Selection, Installation and Initial Maintenance of Internal Combustion Engines for Oil Fields

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INTRODUCTION

The intent of this paper is to cover various types of oil field engines, their advantages and disadvantages, their rating, equipment that is available, installation features, and preventive maintenance, in order that proper selection of the prime mover may be obtained.

The proper selection of a prime mover involves many factors other than the make and size of engine required. Too often only these factors are considered.

To make a proper selection, some of the things that are to be considered are type of installation, maximum horsepower, speed, life expectancy, initial and maintenance costs, availability of service, controls and equipment needed, as well as many other deciding factors.

These things cannot all be determined unless we start with the basic analysis and build and engineer the available information into our requirements. A knowledge of the types of engines, their advantages and disadvantages, the equipment available for each type, and the job to be done is the necessary first step.

The size of the engine is determined by the horsepower required to do the job. This may mean an engine to meet expected lead requirements several years hence; therefore, careful calculations should be made for all probable conditions. To arrive at the proper size engine, the engineer must take into his calculations correction factors according to the type of engine, the service expected, and the type of equipment to be operated.

Let us start with the basic power unit. This is the engine equipped with only the essential parts required for the engine to deliver power to the machine being driven. Thus, the basic power unit consists of the bare engine plus the cooling, ignition, fuel and power take off (clutch) systems. To this, certain equipment is offered by the manufacturer as optional or accessory equipment.

A discussion of types of engines available is next in order, followed by the various optional constructions available. We are then ready to consider the horsepower required and apply service and correction factors to meet the conditions required of the prime mover. When the size and type have been selected, the accessory equipment best suited to the type of engine and to your requirements can be chosen. All of these factors should be carefully considered and specified at the time the engine is requisitioned.

Oil field engines can be classified into types as:

a. High speed four cycle multicylinder
b. Slos speed four cycle
c. Slow speed two cycle

OIL FIELD ENGINES

High Speed Multicylinder Engines

High speed multicylinder are also called automotive type, from which design they have been developed. This type of engine usually has four to six cylinders which are vertical, however, some larger engines are of "V" design with four to twelve cylinders. Their speeds are high - 1000 RPM and above - and their torque curves are rather sharp; the torque curve rises and falls rather quickly from a peak and thus narrows the effective speed range of the engine.

The light fly wheels used allow the engine to respond quickly to load variations, but under pumping unit operation cause surging or widely varying speed change. The forces of loading are downward; therefore, the foundations required are lighter than that of horizontal engines.

The high speed engine is built with a small enclosed fly wheel and with sheet metal sides fitting the outline of the radiator to enclose all working parts, making a weatherproof covering for the exposed parts mounted on the engine.

Some of the advantages and disadvantages of the high speed engine are:

Advantages

1. Low initial cost.
2. Wide speed range.
3. Light weight per horsepower.
4. Low installation cost.
5. Best used for intermittent service.
6. Can be equipped for gasoline operation, as well as gas and LPG fuels.
7. Electric starters and safety controls for oil and water are usually factory installed.

Disadvantages

1. Trunk piston design allows combustion products to enter crankcase causing sludging and contamination of crankcase oil by combustion gases.
2. Frequent oil changes required because of above.
3. Basic engine is not designed for oil well pumping.
4. Short engine life.
5. Multiplicity of small precision parts.
6. Maintenance is required frequently.
7. Valves in combustion chamber in contact with heat warp and burn.
8. Major repairs require removing engine from pumping installation.
9. Large speed variation on pumping cycle due to insufficient flywheel effect.
10. Engine operates on fixed throttle, governor acts as overspeed only.

Slow Speed Four Cycle Engine

The slow speed four cycle engine usually has a single horizontal cylinder with one or two large fly wheels which are not enclosed. The usual speed range is 250 to 600 RPM. This type engine is presently built in sizes only up to 30 HP. The basic design of the engine is the same as the high speed engine except the parts are larger and built for slower speeds. Cooling is usually by condenser system, eliminating water pumps.

Foundations for this type engine must be sturdy to resist the horizontal forces as there is only one power impulse for every other revolution of the crankshaft. Slide rails set parallel to the crankshaft are not recommended except in the very smallest size. Engines larger than 5 HP should be set on slide rails placed in plain of the cylinder.

