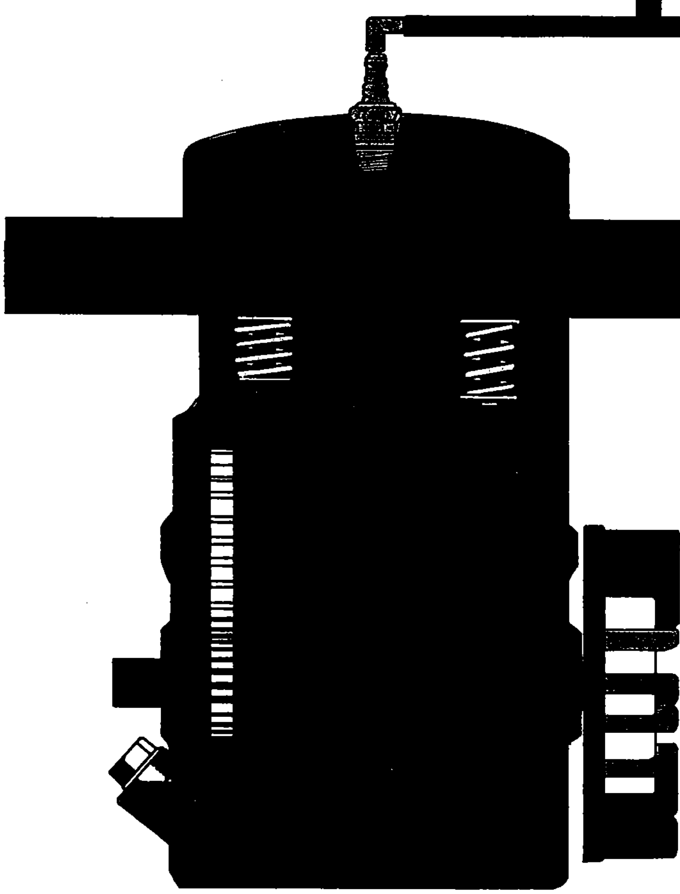
4-H SMALL ENGINES

UNIT I



MEMBERS' MANUAL

NAME___________________
CLUB___________________
BIRTHDATE______________
YEARS IN PROJECT___
YEARS IN 4-H___

CO 650

4-H SMALL ENGINES PROGRAM IDENTIFICATION SHEET

Name ______________________________ Age ____

Address ______________________________

Engine Manufacturer ______________________________

Address ______________________________

Model No. ______________ Serial No. ______________

Horsepower ______________ Drive: Vertical ____ Horizontal ____

TABLE OF CONTENTS

Acknowledgment

This educational material has been prepared for 4-H use by the National 4-H Petroleum Power Development Committee, composed of representatives of the Cooperative Extension Service of the State Land-Grant Universities, and SEA-Extension, U.S.D.A. in cooperation with the National 4-H Council, publisher. Edward O. Eaton, extension agricultural engineer, Cornell University, served as principal author.

Special thanks are extended to Amoco Foundation, Inc. for financial assistance and to Briggs and Stratton Corp. and the American Association for Vocational Instructional Materials for technical information and illustrations. This material is published by the National 4-H Council, 7100 Connecticut Avenue, Chevy Chase, Maryland 20815.

50-5-76/50-5-77/50-1-78/50-8-79/40-10-81/25-3-83/25-3-84

4-H SMALL ENGINES PROGRAM
INTRODUCTION TO SMALL ENGINES

It is estimated that there are over seventy million small engines in use in the United States today. They are filling a great need for both work and recreation. They are meeting a need for power which cannot be met by other sources. The popularity of these small engines has increased rapidly as new applications have become a reality. There is hardly a home that doesn't have at least one. They are used by young and old and in many cases a second or third unit is available for different uses.

A lack of understanding of how the engine works is a common reason why problems develop in the operation of a unit. A knowledge of the principles of operation, proper service, maintenance and simple repairs is important. This knowledge, if put into practice, can provide many hours, if not years, of trouble-free operation. It will also provide a sense of pride and satisfaction in operating your power unit.

Your study of the small engine will be interesting and beneficial.

Types of Engines

All engines require a source of fuel which must be consumed to provide mechanical energy. This fuel may be gasoline, oil, gas or electric.

Internal Combustion. This type of engine makes its power by burning the fuel inside of the cylinder.

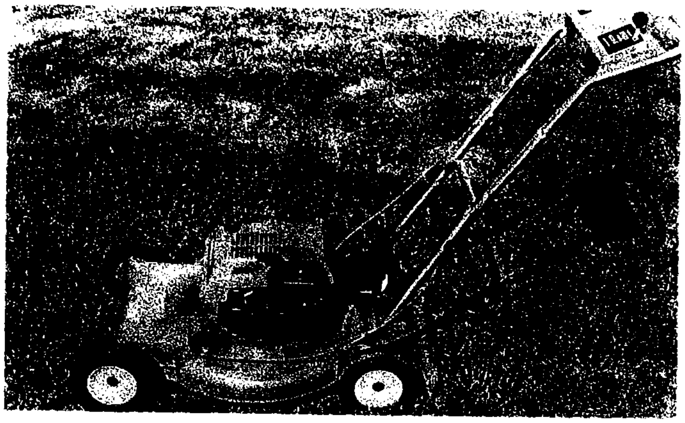
External Combustion. This engine gets its power from an outside source. A steam engine is a good example where steam, which provides the power to run an engine, is generated in a boiler.

