a day without shop facilities. In servicing the power end it is not necessary to disturb the fitted parts in the crankcase as in the case of the four cycle engines.

The piston and cylinder are lubricated by a force feed lubricator which delivers an exact amount of oil for lubrication regardless of the condition of the piston rings. Oil consumption is constant and does not change unless the operator desires. Some have complained of the trouble experienced with lubricators running low on oil and air locking because of lack of attention. One manufacturer uses the oil pressure system of the engine to keep the lubricator filled and has eliminated many of the complaints of the lubricator failure. In spite of occasional lubricator difficulty, the two cycle engine is more dependable and economical to operate.

The two cycle engine has been criticised because of the misfiring of the engine. The nature of the cycle causes misfire at light loads, however, this in no manner affects the performance or life of the engine. It is merely an indication that the engine is not loaded. When it has sufficient load, it will fire evenly and have a very steady rotational speed.

Two cycle engines previously have had the drawback of not being provided with starters. Kicking the flywheel was the usual proceedure. Today, this is not necessary as two cycle engine manufacturers can furnish as built-in equipment electric, gas motor, air or friction wheel starters.

Two cycle engines cannot be run on gasoline since they are built as a gas engine -- LPG gases are very satisfactory.

INSTALLATION

High speed multi-cylinder engines have vertical cylinders. The resulting forces which cause vibration in the installation are vertical. This allows the engine to be set on cross slide rails on the unit and does not require as rigid mounting of the engine to the foundation as is necessary with horizontal engines.

Slow speed two and four cycle engines, because of horizontal cylinders, make the engine vibrate back and forth in line with the cylinder. This type of engine must be installed on a rigid structural base or on a concrete foundation. Cross or universal slide rails can sometimes be used, but only heavy cast iron should be used. Structural cross rails are not satisfactory. Slow speed engines are best when they are set on structural steel bases or on concrete foundation with rails in line with the cylinders. This will allow moving the engine to adjust tension of V-belts and at the same time hold the engine steady on its mounting.

Four cycle slow speed engines normally do not require exhaust systems, or if the exhaust gases are piped away, the length of pipe is not too critical. However, in the two cycle engine the exhaust pipe installation is considered a part of the scavenging system and proper installation of the exhaust pipe, as to the size and length for the speed, is very important. The recommendations of the manufacturer should be closely followed for best results and performance.

Volume tanks with suitable scrubbers are considered good practice on both high speed and slow speed engines. It is important that the gas be cleaned of oil and gasoline by the scrubber. Bad gas should be treated before entering the engine. The four cycle engine requires a cleaner gas than is absolutely necessary in the two cycle engine. This is not to say that the two cycle engine can be operated on any kind of gas, however, it can be operated on poorer gas than the high speed engine. Good clean dry gas pays for itself in reduced maintenance expense in any engine.

MAINTENANCE

A comparison of high speed and low speed engines would not be complete without including maintenance. Proper maintenance is vitally necessary on any type of engine if the operator expects to get satisfactory service. Preventative maintenance is checking, replacing, and adjusting parts on the engine at regular intervals BEFORE something wears out or breaks and causes a shutdown. A regular schedule for checking and adjusting should be set and rigidly followed.

Regardless of type of engine, magnetos, cooling systems, spark plugs, governor linkage, starters, clutches, fan belts, etc., must have regular inspection, adjustment, and replacement.

Much effort has been put forth by the engine manufacturers to improve their engines and reduce the number and frequency of maintenance items. Much engineering has gone into the so-called "long run" equipment. Some of this is good, and much progress has been made; however, the fact still remains that the engine, due to natural conditions, must still be attended to at intervals.

The high speed four cycle engine generally requires more attention and maintenance because of its design, life, etc., as previously discussed. This engine requires frequent oil changes in the crankcase, the average being from two weeks to one month. Oil filters also have short life and must be maintained and replaced. It is necessary that valve clearance be carefully checked and valves ground when the compression begins to drop. The high speed engine should be removed from the job and put in the hands of a skilled mechanic if it is necessary to dismantle the engine to make repairs other than preventative maintenance items.

Slow speed four cycle engines require somewhat less maintenance as there are fewer adjustments. Regular maintenance of oil changes as suggested for high speed engines should be used with this engine. Proper regular lubrication and adjustment of clutches, fans, belts, etc., should not be overlooked. Regular checking and servicing of magnetos, spark plugs, etc., will pay dividends in performance. This engine can normally be overhauled when required at the well as the parts are simple and no delicate adjustments are necessary.

Two cycle gas engines also require a regular maintenance schedule. Although the crankcase oil is normally changed only twice a year, the engine requires servicing of magneto, spark plugs, and lubrication of fan and clutch. Maintenance of oil level in cylinder lubricator is very important. It is also necessary that the lubricator pump units be cleaned and adjusted at six month intervals.

The two cycle engine is subject to formation of carbon in the intake and exhaust ports. Removing the cylinder head at intervals of nine to twelve months and removing the carbon should be in the regular preventative maintenance proceedure.