Some of the advantages and disadvantages of the slow speed four cycle engine are:

Advantages

1. Longer life due to fewer and slower moving parts.
2. Repairs are usually made at well location without removing engine from foundation.
3. Uniform rotation due to heavy flywheel effect.
4. Normally operated on gas but can be operated on gasoline or LPG.
5. Operates on governor to compensate for load changes.

Disadvantages

1. Trunk piston design allows combustion products to enter crankcase causing sludging and contamination of lubricating oil.
2. Frequent oil changes because of above.
3. Weight per horsepower is high.
4. Does not have built-in starting system.
5. Safety controls not standard, but certain types can be installed at extra expense.
6. Range of horsepower is limited to smaller sizes.
7. Severe shock on power stroke.
8. Valves in combustion chamber burn and warp requiring frequent maintenance.

Slow Speed Two Cycle Engine

The slow speed two cycle engine has been the workhorse of the oil fields from the very beginning of oil field pumping and other operations and is today a very popular mode. The two cycle engine is built in sizes from 10 HP to 150 HP. The normal speed range is 300 to 650 RPM with the larger engines having a speed range of 200 to 500 RPM.

There was a period when manufacturers of this type of engine were slow to accept modern concepts. Their engines were very slow speed, large, and required very large foundations. This caused operators to select lighter weight, higher speed engines to reduce installation expense.

Today, however, the two cycle engine manufacturers have met this competition by reducing dimensions of the engine to fit pumping unit bases. This has been accomplished by increasing speed, using one or two cylinders and smaller well balanced parts, and developing increased power, yet retaining all of the time tested principals of long life, dependable, simple operation.

A few of the advantages and disadvantages of the two cycle engine are:

Advantages

1. Slow speeds result in long life.
2. Rugged heavy-duty construction.
3. No crankcase contamination resulting in long intervals between oil changes.
4. Uniform rotation due to more power impulses and large flywheel WR^2 effects.
5. No delicate adjustments.
6. No intake or exhaust valves in combustion chamber to burn or stick.
7. Simple maintenance.
8. Engine can be repaired or completely overhauled without removing from foundation.
9. Operates directly on governor for better control of varying load conditions.
10. Built-in starting and safety control systems.

Disadvantages

1. Improper lubrication of cylinders. Lubricated by force feed. Lubricator under the control of the operator.
2. Port clogging caused by carbon formed by gas or too much oil.
3. Weight per horsepower higher than multicylinder.
4. Natural gas or LPG gases only can be used as fuel. Gasoline cannot be used.
5. Foundations required are heavier than those for multicylinder engines.
6. Initial cost higher.

RATING

The American Petroleum Institute has established standards by which engines are to be rated. From API Standard 7B-11C.

"At any rotational speed, maximum standard brake horsepower shall be the greatest horsepower, corrected to standard conditions, that can be sustained continuously under the conditions as outlined under test procedure.

"Test engines and power units shall be of exactly the same design and equipped with the same components and accessories as engines and power units delivered to the purchaser. They shall be tested with all their regularly included component parts in place and operating normally."

It is the practice of some manufacturers to show on API forms the maximum potential horsepower of their engines yet when equipped for oil field service they use load limiting devices that prevent the engine from developing this power; therefore, if calculations are based upon the manufacturer's potential curve, much greater correction factor must be applied.

In many instances, the manufacturer provides load limiting features which will permit the engine, when new and in perfect mechanical shape, to develop only the power shown on their recommended curve. Loads applied to such engines must then be lighter than that shown by the manufacturer's recommended curve to allow for loss of power due to natural wear and inefficiency.

We believe if an engine is to be rated according to API standards that for the protection of the purchaser, he should be informed that such load limiting factors are included. Certainly manufacturers who use this practice are in direct violation of API standards.

You will note that API makes no specified reduction for service factors. However, the manufacturer may make recommendations as to rating under various types of service. Or the purchaser may apply his own service factors based upon his experience. It has become common practice for high speed engines to use 65 per cent of the maximum API rating curve for applying to pumping loads. Low speed engines are more heavily constructed, have large fly wheels to carry the loads through peaks, thus a figure of 75 per cent of maximum API horsepower can safely be used unless load limiting devices are applied to the engine. In fact, engines which are well loaded usually give much better results than those which are lightly loaded.