Electric Motor. This project will not deal with the electric motor, but it should be noted that it has an outside source of power; the energy that runs it, comes through wires.

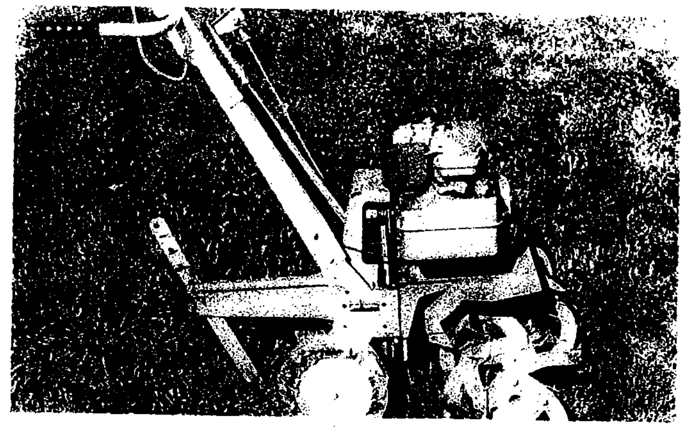
This project will concern itself with internal combustion engines. There is more than one type and the beginner should first learn about the *four stroke cycle* engine.

Distinguishing Features of Small Engines

Small engines must have many different features to meet the requirements of different types of equipment. Some engines of the same type have different designs and accessories. Fuel systems, starting assemblies and ignition systems may differ a great deal from one power unit to another. Vertical crankshafts are common on rotary lawn mowers while horizontal shafts are found on rototillers.



Suction-Type Fuel System
Vertical Shaft



Gravity Fuel System
Horizontal Shaft

A major difference in the two most common types of small engines is in the number of strokes per cycle.

Four Stroke Cycle Engine

There are four strokes of the piston in one complete cycle of this engine. The four strokes, in the order of occurrence are intake, compression, power and exhaust. These four strokes complete one cycle of events and require two complete revolutions of the crankshaft. It is commonly referred to as a *four-cycle engine.*

Two Stroke Cycle Engine

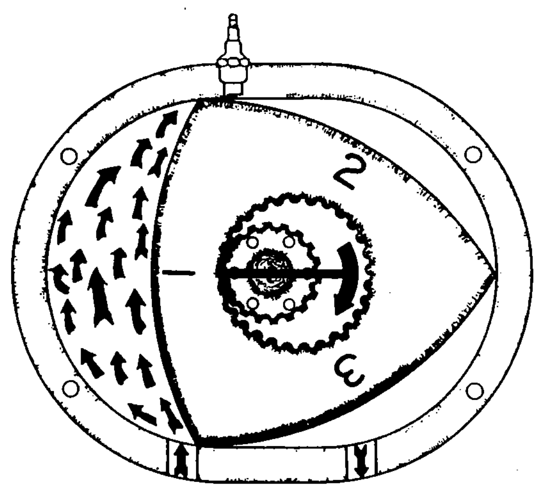
There are only two strokes of the piston for one complete cycle. Four events must occur; intake, compression, power and exhaust for the engine to run. Intake and compression are combined in one stroke while power and exhaust are combined in the other. Sometimes intake and exhaust are referred to as side effects or scavenger events. Only one complete revolution of the crankshaft is required for a complete cycle of events. This is commonly referred to as a *two cycle engine.*

Rotary Engine

The "Wankel" is one form of a rotary engine. The rotor follows a circular motion instead of stopping and changing direction as the piston does in common internal combustion engines. There are also other designs of the rotary engine.

In the "Wankel" rotary engine the ratio between the crankshaft and the rotor is 3:1. All four events — intake, compression, power and exhaust are accomplished on a side of the rotor in one revolution of the rotor. Since all three sides of the rotor are used, there are actually three power strokes per rotor revolution. Due to the 3:1 ratio there is one power stroke to each revolution of the crankshaft.

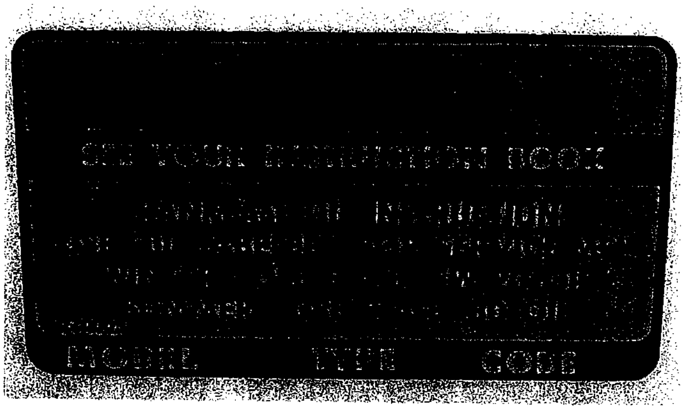
Many challenges still exist before the rotary engine can be commonly applied to small engine uses.



