Slow Speed Engines

By G. L. REID
Bethlehem Supply Company
Tulsa, Oklahoma

The horizontal type internal combustion engine evolved very naturally within the oil industry and it is, next to the steam engine, probably the oldest type prime mover in continuous use in the field.

Originally a steam engine - usually the one used to drill the well - was left at the location together with a gas fired boiler for the pumping and servicing of the well. As natural gas increased in demand and value it became imperative to find a more economical method of utilizing its power.

Some previous experimenting had been done with gas fueled internal combustion engines and it was natural and logical to remove the steam cylinder from the engine frame and apply a gas engine cylinder which greatly increased the fuel economy. There are still some of these old engines in operation after well over sixty years of use and from these has evolved today's line of highly developed, economical, horizontal internal combustion engines.

Since the Otto, or four-stroke cycle had already been established, the early engines followed this, and from an effort to reduce weight and moving parts evolved the two-stroke cycle engine. So today we have the four-stroke cycle and the two-stroke cycle engines in general use in the oil fields. Variations in these cycles are shown in figure one.

Let us examine the events that give the name to the two types of engines.

Four-stroke Cycle Events

In the four stroke cycle engine consider the piston to be forward at the combustion head:

> The exhaust valve is closed and the intake valve opens as the piston moves back and permits the fuel mixture to enter the cylinder.
>
> At the back end of the stroke the intake valve closes and, with both valves closed, the piston moves forward to compress the fuel charge.
>
> At the end of the compression stroke ignition takes place and with both valves still closed the piston is driven back on its power stroke.
>
> At the end of the power stroke the exhaust valve opens and on this fourth stroke the spent gases are discharged through the now fully open exhaust valve.

Upon completion of this fourth stroke the exhaust valve closes and the engine is ready for another cycle. Thus we have four strokes of the piston during two revolutions of the flywheel and one power stroke is delivered to the crankshaft.

Two-stroke Cycle Events

In the two-stroke cycle engine the back of the piston acts as a compressor to force a fresh fuel charge through the scavenging chamber and the cylinder intake ports. Thus at the back end of the stroke just as the piston goes over back dead center the intake ports are fully uncovered allowing the fuel charge to enter the cylinder and the exhaust ports are also open at this instant. The following events then take place:

> On the continued forward motion of the piston all ports close as they are covered by the piston movement and compression of the fuel charge takes place.
>
> At approximately dead center, firing takes place and the piston is driven back on its power stroke; the exhaust ports uncover to permit escape of the burned charge. At the extreme end of the stroke the intake ports are uncovered and the engine is now set for its next cycle.

Thus in two strokes of the piston and one revolution of the flywheel the cycle is accomplished in the two-stroke cycle engine.

It might be well at this point to define the speed limits of the engines under discussion since there are still some who think in terms of the 180 to 225 RPM engines of twenty years ago.

Speeds of the engines under discussion will be from 300 to 900 RPM, with an engine designed to keep top piston speeds of about 1,000 feet per minute. It is felt that these limitations greatly add to engine life and make for much less wear on all rubbing parts.

Basically the main components of both the two and four stroke cycle engine are quite similar.

Common to each engine is the frame which supports the cylinder with its combustion head. Inside the cylinder moves the piston.

The frame further supports the crankshaft and the flywheel or flywheels, as the design may employ, and also the clutch and drive sheave.

Thus, the frame may be said to support the rotating and reciprocating elements of the engine and fundamentally these are common to both types of engines.

Further common to both types of engine and necessary for the successful operation of any engine there must be a suitable and stable fuel supply; a precise and dependable fuel ignition system; a governing system with a very minimum of variation within the set operating speed of the engine; and suitable cooling and lubricating systems.

Too great a variation in the fuel supply or in the operation of the other items mentioned in the above paragraph will result in the malfunction of the engine, and if not corrected may result in the destruction of the machine.

Peculiar to the four-cycle engine are the valves which must be operated by either push rods or a layshaft and cam arrangement to provide proper lift and timing.

Of particular interest in the two-cycle engine is the use of the stuffing box between the frame and the cylinder. This seals off the crank end from the combustion end and prevents contamination of the lubricating oil in the frame or bed of the engine and also prevents excess oil coming over into its power end.