Using above service factors, the size of the engine can then be determined by several standard formulas that are currently being used. A few of these are:

1. Prime Mover Shaft BHP - Hydraulic HP x 2.5

   Where: $\text{Hydraulic HP} - \frac{\text{Bbls/da. X Wf X D}}{33{,}000 \text{ X } 24 \text{ X } 60}$

   Wf - Weight Fluid per Bbl. - Use 350 lbs.
   D - Depth to Pump in Feet

2. Prime Mover Shaft BHP - Polished Rod HP x 1.5

   Where: $\text{Polished Rod HP} - \frac{\text{Bbls/da. XD}}{85{,}000}$

3. Prime Mover Shaft BHP - (Hyd. HP - Fr HP) 1.5

   Where: Hydraulic HP is Shown in Formula 1

   and $\text{Fr HP} - \frac{\text{SPM X L X Wr}}{1{,}600{,}000}$

   SPM - Strokes per Minute
   L - Length Strokes in Inches
   Wr - Weight Rod String Pounds

In the above, the term "Prime Mover Shaft BHP" is used to mean the actual horsepower at the prime mover clutch shaft. This is the size of the prime mover required after service factors have been applied.

BASIC ENGINE FEATURES

In the selection of the prime mover, when the horsepower and type have been determined, there are several desirable features to be added to the basic engine that will warrant consideration. These are not considered accessories, but are options to the basic engine before consideration of accessories and depend upon the service expected.

Air Filters

Practically all engine manufacturers use as standard equipment, Oil Bath Air Filters. These are excellent but require proper maintenance for good efficiency. In dusty areas this maintenance interval may be too frequent for the busy pumper or maintenance man. Recently dry type air filters have become available for various engines.

The dry type filter, which is a paper filter element, if properly sized, will deliver clean air with less resistance over a longer maintenance period than the oil bath type. Regardless of the type of filter used in dusty areas it is necessary that they be serviced after each blow. Servicing of the dry type filter is simple however they must be handled carefully and renewed after reasonable use. They must be carefully examined, for small pin holes which completely destroy their value.

The dry type filter is not satisfactory for use in areas where there is considerable moisture. Their life expectancy is short where moisture or oil is allowed to come in contact with the filter element.

Dual Fuel Equipment

Where natural gas may not be available at all times, it is desirable to purchase dual fuel equipment. This equipment is designed so that, normally, natural gas is not available and the engine is then operated on LPG automatically. The equipment switches from natural gas to Butane-Propane when there is insufficient natural gas, then taking only the necessary LPG to operate. As soon as natural gas again becomes available, the butane is automatically cut off until needed later.

Low Tension Ignition

Low tension ignition is not new. For pumping engines, however, it is a new application which results in reduced spark plug maintenance and much longer spark plug and magneto life. All of which are important factors in lower maintenance and operating costs.

Low tension ignition makes use of a magneto resembling the regular high tension magneto. Instead of high tension wires leading from the magneto to the spark plugs, the primary or low voltage (6 to 12 volts) is wired to transformers, one for each cylinder located close to the spark plug. The transformer transforms the low voltage primary to the high voltage secondary delivered to the spark plug through a short length of wire.

Oil Cooled Pistons

Some manufacturers offer engines equipped with oil cooled pistons. This is a term applied to engines in which oil from the crankcase is forced under pressure to the underside of the piston head so that much of the heat in the piston is absorbed by the oil, thus cooling the piston.

In an uncooled piston engine, the heat in the piston head is dissipated to the piston rings which carry the heat to the cylinder walls and into the jacket cooling water. Since in oil cooled piston engines most of this heat load is absorbed by the oil circulated or sprayed on the under side of the piston head, the rings are relieved of the duty of heat transfer and can do the job intended for them - that of sealing.

The lubricating oil film on the cylinder walls is better; therefore, there is better lubrication and less wear on ring and cylinder walls. Oil cooled piston engines can carry continuously a greater percentage of maximum load with less wear. Even when normal correction factors are applied, the life of rings and cylinder walls is greater.