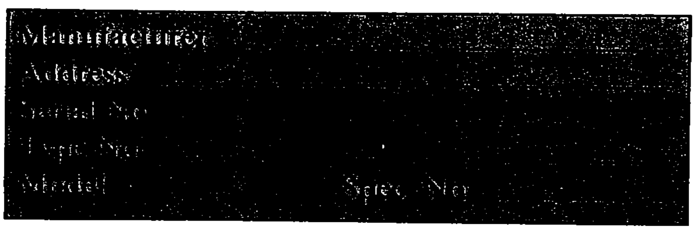
Single Rotor Engine

Nameplate Data

Some very important information will be found on the nameplate of your engine. Some nameplates provide only information such as manufacturer's name, serial number, type and model numbers. Others provide some operational and maintenance information. All is important, but the numbers are a must when you need to purchase replacement or new parts.



Find the nameplate on your engine and fill out an Owner's Engine Information Form.



Basic Requirements for Engine Operation

Three basic requirements have always been necessary to make an engine run. These applied to the first engines invented and also apply to modern ones. A combustible air-fuel mixture is needed in the cylinder (intake stroke). This air-fuel mixture must be compressed (compression stroke). The compressed air-fuel mixture must be ignited at the proper time (power stroke). The burned gases must be cleared from the combustion chamber (exhaust stroke). With these basic requirements met, one cycle of events is complete, another cycle starts, and the engine operates.

Activities and Demonstrations

1. Complete owner's information sheet (nameplate).
2. Clean external surfaces of engine (use cleaning solvent - kerosene - "gunk").
3. Drain oil and gasoline from engine (use proper disposal containers).
4. Compile a list of uses for small engines.
5. Identify and explain the basic differences between engine types.

List of small engine uses at your home or farm. Check those that apply (✔).

_____ 1. Lawn mower
_____ 2. Garden tractor
_____ 3. Rototiller
_____ 4. Snowblower
_____ 5. Mulcher
_____ 6. Edger
_____ 7. Generator
_____ 8. Motor scooter
_____ 9. Air Compressor
_____ 10. Other ____________________

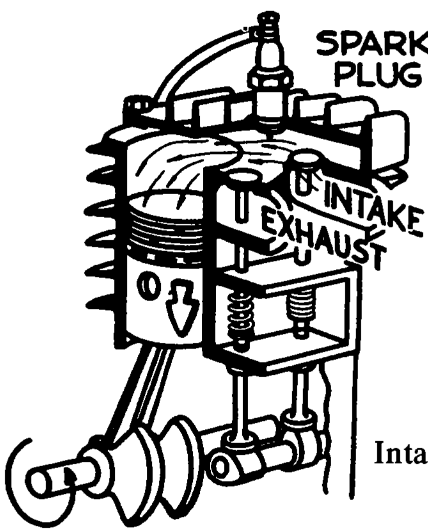
PRINCIPLES OF FOUR CYCLE ENGINES

Operation of the four stroke cycle engine is the easiest to understand. It also probably is the most common type of engine in use for the many applications around the home. You may limit your first year of study of small engines to the four cycle unit. Remember that there are four strokes of the piston for one complete cycle of events.

The Intake Stroke

The intake stroke is the first stroke. The intake valve opens as the piston moves away from the cylinder head. Because of the suction created by the piston moving away from the head, the air-fuel mixture rushes into the combustion chamber. This continues until the stroke is complete and the intake valve closes.

The carburetor regulates the air-fuel mixture entering the cylinder.

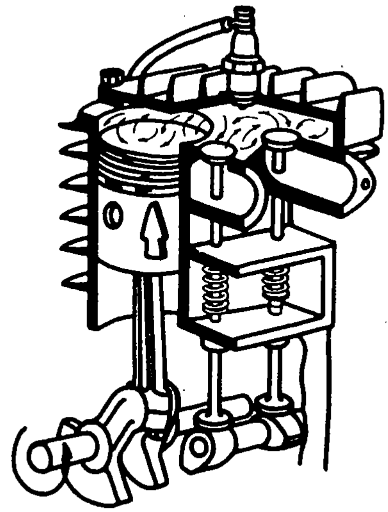


Intake Stroke

The Compression Stroke

When the piston reaches the bottom of the cylinder it moves back towards the cylinder head. The intake valve closes and the exhaust valve remains closed.

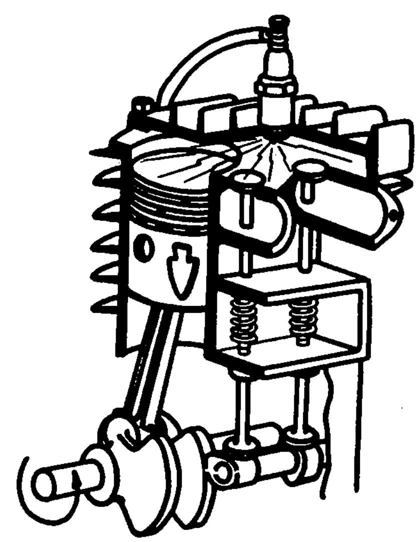
The air-fuel mixture is crowded into less and less space compressing it to only one-sixth the volume of the whole cylinder. The compression of the fuel-mixture raises its temperature and prepares it for burning.