Ignition in both types of engines is usually by means of a rotary type magneto and governing by use of a flyball governor. On the two-cycle engine the drive for these accessories as well as the lubricator is from a layshaft, gear driven from the engine crank. This layshaft is generally on the outside of the engine frame and cylinder.

The four-cycle engines use various push rod and cam motions for the operation of the above accessories - some of these drives being inside the engine frame.

As stated above each of these components has a direct bearing on what goes on in the engine cylinder and their proper care and adjustment are imperative to proper operation of the engine.

We are, of course, taking it for granted that you have purchased an engine of known quality and manufacture.

Manufacturers furnish, generally upon request, curves on engine performance and from these you may choose the points of best operating characteristics to suit your particular application.

It should be born in mind that one reason for the purchase of the slower speed horizontal engine is to take advantage of the lower piston speeds in the horizontal engines, and most manufacturers furnish this information in conjunction with horsepower, torque and fuel consumption curves. Study of these curves, particularly in consultation with your suppliers' engineer will greatly help you in a proper choice of engine size to do a given job.

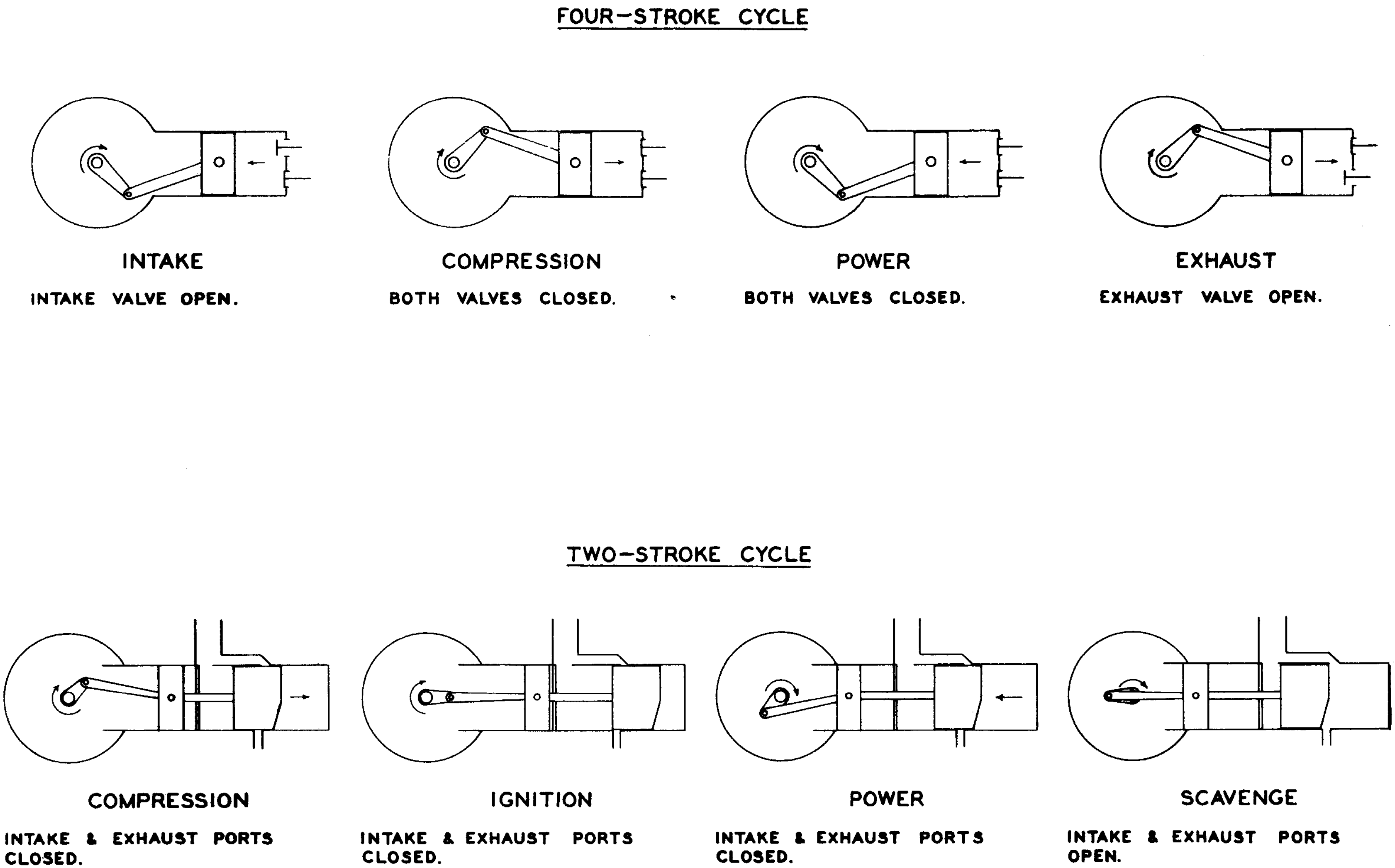
FOUR-STROKE CYCLE
INTAKE
INTAKE VALVE OPEN.
COMPRESSION
BOTH VALVES CLOSED.
POWER
BOTH VALVES CLOSED.
EXHAUST
EXHAUST VALVE OPEN.
TWO-STROKE CYCLE
COMPRESSION
INTAKE & EXHAUST PORTS CLOSED.
IGNITION
INTAKE & EXHAUST PORTS CLOSED.
POWER
INTAKE & EXHAUST PORTS CLOSED.
SCAVENGE
INTAKE & EXHAUST PORTS OPEN.