The oil in the crankcase is cooled by an externally mounted cooler to hold crankcase oil temperatures to no more than 175° F.

Oil cooled piston engines are a refinement over the basic engine that the operator will find well worth their additional cost in reduced maintenance and increased life.

Long Interval Maintenance Features

Several engine manufacturers, under various names, offer engines equipped with features to reduce the interval of maintenance by furnishing such items as prepaked bearings on clutches and fans, also low tension ignition, platinum point spark plugs, and oil and water controls. These features are proved and are very desirable on new installations.

The goal of such features is to allow an engine to operate for 6 month periods without the usual daily or weekly check over. It is to be stressed that with such equipment, a rigid maintenance schedule must be maintained. At each maintenance period, the servicing, checking and replacement of worn or damaged parts must be thorough. The mere greasing or checking of a few items is not sufficient to give the service that should be expected.

ACCESSORIES

There are many kinds of accessory equipment. Some of those listed are supplied as optional equipment by some manufacturers. Other manufacturers do not furnish this accessory equipment; however, accessories for their engines can be had from various suppliers.

STARTING EQUIPMENT

Starting equipment for oil field engines can be classed as follows:

1. Motor Driven
2. Air Starting
3. Friction Wheels

Motor Driven

Electric Motor Driven Starters which require batteries of 6 to 24 volts are most commonly used on multicylinder and some slow speed two cycle engines. Today the 12 volt system used on cars and pickups is very popular in that it eliminates separate battery and charging equipment for each installation. There have been some who dislike this system because most often the car battery does not have the capacity to do a good job of starting a large, cold engine.

Gas Turbine Motor Starters are very satisfactory where a supply of clean gas at 30 to 100# is available. The gas pressure supplies the necessary energy to turn the vane type motor at high speed. Lubrication of the turbine and properly maintained filters are very necessary for satisfactory operation.

Hydraulic Motor Starters are used in some instances, but high pressure cylinders of nitrogen and hydraulic pumps are necessary for operation. They provide a fast start, but have not become too well established in the oil field due to maintenance expense.

Gasoline Motor Driven Starters are available for large multicylinder and some slow speed engines. A small gasoline powered engine, through a clutch, is connected to the main engine. The starting engine is started and the clutch is engaged causing the main engine to rotate for starting. Maintenance of the small motors Mounted on engines is important and required at frequent intervals due to vibration and other factors.

Air Starting

Air starter valves are used to admit high pressure air (150 - 200#) to one or more cylinders to rotate the engine for starting. This is a very dependable and inexpensive method of starting. The objection to such a system is that a compressor system must also be installed. This can be a small gasoline powered engine connected to a compressor mounted on a storage tank. In central plants where air is available, air starting valves are one of the most reliable systems available. Usually the air starting valve system is used only on large multicylinder and slow speed two cycle engines.

Friction Wheels

Friction wheel starters have been popular with operators of large fly wheel engines. A gasoline driven engine, through reduction gears or chain, is connected to a small friction wheel. A foot lever raises the friction wheel into contact with the main engine fly wheel, causing the engine to rotate. There are several companies manufacturing a friction wheel starter driven by an electric starting motor. This allows the use of car or pickup batteries for the power medium.

SAFETY CONTROLS

Whatever element the operator wants protected can be so protected by a vast arrangement of various safety controls. Practically all of them ground the primary side of the magneto to short out the ignition system and thus cause the engine to stop when an alarm is given by that particular safety control.

Certain safety controls are sometimes put upon the driven equipment and wired to the engine to shut off the power in case of failure of the driven unit. An example of this is the pumping unit beam switch which grounds the magneto on the engine in case of rod breaks or sudden jars or vibration.

Water Controls

Water safety controls are important and can be secured for high temperatures, pressure, or low water level, thus protecting the engine from overheating due to temperature, broken fan belts, etc., or at such times as a leak may develop and water is lost from the cooling system.

Various means for water makeup are available. Exhaust gases are passed through a condenser where they are cooled and water is formed and filtered. It is then fed to the radiator as needed. Excess water is spilled and evaporates. Float levels with an auxiliary drum are also available. The condensers and floats, however, are not for use with pressure or thermosyphon cooling systems as they will only admit water under atmospheric conditions.