Compression Stroke

The Power Stroke

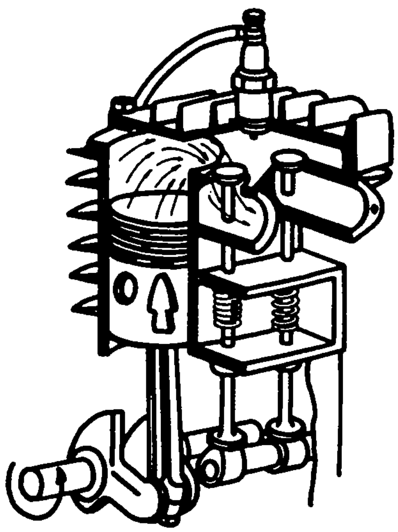
The power stroke may be called the third stroke in the cycle. Just before the piston reaches top dead center at the end of the compression stroke, a high voltage spark is introduced at the spark plug. This spark ignites the compressed fuel mixture that is ready to burn and rapidly expand. The force of the expanding gases pushes the piston down to turn the crankshaft and creates power.



Power Stroke

The Exhaust Stroke

Just before the piston reaches the bottom of the power stroke, another valve opens - the exhaust valve. Exhaust gases rush out. They are under their own power at first because they are still expanding. Then, as the piston drives upward, the rest of the gases are pushed out.



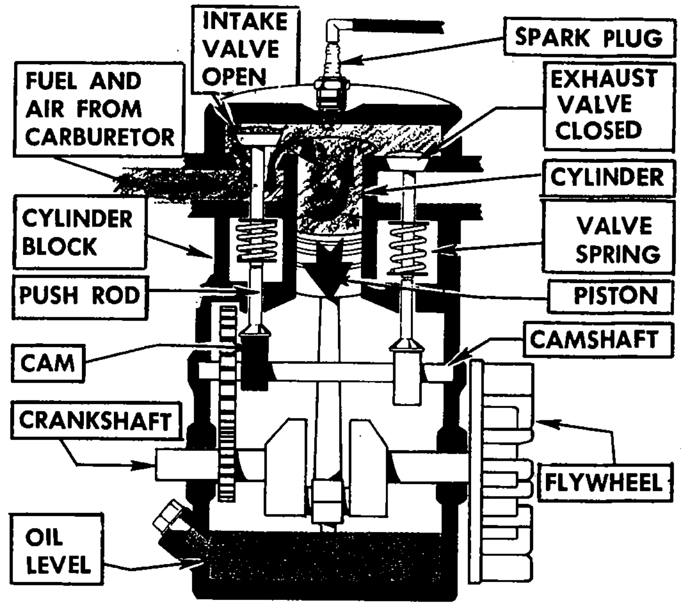
Exhaust Stroke

That's it. We call this a four stroke cycle engine because of the four things that happen in the cylinder during four strokes of the piston — intake, compression, power and exhaust. The piston goes down twice and up twice for every power stroke while the flywheel goes around twice. That makes four strokes for a complete cycle.

You are now acquainted with the four strokes and the related events. Different internal moving parts of the engine make these events possible. Some of these such as the piston, cylinder and valves have been mentioned.

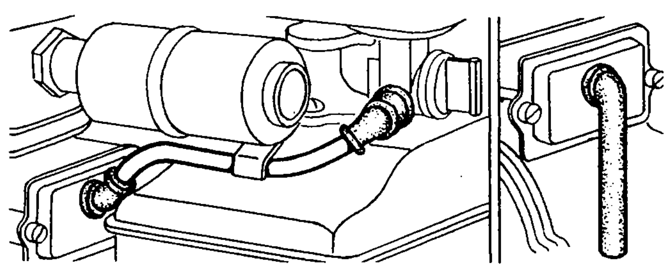
The valves which are located in the cylinder head, must be opened and closed at the correct time. They are kept closed by strong springs and are opened at the proper time by means of push rods which are driven by cams. The cams are located on the camshaft which is geared to the crankshaft or they may be on the crankshaft.

Sometimes excessive pressure may build up in the crankcase. During combustion a certain amount of "blow-by" from the chamber passes by



Cutaway Engine

the piston rings into the crankcase. Oil leaks will result if this pressure is not released. A crankcase breather valve located in the valve-tappet access well or in its cover relieves this excessive pressure. This breather needs service at least once a year.



Breather Assemblies

Activities and Demonstrations

Disassemble an engine.

- A partial disassembly should be sufficient for a beginner. Remove the air shroud, head, crankcase breather and engine base. (New gaskets may be needed before reassembly.)

- complete tear-down will be necessary for the preparation of a parts display board.

- Identify all parts.

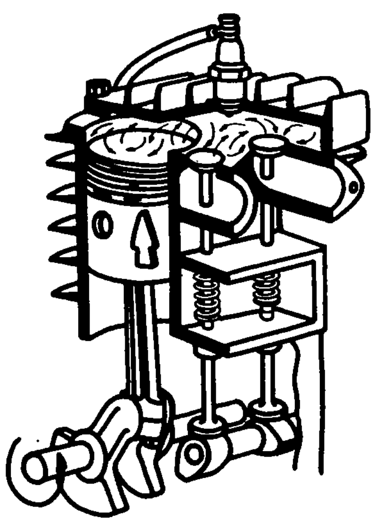
- Prepare a demonstration of the principles of operation of the four cycle engine.

COMPRESSION

Compression is one of the necessities to make it possible for an engine to run. Good compression is essential for easy starting and for horsepower output. If the engine produces the power for which it was designed, the compression must be good.