Figure 1

Even though API curves are available a buyer may wish to examine other curves than the API. The important thing is a check to see under what conditions the engine ratings have been set up. For instance, was it tested while driving the fan, lubricator, water pump, etc. ?Is BTU rating of gas equal in all test cases ? Maximum test horsepower should be taken on this basis and corrected to standard conditions of temperature and atmospheric pressure. It is also to be remembered that altitude affects the power delivered by an engine and this should also be checked with the supplier. It is not to be inferred here that engines may not be operated at a higher and possibly more effective rating but this is a matter to be decided between the manufacturer and the buyer.

When your engine is delivered you should first inspect it thoroughly for any damages that may have occurred during delivery or unloading. Don't sign the receiving papers until you have done this. This should apply to any piece of machinery or other equipment you receive. You should also inspect the boxes that are received with the machinery and see that every thing is checked against the bill of material. Such procedure protects you and your company in the event of claims at a later date.

The next thing to do is take time out to carefully read the book of instructions furnished with the engine. One of the greatest sources of difficulty is the failure of the operator to have acquainted himself with the operating details as applied to his particular engine. If an outside contractor is involved in setting or maintenance you should be certain that he is guided by the same discretion you are expected to display as the operator or owner of the engine.

In setting the engine, slings or lines should be so arranged that the load is taken preferably under the bed or frame at good balance points. Engines should never be handled by lines around the cylinder, the flywheels, or on the crankshaft if at all avoidable.

If you are setting the engine on concrete the block should be run according to the manufacturer's recommendation for the soil encountered and sufficient footing should be insisted on as well as proper reinforcement and mix specifications of the concrete. The block should roughly be three times the engine weight.

When an engine is set on steel skids to drive a pumping unit, pump, generator or anything else care should be taken to see that the skids have sufficient and proper bracing in order to prevent vibration. The rails which permit adjustment for belt tightening should set in a longitudinal direction with the engine and these should be supported by adequate crossbracing. They should have good contact with their supporting members and the entire unitized assembly should be securely bolted to a concrete pad or foundation wherever possible. After the machinery is properly aligned and the piping and belting properly adjusted final bolting should take place. All fastners should be made secure and maintained securely thereafter to prevent vibration.

When it is necessary to put the flywheel on the engine shaft the first step is to be sure that the shaft of the engine and the bore of the wheel are clean, free from rust, paint, grease, dirt or any other abrasive materials.

The flywheel should be wedged open and the keyways of the wheel and shaft aligned. The key is then started only a sufficient distance to hold it. The wedges are then removed; the binding bolts tightened; and the key sledged home by using a brass slugging bar. A light coating of thin white lead may be used on the keyway.