Water filters can be supplied. These are designed to prevent clogging of radiator passages. We see no value to them as long as the cooling system is properly maintained and rust inhibitors are regularly added to the cooling system.

Oil Controls

Oil safety controls are very important on every engine. The most common is an oil pressure control which, should the oil pressure drop for any reason, will ground the magneto. Controls are also available for low oil level and high oil temperatures. Splash lubricated systems rely upon oil level instruments.

Several manufacturers can supply oil level systems in which the oil level in the engine crankcase is maintained from an auxiliary tank or drum. Capacities of these range from 5 to 55 gallons. Using such systems, the operator is relieved of daily checking and filling of the crankcase; also, a more uniform oil level is maintained.

Oil filters have become standard on almost all engines except those employing splash lubrication. Certainly their value is proved. For oil field service filters need to have ample capacity for at least 6 months service before renewing the filter element. The type and size of the filter required varies with the make, size and condition of the engine.

Speed Control

Speed control is a must on the oil field engine. Multicylinder engines usually operate on fixed hand throttle, but are governed at the maximum speed by a centrifugal governor. This is considered an over speed governor or a speed limiting device. Slow speed engines operate on governor, that is, the governor is in operation at all times. It closes the mixer butterfly valve upon increase of speed and opens the butterfly valve upon decrease of speed.

Some slow speed engines are also equipped with over-speed devices to shut down the engine, usually by grounding the magneto, in case of over speeding. These devices are centrifugal and if maintained are quite accurate and dependable.

ENGINEERING THE INSTALLATION

Foundation

After securing the foundation drawings from the manufacturer, check these with other equipment to be installed and against the soil upon which the foundation will rest. Make proper allowances for soil which is not firm. Remember, spreading the foundation gives greater load carrying capacity. The total cubic yards should not be reduced as the manufacturer has given a definite size foundation required for his machine.

Foundations for engines are usually made integral with the foundation for the driven equipment and are of two general types:

1. Concrete foundations on which the engine will set directly on the foundation or upon slide rails embedded in the concrete. This method is generally used for the larger sizes of engines. The engine and the slide rails must be leveled and grouted for best service.
2. Fabricated steel bases upon which the engine is mounted. This method distributes the load through the steel to the foundation. The concrete foundation is still required below the steel, but is usually not so deep. Sometimes the concrete block is leveled and tie down bolts are used. Care must be taken to use a sufficient number of tie down bolts to prevent movement of the structural base. Grouting is still the preferred method to secure a proper bedding of the steel to the concrete.

The foundation for the multicylinder engine needs only to resist the vertical vibration forces and resist the belt pull of the drive. Normally, foundations for this type engine are made a part of the driven machinery and the slide rails are parallel to the crankshaft of the engine.

The foundation for the slow speed engine, whether two or four cycle, requires more attention. The power cycle produces strong horizontal forces which the foundation must resist. There is also some tendency for the engine to want to "nose dive", which the foundation must resist.

With slow speed horizontal engines, the slide rails must be set parallel to the cylinders. If it is necessary to place rails in line with the crankshaft, they should be only heavy cast iron type. "I" beam rails are not satisfactory because the horizontal forces are in the weakest plane of the "I" beam.

Where buildings are to be erected, insulation should be placed between the engine foundation and the house floor to prevent vibrations being transmitted to the building.

While engineering the foundation, make sure to provide proper troughs in which gas and exhaust pipe systems can be placed, so as the engine is moved on slide rails, these lines can move with the engine. Do not bury exhaust lines, but provide a means where they have freedom to expand and contract. Flexible hose is very good to allow for moving the engine and to prevent vibrations being transmitted.

Exhaust System

The engine exhaust system is a very important part of the installation which is often overlooked or haphazardly installed. Any engine will give better performance with a proper exhaust system. The exhaust system in two cycle engines must be correctly installed, however, as it comprizes an important part of the scavenging system and good results will not be obtained unless you follow your manufacturer's recommendations as to size and length. Fig. 1 shows the effect of the exhaust pipe length upon the output of a two cycle engine. Incorrect lengths or sizes result in unsatisfactory operation.