Good compression:

- It provides for high pressure and temperature which are near the ignition point.
- It concentrates the fuel mixture into a more restricted space, thus making it easier to ignite.
- It helps distribute the fuel particles in the combustion chamber for improved burning.
- The higher the compression, the greater the expansion of gases after the fuel burns in the cylinder. The expansion pressure provides more power to the piston.

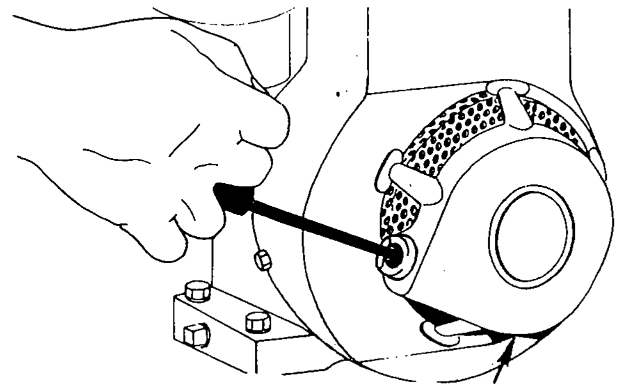


Compression Stroke

Checking Compression

It is extremely difficult to make an accurate compression test on a small, one cylinder engine. The reasons for this are the lack of a starter to crank the engine at a constant speed and the small displacement of the cylinder.

As a simple compression test, give the flywheel a quick spin. If the flywheel rebounds on the compression stroke, the compression is at least good enough to start the engine. If the compression is poor, there will be little or no resistance to the flywheel turning, neither will it spring back.



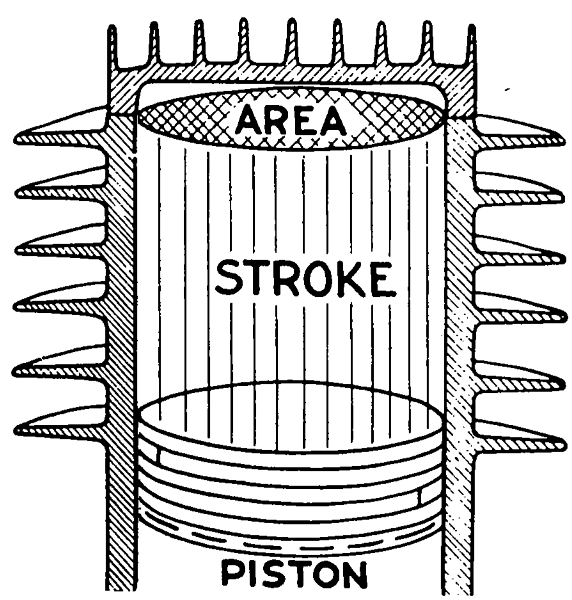
Spinning the Flywheel

Piston Displacement

Piston displacement indicates the relative size of the engine, and usually horsepower is in direct proportion to size..

It is the space or volume displaced by the piston in its up and down movement. The bigger the bore and the longer the stroke, the greater the piston displacement.

$$\text{Displacement} = \frac{(\text{Bore})^2}{4} \times \pi \times \text{stroke}$$



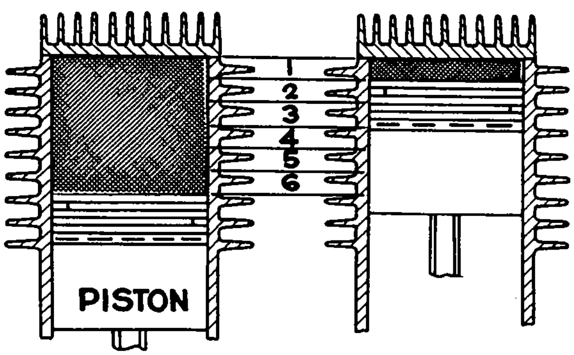
Piston Displacement

An engine with a 2" bore and a 2" stroke would have a displacement of 6.28 cubic inches. If converted to the metric system it would be 102 cubic centimeters.

Compression Ratio

What do we mean when we say an engine has a 6 to 1 compression ratio. It means that the space in the cylinder when the piston is at the top of the stroke is only one-sixth as great as when the piston is at the bottom of the stroke.

Compression ratios have a meaning relative to the efficiency of an engine. Generally, the higher the compression ratio, the greater the efficiency. They do not tell us the horsepower.



Compression Ratio

Reasons for Poor Compression

Any condition which allows the gases to escape from the cylinder during the compression stroke will cause poor compression.

1. Stuck or burned valves
2. Loose spark plug
3. Loose cylinder head bolts
4. Dry cylinder walls
5. Cylinder and piston ring troubles.

Activities and Demonstrations

1. Check the compression on a good and a very poor engine.
2. Identify engine parts related to compression.
3. With engine head removed study valve and piston movement.
4. Demonstrations.
   a. Replacing a head gasket
   b. Compression test
   c. Valve timing

List engine parts which may cause poor compression.

1 ______________________________

2. ______________________________

3. ______________________________

4. ______________________________

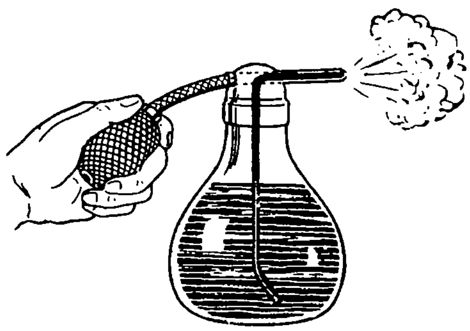
If you hear air escaping when you crank an engine, what does it indicate?