Initial, careful, and proper application of the flywheel and key will insure a true running wheel and a long lasting tight fit and make for smooth, vibrationless operation.

Heavy flywheels on present day engines act as reservoirs of energy to help an engine carry through its non-power strokes at points of instantaneous demand. Such a demand may develop when carrying over the counterbalance of a pumping unit.

Flywheel weight alone does not add to the smoothness of engine operation nor does it add anything to its horsepower. The smoothness of operation may be expressed by the following formula for the degree of irregularity.

$$I = \frac{C \times ND}{\left(\frac{n}{100}\right)^3 \times WD^2}$$

where I = Degree of irregularity
ND = Horsepower delivered
n = RPM
W = Weight of flywheel rim X 1.15
D = Diameter of center of gravity of rim
C = A constant as follows
1100 for four-cycle single cylinder engine
500 for two - cycle single cylinder engine
80 for two - cycle single cylinder engine

By working through the formula it will be demonstrated that the smaller the fraction the smoother the operation of the engine. A degree of irregularity something on the order of 1/150 is acceptable for electric generation where lighting is not the chief objective. Therefore degrees of irregularity approaching this figure make for smooth engine operation provided all other engine characteristics are right.

This formula may be applied when the values of the given factors are known and they will have to be obtained from the manufacturer if you wish to apply them.

The Fuel System

In hooking up the fuel system it will be well to follow the manufacturer's recommendations.

An ample supply of dry, sweet gas is preferable. It should be delivered to a volume or scrubber tank ahead of the engine at a pressure of not over 50 psi. It is the function of this tank to clean the gas and reduce it to a pressure of about 6 oz. or not to exceed that recommended by the manufacturer. A typical scrubber volume tank is shown in figure two.

Too much emphasis cannot be laid on this matter of clean gas under correct pressure. Lack of proper fuel hook-up is one of the most common causes of failure of an engine to start or to operate eratically and finally shut down.

Connections from the well head direct to the regulator on the engine should never be made as oil may slug through the system and foul valves and spark plugs and destroy sensitive diaphragms in the regulator. These sensitive mechanisms are just not built for this kind of abuse.

Scrubber or volume tanks may be purchased from your supplier together with the necessary regulators and fittings or you may have a welder build one after getting the proper specifications for your particular engine. Most manufacturers give the specifications for volume tanks in their literature and these should be followed as set forth.

Most systems are set for a BTU value of about 1,000 for natural gas. Where liquified petroleum gases are used the regulator and carburetor nozzles should be changed to accept the higher BTU value gas.

Sour gas should have corrective measures applied where possible. If it cannot be corrected you may expect difficulty and be prepared to pay for it in greater maintenance costs.

The use of gasoline or ether for priming is to be avoided particularly in the two-cycle engine.

To control the engine speed a governor is used to regulate the volume of the fuel charge entering the cylinder.

Various methods of drives are used for the governor but the governor itself is essentially the old time flyball governor as used for many years and familiar to almost every operator.

Modern governors are fully enclosed and gear driven thus aiding in stability and reducing lost motion. They require a minimum of care and lubrications. However, they should be inspected regularly to insure that the linkage has not worn and allowed play to develop. The proper adjusting spring should be applied to suit the speed range desired of the engine.

TYPICAL VOLUME-SCRUBBER TANK

TABLE

FIELD INLET PRESSURE (PSI) 1" OR $1\frac{1}{4}$" REG.	$1\frac{1}{2}$" OR 2" REG.	ORFICE DIA. IN INCHES
	$\frac{1}{2}$ TO 13	1
	13 TO 25	$\frac{3}{4}$
1 TO 8		$\frac{7}{16}$
8 TO 20	25 TO 50	$\frac{1}{2}$
20 TO 35	50 TO 100	$\frac{3}{8}$
35 TO 75		$\frac{1}{4}$