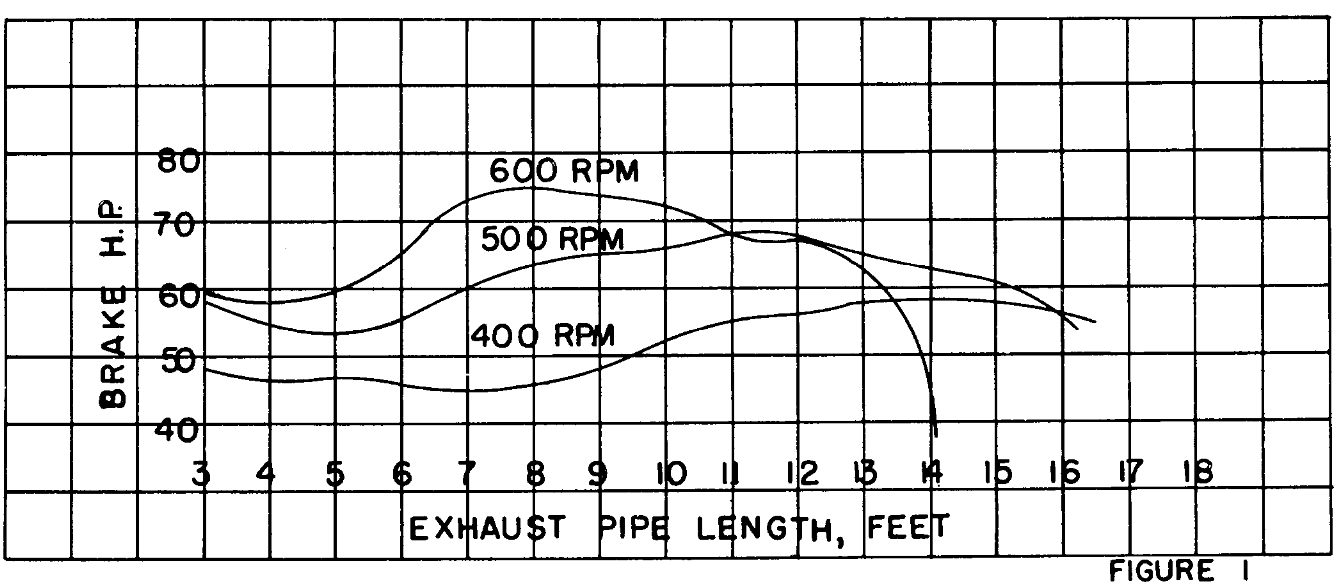

FIG. 1
EFFECT OF EXHAUST LENGTH ON 2 CYCLE ENGINES

Silencers are often necessary to prevent undue noise. At best they reduce power and must be engineered to the engine. Field made silencers often do much harm to engines and increase maintenance. The recommendations of the manufacturer must be followed for satisfactory service.

Fuels

The source and type of fuel to be used by the engine is an important engineering feature of every installation. Normally, natural gas is readily available; however, many times other fuels must be used initially or during period of well servicing. During such times provision should be made for auxiliary fuel.

Natural gas is divided into sweet and sour types. Sour gases due to sulphur, etc., are very detrimental to any internal combustion engine and must not be used unless all other sources have been explored. Sour gas can be treated, however, at some expense.

Raw gas, that is gas direct from the casing, should not be used unless run through a suitable scrubber or treater before going to the engine. Even with separator gas, scrubbers should be installed near the engine to remove oil and moisture.

Residue gas, that is gas from which the heavy hydrocarbons have been removed, is a dry, uniform gas and entirely satisfactory for all types of internal combustion engines.

Where gas is at times not available or not available in sufficient quantities, LP gases should be considered. Butane-Propane tanks are readily available and quick service is near. These provide an ideal fuel, burn clean and develop smooth power, but the cost of LP gases allows them to be used only in isolated places or for part time operation.

Oil burning engines such as oil and diesel engines have not found a great deal of favor in the oil fields because of higher maintenance and the availability of natural gas or LP gases. Small engines are often started on gasoline then switched to natural gas for operation.