____

____

CARBURETION

A combustible air-fuel mixture is a necessity to make an engine run. Liquid fuel such as gasoline will not burn. The fuel must be broken up (atomized) and mixed with the right amount of air before it will burn readily. The carburetor, when properly adjusted, mixes the fuel and air in the right proportion for good burning.



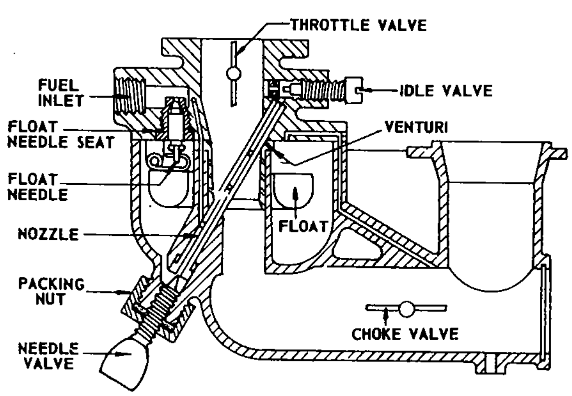
A Simple Atomizer

Purpose of the Carburetor

It breaks up the fuel into a fine spray and mixes it with air.

It regulates the ratio of air to fuel to provide economical and smooth engine operation.

It regulates the amount of air-fuel mixture going into the combustion chamber.

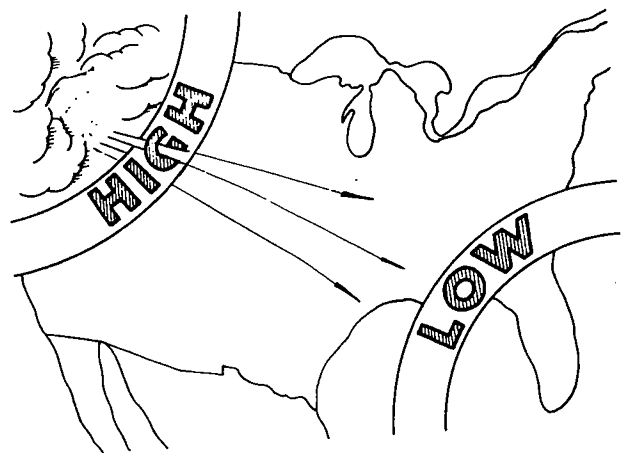


Principles of Operation

Atmospheric pressure, carburetor design, and parts of the fuel system make possible the introduction of the fuel-mixture into the combustion chamber.

Atmospheric pressure, while it may vary slightly due to altitude or temperature, is a constant potent force which tends to equalize itself in any given area. It is the weight of the air in the atmosphere pushing down and outward in all directions and is commonly figured as between 13 and 15 pounds per square inch. We know that air moves from a high pressure area to a low pressure area.

To use this force of atmospheric pressure in a carburetor, we artificially create low pressure areas. And thus we obtain movement either of air or of fuel.



Atmospheric Pressure

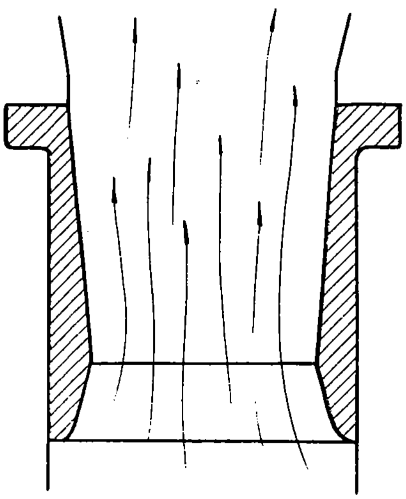
The greater the difference in pressure between the two areas the greater the velocity or the greater the distance the fuel can be raised. The terms vacuum or suction are commonly used in referring to the difference in pressures.

Venturi

What is a venturi? Have you ever noticed that the wind blowing through a narrow space between two buildings seems to be much stronger than in the open? In other words, the velocity is greater. The same thing can be seen in a river. The current is always faster in a narrow, shallow place than in the deep wide pools.

In a fashion, these narrow places are venturis. The greatest bulk of air or water suddenly forced through a constricted space has to accelerate in order to maintain the volume of flow.

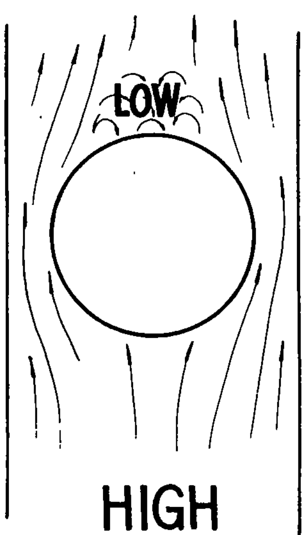
This is the way a venturi is placed in a carburetor. The shape is carefully designed to produce certain air flow patterns.



Venturi

Airfoil

Now, what is an airfoil? Here is a picture of a tube in an air stream. When still, the pressure is equal on all sides. Under movement, an air pattern is formed, so that we have a high pressure area and a very low pressure area.