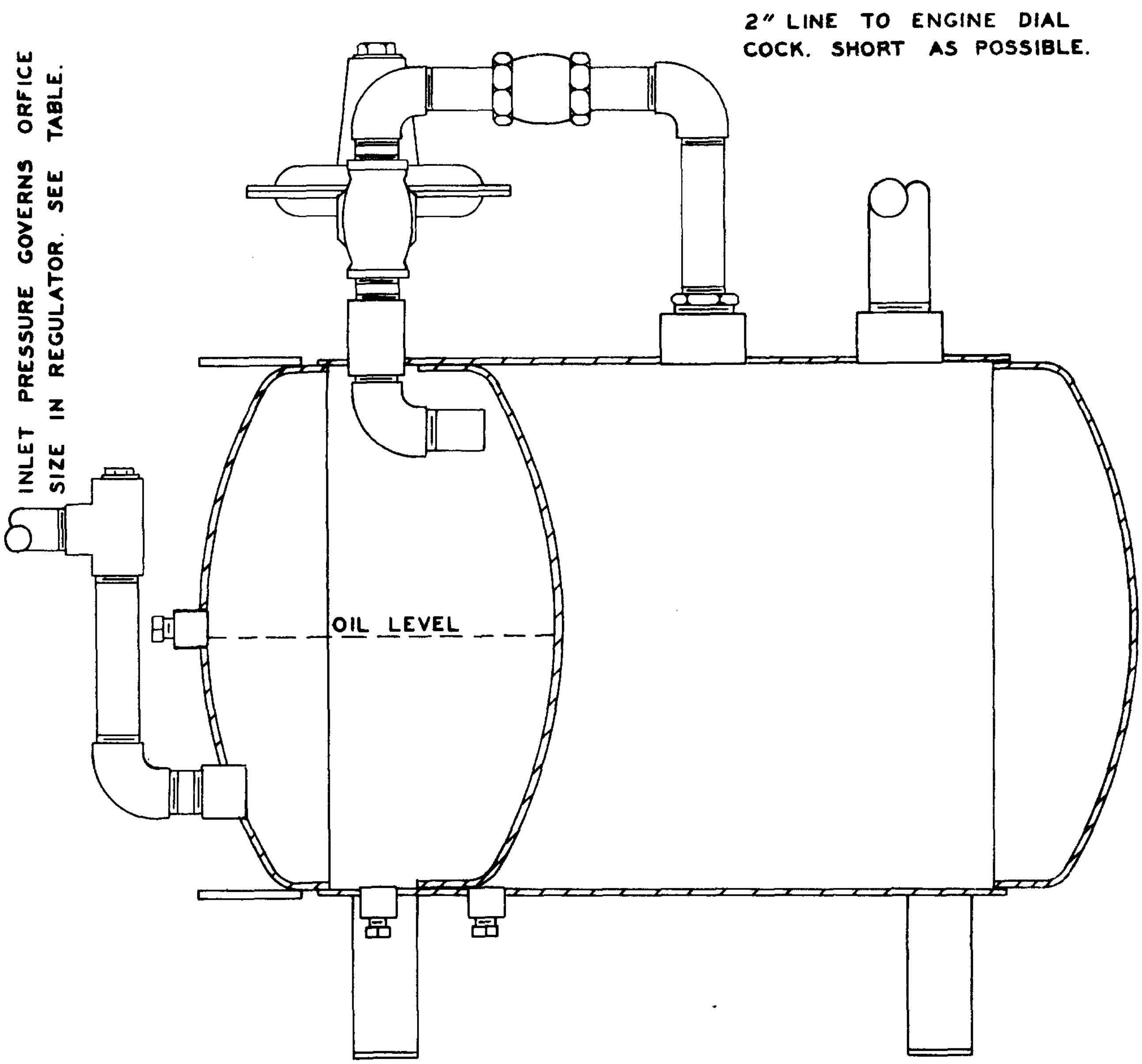

Figure 2

Governors should never be bypassed or so rigged that they are non-effective as they are applied for the ultimate purpose of preventing the engine from running away and destroying itself.

Governor action becomes more critical with the use of light flywheels since the time allowed for governor action is proportional to the size of the flywheel and this should be kept in mind both in the choice and operation of an engine.

Cooling System

Proper engine cooling is without doubt one of the most important factors in satisfactory engine performance. Lack of it results in contributing to the break down of lubrication and this results in plugged parts, burned valves, carboned and stuck rings, cylinder scoring and fouled spark plugs.