Fuel System

Engineering of the fuel system should be thorough to prevent freezing of moisture pockets in cold weather and to prevent the carryover of oil and water into the engine at all times. Suitable drains at low places in the field line should be provided. Scrubbers, regulators, volume tanks and piping must be maintained in good working order.

The reducing regulator, which reduces the incoming line pressure down to the pressure required at the engine, must have sufficient size orifice and spring combination to supply a steady flow of gas at 4 to 6 ounces at the engine. Too small an orifice will starve the engine. Too large an orifice will cause surging and uneven flow of gas.

The size of the gas line from the reducing regulator to the engine should be of such size that there is no more than two ounces drop in pressure from idle to maximum load and speed of the engine. Normally, for pumping engines to 50 HP, a 1 inch gas line not more than 10 feet from the volume tank to the engine can be used. For larger engines use 2 inch pipe or larger, as required by the manufacturer.

Cut off valves should be placed before the reducing regulator, scrubber or volume tank and at the entrance to the engine to allow easy servicing of these items.

Scrubbers are a very necessary part of the fuel system, even if residue or dry gas is used. A scrubber is a tank into which the gas flows, reverses direction or swirls, in order to drop out particles of moisture, oil, scale, etc., before the gas goes to the engine. Most scrubbers are made to hold a light liquid and the gas is washed or scrubbed by this liquid to remove foreign matter to prevent it entering the engine. The proper fluid level should be maintained.

Some manufacturers furnish a combination scrubber, reducing regulator and volume tank all in a neat package. Their use is advocated.

Some engine builders so not require a volume tank (a scrubber is always recommended) provided the reducing regulator is placed within two feet of the engine gas inlet.

The volume tank is used to reduce pressure pulsations in the gas flow to the engine. Its size is important. Normally, manufacturers recommend that the size of the volume tank be a minimum of five times the cubic inch displacement of the engine; larger does no harm. It is well to install manometers on volume tanks so that gas pressure may be observed readily. Suitable drains should be provided.

Certain accessories such as reserve oil drums, water reservoirs, etc., are usually afterthoughts in making the installation. This is a mistake. They should be engineered to give access to all parts of the engine without having to reach over lines or pipes. Proper servicing of these tanks etc., should be considered from a standpoint of accessibility and safety. Arrange accessories so that gauges can be readily observed from the operating side of the engine.

Safety Guards

Most engine manufacturers provide suitable guards for the moving parts on the engine; however, no attempt is made to enclose fly wheels and clutch sheaves. These guards are desirable for safety, but should be easy to remove so that the engine can be serviced. Hot exhaust pipes can cause burns and should be jacketed or guarded to prevent accidental burns.

MAINTENANCE

Preventive maintenance is work done at regular specified intervals to prevent emergency shut downs. A proper program of maintenance and repair will insure continuous, reliable and dependable power from the prime mover. Preventive maintenance cannot be over stressed. Don't wait until the engine fails - prevent failure by corrective maintenance.

Initial Preventive Maintenance

The supplier of your prime mover has carefully checked it before it left his factory, but there are many things that can go wrong before the engine is placed in service. Therefore, it is very important that each new installation be carefully checked, preferably with the manufacturer's representative, at the time of initial installation and starting. The following items must be checked:

Lubrication

a. The proper type, weight and amount of lubricating oil in the crankcase and lubricator is very important.
b. Proper type and grade of greases and location of each grease or oil fitting.
c. Have all oil and grease levels been double checked?

Cooling
a. Has the proper amount of pure clean water been added to the cooling system? In winter, has antifreeze been added?
b. Fan belts, water pumps, etc., properly installed, adjusted and serviced.
c. Observe for leaks caused by damage in shipping or installation.

Fuel System
a. Has fuel system been checked for leaks and all air expelled before attempting to start?
b. Check gas pressure for proper regulator setting. Most engines operate on 4 to 6 ounces at engine.
c. Has air filter been properly serviced?
d. Examine governor linkage for freedom of movement.

Exhaust System
a. Has exhaust system been installed properly?
b. Have all sealing plugs, blocks, etc., been removed from intake and exhaust lines?

Ignition System
a. Check spark plugs and clean all moisture or corrosion from tips. Tighten securely in head.
b. Check magneto for proper timing and spark.
c. Are safety controls connected to primary ground on magneto?