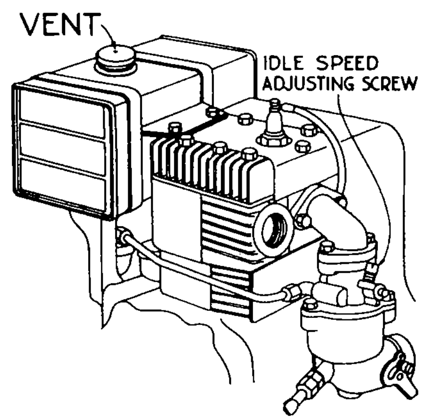


Airfoil

A better understanding of how atmospheric pressure, the venturi and airfoil make possible the operation of a carburetor, should come from a study of how the different types of carburetors function. There are three types of carburetors used on small engines.

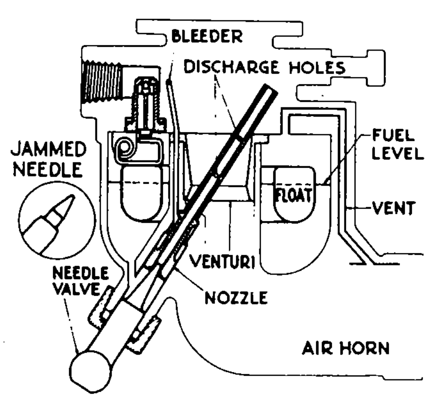
Gravity Feed Carburetor

In the gravity feed system, the fuel tank is above the carburetor. The fuel flows into the carburetor by gravity. Notice an air vent hole in the tank cap so that air can flow in as fuel flows out. Note the vent hole in the carburetor bowl so that air can flow out as fuel flows in. If one or both of these holes were plugged, the flow of fuel would cease and stop the engine.



Gravity Feed System

As the fuel enters the bowl, it raises the float. The float in turn raises the needle in the float valve. When the needle touches the seat, it shuts off the fuel flow, and the position of the float at this time is called the float level.



Float Type Carburetor

The float level generally should be high enough to afford an ample supply of fuel at full throttle and low enough to prevent flooding or leaking.

The fuel in the bowl seeks its own level, which is well below the discharge holes in the nozzle. Notice that the discharge holes are in the venturi, the place of greatest air velocity. With fuel in the carburetor bowl how does it get into the cylinder?

As the piston in the cylinder moves down with the intake valve open, it creates a low pressure area that extends down into the carburetor throat and venturi. Two things start to happen.

The air pressure above the fuel in the bowl pushes the fuel down in the bowl and up the nozzle to the discharge holes. At the same time, the air rushes into the carburetor air horn and through the venturi where its velocity is greatly increased.

The nozzle extending through this air stream acts as an airfoil. And it creates a still lower pressure area on the upper side. This allows the fuel to stream out of the nozzle through the discharge holes into the venturi. There it mixes with the air and becomes a combustible mixture ready for firing in the cylinder.

A small amount of air is allowed to enter the nozzle through the bleeder. This air compensates for the difference in engine speed and prevents too rich a mixture at high speed.

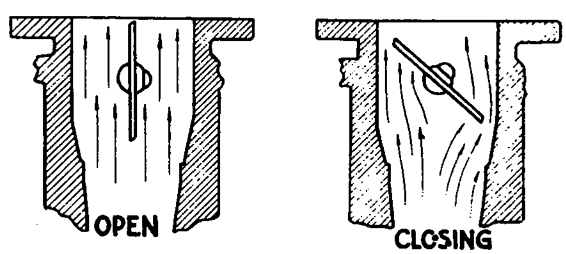
The story of carburetion could end right here if the engine were to run at only one speed and under ideal conditions. However, since smooth economical operation is desired at varying speeds, some additions must be made to the carburetor.

The ideal combustion mixture is about 14 or 15 pounds of air, in weight, to one pound of gasoline. Remember that an engine operating under heavy load requires a richer mixture than under light load. In order to regulate the mixture, we place a threaded needle valve with a tapered point in the carburetor. This projects into the end of the nozzle.

Carburetor Adjustments - Load Valve

To adjust the carburetor for maximum power, run the engine at the desired operating speed. Turn in the needle valve until the engine slows down, which indicates a lean mixture. Note the position of the needle valve. Then turn the needle valve out until the engine speeds up and then slows down, which indicates a rich mixture. Note the position of the needle valve. Turn the needle valve to midway between the lean and rich position. Adjust the mixture to the requirement for each engine. Remember that too lean a mixture is not economical. It causes overheating, detonation, and short valve life. Also, since there is no accelerator pump, the mixture must be rich enough so that the engine will not stop when the throttle is suddenly opened. Engines which run at constant speeds can be slightly leaner than those which require changes in speed.

The inset of the previous illustration shows what happens when the needle valve is turned too far. A square shoulder is produced on the taper. It is possible, of course, to adjust the carburetor with the needle valve in this condition. However, it is quite difficult, because a small movement of the needle makes a big difference in the amount of fuel that can enter the nozzle. And, if you do get it adjusted, the vibration can soon throw it off.



Throttle

To allow for different speeds, a flat disc called a butterfly, mounted on a shaft, is placed in the carburetor throat above the venturi. This is called the throttle.