On present day horizontal engines two systems of cooling are employed viz:

1. Thermo syphon
2. Vapor phase

Neither of these systems requires a water pump or a tank or pond for water circulation. The less the cooling water comes in contact with the atmosphere the less oxygen it absorbs to combine with metal to create rust. The elimination of the pump does away with opportunities for packing wear which permits sucking air into the water when the engine is running. Further, these systems eliminate pumps and drives as engine accessories and thus do away with added maintenance requirements.

The cooling system should be so designed as to be self regulating. It should be able to accept anti-freeze solutions and should require a minimum of make up water.

Both the forementioned cooling systems use a radiator and fan which are engine mounted and an integral accessory of the engine.

In the thermo-syphon system the natural circulation of water is used to accomplish the cooling of the engine.

The engine jacket and radiator are filled with water and the pressure cap placed on the radiator.

When the engine is started a portion of the heat of combustion is transferred to the cylinder wall and thence to the jacket water and the thermo-syphon system is set in progress. The colder water in the bottom of the radiator circulates into the exhaust port area which is a critical temperature area. It then continues on through the cylinder jacket to the top of the radiator where the fan and radiator fins reduce it to an operating temperature. This system of cooling induces a cylinder wall temperature somewhat above the dew point and thus prevents condensation of the water of combustion on the inside cylinder wall. Circulation is also in proportion to the work done by the engine and thus makes for more uniform temperatures. This tends to eliminate cylinder distortion under changing load conditions. Further, if the fuel gas has any trace of sulphur in its makeup the matter of keeping the cylinder wall above the dew point takes on added importance. The sulphur product will combine with the water of combustion to form damaging acids which aid in destruction of the internal working parts of the engine.

The use of pressure caps prevents the escape of the cooling liquid. A cap of about 7 psi rating should be used for summer use and about 13 psi when using ethylene glycol types of anti-freeze.

The vapor phase or steam condensing system makes use of a radiator and fan mounted on a hopper or similar reservoir on the cylinder.

In this system the water is not brought up into the radiator in filling but only to the proper level in the hopper. Thus the water enters the top of the radiator as steam and is condensed in the radiator and returns to the hopper.

In this type system ethylene glycol type anti-freeze solutions CANNOT be used. Alcohol should be used according to the manufacturer's recommendations and in freezing weather and even under continuous operation the engine should not be run with water alone since the water will freeze in the condenser (radiator) even though it is not frozen in the rest of the system.

Needless to say all radiator piping and hose connections should be kept tight to prevent fluid loss. Fan belts should be kept at proper tension and the radiator protected from external damage due to rough handlings. Bugs, dust, leaves and other foreign materials should be cleaned from the radiator. If the engine is housed, arrangements should be made for proper air circulation to give the most advantageous ambient air temperatures during hot weather.

Radiator braces and fasteners should be kept tight to prevent vibration.

To put it briefly, the cooling system on your engine is just as important as on your automobile and it deserves the same attention.

Exhaust Lines

Exhaust lines should be no smaller in diameter than the largest opening at the engine or the exhaust flange. Clean pipe should be used and all sharp turns and bends avoided. Anything that tends to obstruct free discharge of the burned charge should be eliminated and the use of pits, mufflers and "barkers" should be eliminated when possible. When it is necessary to silence an engine the manufacturer of the engine should be consulted for specifications.

On installing the line be sure that there is no blank gasket or a plug of any kind sealing off the exhaust at the engine. Openings are sometimes plugged at time of shipment to prevent entry of moisture and dirt into the cylinder or valve mechanism and these obstructions must be removed.

When an engine has been shut down for some time the exhaust line should be again inspected against plugging by rodents, birds, mud, or other debris.

On the single cylinder two-cycle engine careful attention to exhaust pipe length must be given if best performance is to be attained. The reason for this is that when the exhaust ports uncover a high pressure wave is generated which traverses the exhaust pipe at sonic speed. As it reaches the end of the pipe it is reflected back along its path where it is again reflected from the closed exhaust port and this goes on until the wave is damped out. Should the impulse reach the exhaust port as it is opening, or is already open on the next cycle, it will adversely affect the scavenging of the engine.