Clutch
a. Engage and disengage clutch to check its operation and correct adjustment.
b. Check mounting of sheave or coupling.

General Checking
a. Acquaint operator with starting and operating procedures.
b. Check engine for looseness or damage to any parts.
c. Turn engine over by hand to check for tightness and general conditions.
d. On engines equipped with lubricators, operate by hand to furnish oil to cylinders and to make sure of the operation of each feed.
e. Start engine and observe gauges for proper reading, oil leaks, water leaks, vibration, speed control, noises; locate and identify if normal or abnormal. Check engine as it warms up. Check safety controls for proper operation both in starting and stopping.
f. Set speed regulating devices, gas mixer, etc., for load under which engine is required to operate.

Preventive Maintenance

After the initial checking and adjusting period, the operator should establish a regular checking and adjustment schedule. Various types of engines and service under which they are opeated will determine the periods of inspection. A preventive maintenance program will include checking each engine installation at each check period for the following:

Ignition

Magneto - Clean outside, remove distributor cap, clean magneto inside, check magneto points for proper opening of approximately .015 inch. Examine points for burning or pitting and replace if required. Condenser should be replaced each time points are replaced. Oil cam wick sparingly. Check magneto for proper impulse and timing. The Magneto should produce a hot blue spark to insure good ignition.

Ignition wiring - Check and replace broken, damaged or oil soaked ignition wires. Make sure a good connection is made by wires at magneto and at spark plugs. Check safety control wiring for good connections at switches and at the magneto.
Spark Plugs - The spark plugs must be checked often. Interval will depend upon engine, fuel, type plug, etc. Set Spark gap to that specified by engine manufacturer. Select the proper heat range of plugs. If plugs burn use colder type; if fouling, use hotter type. Plugs should be cleaned outside as well as inside. Examine carefully for broken porcelains. Clean threads and make sure plugs are properly seated on good copper gaskets.

Air and Fuel System

Air Cleaners - Oil Bath Type - Remove dirty oil and clean filter thoroughly. Replace oil using weight specified by engine manufacturer. Check and replace gaskets, hose, etc., to insure that no unfiltered air reaches engine.
Air Cleaners - Dry Type - Remove dirty filter element, clean all dirt from element and examine for small holes, encrusted with dirt or oil. Replace if damaged and after reasonable service. Check and replace gaskets, hose, etc., to insure that no unfiltered air eaches the engine.
Gas Scrubber and Volume Tank - Drain any accumulation of oil or moisture from tanks. Check for proper level of scrubbing fluid if fluid scrubbers are used. Keep volume tank free of oil and water accumulations.
Gas Regulators - Check for proper operation and pressure settings. Replace diaphram or orifice seat if leaks are found. Check operation of Ensign B Regulator. Dismantle and clean if operation is not correct. Replace lower diaphram if stiff from age. Remove any oil accumulations in lower part of regulator.
Fuel Mixer or Carburetor - Oil and check mixer to governor linkage for worn or binding parts replacing such items as are worn. Check bushings and seals on butterfly shaft as dirty air can enter here. Adjust mixer load and idle adjustments for best engine performance. Check for proper operation of governor. Make sure throttle will completely close, preventing runaway engines.
Clean the radiator core of dirt, trash, etc., check for leaks or loss of water, tighten or replace hose, hose clamps, gaskets, pumps, etc., where leak occurs. Check fan belts for condition and tension. Replace when worn or stretched. Run snug but do not tighten excessively. Use rust inhibitor in water. Use only clean clear water. In winter use specified antifreeze.

MAINTENANCE SUMMARY

In addition to the above specified check points, it is necessary that engines be maintained in good mechanical condition. We feel that once each year, engines should be carefully gone over, the pistons pulled, the rings examined or renewed and all bearings be carefully checked. Periodically, depending upon loads, gas and many other factors, it is necessary that the cylinder heads be removed and the valves be ground on 4 cycle engines. On two cycle engines, it is necessary that the heads be removed and the intake and exhaust ports be cleaned of carbon. An engine cannot be expected to give trouble free performance unless the maintenance schedule is definite and exacting.