Much experimenting has been done and formulae have been set up by the manufacturers of two-cycle engines to establish the proper exhaust lengths. Either the formula or a curve for exhaust length is obtainable and the exhaust piping installed accordingly.

Better two-cycle engine performance will result from application of this formula. It may be added here that some work has been reported as being done along this line on four-cycle engines.

Consideration should be given to exhaust line supports so that no strain is exerted on the engine cylinder at the cylinder exhaust flange. Expansion type couplings should be used in lines of any considerable length and lines should never be buried in concrete, rock, dirt or anything else that prevents their proper expansion.

Lubrication

As with any machine proper lubrication is vital to the satisfactory operation of the horizontal engines.

There is no one lubricant to suit all makes of engines and it is therefore imperative that you study the recommendations given by the manufacturer of the engine.

For cylinder lubrication an oil should be chosen that is non-detergent. It should have a high flash point and as low as possible Conradson Carbon count. Too high a flash can contribute to pre-ignition. Use of an oil with low Conradson carbon count keeps the cylinder from building up sludge thus preventing sticking rings, valves, clogging parts and increasing abrasion between piston and cylinder as well as spark plug fouling.

A good lubricant should be such that it reduces to a dry, light, fluffy carbon and carries on out the exhaust line.

Since the two-cycle engines presently on the market have stuffing boxes between the cylinder and crankcase there is little possibility of dilution of the lubricant in either end provided the packing is properly maintained. If there is excessive loss of crankcase oil and carbon is building up at too great a rate in the cylinder the packing should be checked to see if it is holding.

Force feed lubricators are used on the two-cycle engines to deliver lube oil to from one to three points on the cylinder depending on the size of the engine. These lubricators may be set to meter the oil as is recommended by the engine manufacturer and his quantity recommendations should be closely followed to maintain proper engine operation.

It pays not to feed too much lubricant to the cylinder - only that amount specified. Excessive cylinder lubrication is false economy and will definitely lead to cylinder trouble.

Lubricator drive linkage should be kept in adjustment and the sight feeds kept clean externally and internally so that you know much oil is being fed to the cylinder.

The modern four-cycle engines generally use a combination of oil pump and splash lubrication. Oil is delivered under pressure to those parts requiring metered quantities and the remainder of the engine is splash oiled.

In both types of engines splash oil is used at the crankcase end for lubrication of rotating and reciprocating parts. Here the oil should be of a quality recommended by the manufacturer and the level should be maintained according to his instructions. Inspection of lubricating systems, clean out of sumps and settling chambers and systematic oil changes and filter changes where filters are used will add years of trouble-free service to the engine and it is to your own advantage to see that these things are done.

Ignition System

The ignition system consists of the spark plug, the spark plug cable and the magneto itself.

Modern magnetos are of the rotary type, heavily insulated and anti-friction bearing mounted and are driven either at engine speed or twice engine speed. Adjustments are only in the breaker point gap and impulse coupling lag. Gap should be on the order of .017.

When the magneto operates at engine speed there should be approximately 20 degrees lag in the impulse coupling and this will give 20 degrees advance spark at coupling disengagement.

A twice engine speed magneto requires 40 degrees lag to give the 20 degree spark advance.

When a new magneto is ordered or a used one repaired you should be sure to specify the make and model of the engine on which it is to be used. In this way lag will be correct as well as direction of rotation.

Everyone is familiar with spark plug trouble but it is surprising how many will work a balky engine over and leave the spark plug till the last inspection.

Plug gap should be about .018 to .025 depending on engine manufacturer's recommendation. Too wide a gap is especially detrimental at the starting period because at the point of impulse coupling disengagement the output of the magneto is at its lowest and this is at the time of greatest electrical demand. Thus if the gap is too great the plug will fail to fire.

Modern ignition cable is practically trouble free unless badly cut or otherwise damaged by mistreatment.

Spark plug gaskets should be inspected to see that they have not been flattened and are not out of round and that they are clean. The plug should fit solidly as at this point the full effect of compression and explosion pressure is exerted.

Engine Safety Devices

Although not strictly a safety device but definitely serving such a purpose are the modern engine starters.

There are several classes of starters using small air-cooled engines as power and these may be classified as follows:

> Air starting where an engine and compressor is mounted on a storage tank and air is admitted to the engine cylinder by a cam and valve arrangement on the control shaft.
>
> Flywheel friction starters where a small engine drives a friction pulley which is brought into contact with the flywheel.
>
> Engine mounted electric starters or engines arranged for starting through a ring gear.

Also available is a shutdown switch for cooling water failures and also for low lube oil level. There is also an overspeed shutdown device for application to the flywheel which operates upon reaching a pre set speed and thus prevents the engine from running away.

Power Transmission

Slow speed horizontal engines are furnished with two types of power take off depending on the manufacturer.

1. The standard Power Take-off.
2. Clutches requiring special V-Belt sheaves.

In the first or standard Power take-off standard V-Belt sheaves may be applied as they are not part of the clutch mechanism. Use of this clutch permits quick changing of sheaves and standard sheaves are generally readily available in supply house stocks.

In the second the arrangement is such that the sheave is a part of the clutch mechanism and the sheave floats when the clutch is out.

Regardless of the clutch used, it is essential that the driver and driven sheaves be in absolute alignment and that correct tension be maintained. Too much tension will deflect the shaft and place undue stress on the bearings or it will cause drag on the friction plates.

Clutches should be regularly lubricated with the proper amount of specified lubricant. Do not over lubricate.

On applying the V-Belts to the drive the shafts of the engine and the driven machine should be checked to see that they are parallel. If shafts are not parallel the belts on one side the drive will get tighter than those on the other.

Sheaves should be clean and lined up by simply sighting along the edge or by the time honored method of stretching a string across them.

Tension should be such that only a slight sag is noted in the slack side when the drive is running.

When a matched set of belts has been purchased the drive should have at least two days time to seat. The drive should then be checked and necessary corrections made.

It is recommended that you read an excellent article on "How to Increase Life of V-Belts" by Mr. W. S. Worley in the January, 1957 issue of *Petroleum Refiner.* It is not lengthy and is well worth your time..

The Instruction Book

It has been my privilege to study the instruction books sent out by most of the slow speed engine manufacturers. Everyone of these books is written in an understandable language and they are well illustrated. They are detailed without being confusing and they should be a bible to the engine user. As I mentioned before, sit down with the book and study it. Refer to it when you have trouble and you will find yourself well served from the installation through the life of the engine. All the necessary information on specifications and operating and maintenance is set forth and it should be followed.

When and if your troubles overcome you, there are always available competent service men - factory trained to help you. Call them and give them an honest report on your trouble and what led up to it. In this way you will get back into operation in the shortest possible time.

Check List

Keep all foundation bolts tight

Inspect flywheel clamp bolt for tightness.

Check all set screws, lock nuts and adjusting screws for proper tightness.

Keep rod packing properly adjusted.

Follow a regular lubrication schedule.

See that sumps and settling chambers are cleaned and flushed.

Be sure that sighting devices are clean inside and out so that flow and level of oil may be seen.

Check spark plug for gap and for general serviceability.

Check spark plug gasket for leakage.

If impulse coupling does not click at starting it should be inspected and washed in a grease solvent if dirty.

Inspect ignition cable and be sure it is not cut or abraided.

Check all filters to see that they are functioning.

Check fuel supply to see that it is ample and steady and within the recommended pressure limits.

Check cooling system to see that water supply is at proper levels and that anti-freeze solutions are sufficient and suitable to the operation.

When shutting down throw out clutch and permit engine to idle a few minutes thus allowing engine to cool down more evenly.

Keep fan belts at proper tension.

Clean bugs, dust, paper and debris from radiator.

See that proper pressure cap is used and that it is functioning.

Be sure that exhaust system is fully open at all times. Use correct length and diameter pipe.

Keep clutch properly adjusted and lubricated.

Keep V-Belts and other drives in proper tension and alignment.

Correctly apply and regularly inspect all safety devices so they will function when needed.

Keep your equipment clean.