The throttle in the wide open position does not affect the air flow to any extent. However, as the throttle starts to close, it restricts the flow of air to the cylinder and this decreases the power and speed of the engine. At the same time it allows the pressure in the area below the butterfly to increase. This means that the difference between

the air pressure in the carburetor bowl and the air pressure in the venturi is decreased, the movement of the fuel through the nozzle is slowed down; thus the proportion of fuel and air remain approximately the same. As the engine speed slows down to idle, this situation changes.

At idle speed the throttle is practically closed, very little air is passing through the venturi and the pressure in the venturi and in the float bowl are about the same. The fuel is not forced through the discharge holes, and the mixture tends to become too lean.

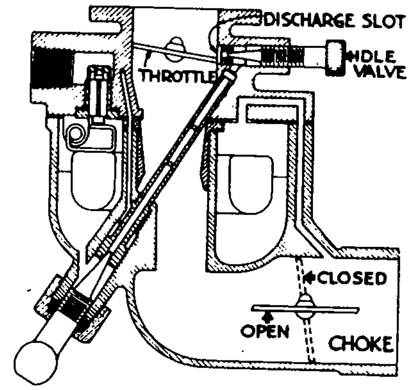
Idle Valve

To supply fuel for the idle, the nozzle is extended up into the idle valve chamber. It fits snugly in the upper body to prevent leaks. Because of this tight fit, the nozzle must be removed before upper and lower bodies are separated, or the nozzle will be bent.

The idle valve chamber leads into the carburetor throat above the throttle. Here the pressure is low, and the fuel rises in the nozzle past the idle valve and into the carburetor throat through the discharge slot. The amount of fuel is metered by turning the idle valve in or out until the proper mixture is obtained. Here again we see what happens if the needle is screwed in too far. A damaged idle valve can result.

Adjustment of the idle valve is similar to that of the needle valve but should be made *after* the needle valve has been adjusted. The idle speed is not the slowest speed at which the engine will run. On small engines it is about 1750 RPM. On larger engines the idle speed may be as low as 1200 RPM. Use a tachometer to set the speed.

Turn the idle speed adjusting screw (located on throttle shaft) until the desired idle speed is obtained and hold throttle closed. Turn the idle valve in until speed decreases, then out until speed increases and again decreases. Then turn the idle valve to a point midway between these two settings. Usually the idle speed adjusting screw will have to be reset to the desired idle speed.



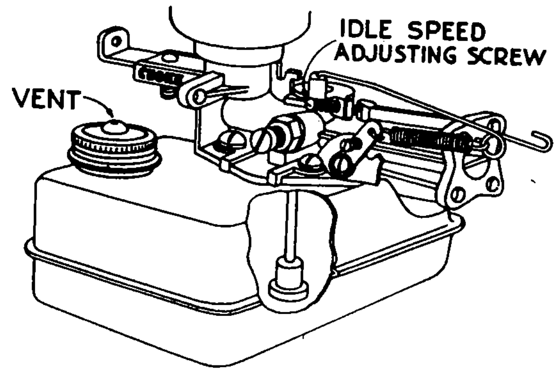
The next problem is starting the engine in different temperatures and with different fuels. A butterfly, mounted on a shaft, is placed in the air horn. With this choke we can close, or almost close, the air horn and get a low pressure area in the venturi and throat.

Thus, a rush of fuel is obtained from the nozzle with a relatively small amount of air. Even with low vaporization this extra rich mixture will give easy starting. Only a portion of the fuel will be consumed while choking, and a large portion will remain in the cylinder. This raw gasoline will dilute the crankcase oil and may even cause scuffing due to washing away of the oil film from between the piston rings and the cylinder wall. For this reason, prolonged choking should be avoided.

This now is our complete carburetor.

Suction Feed Carburetor

Now let us take a look at the suction feed system. Here the fuel tank is below the carburetor. Obviously the fuel will not flow by means of gravity. Therefore, the force of atmospheric pressure must be used.

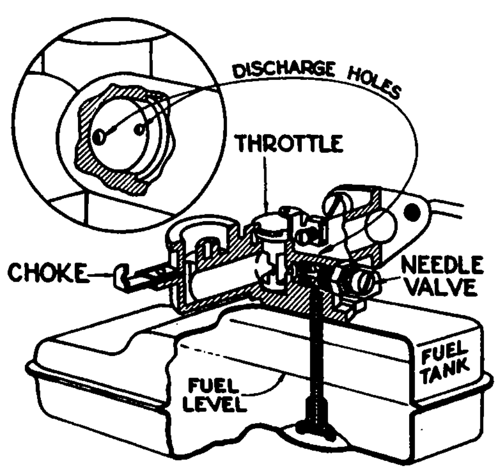


Again we have a vent hole in the fuel tank cap to allow the pressure in the tank to remain constant. Now here is something important. Before adjusting the carburetor, pour in enough fuel to HALF fill the tank. The distance the fuel has to be lifted will affect the adjustment. At half full we have an average operating condition, and the adjustment will be satisfactory if the engine is run with the tank full or nearly empty.

As the piston goes down in the cylinder with both the intake valve and the throttle open, a low pressure area is created in the carburetor throat. A slight restriction is placed between the air horn and the carburetor throat at the choke. This helps to maintain the low pressure.

The difference in pressure between the tank and the carburetor throat forces the fuel up the fuel pipe, past the needle valve, through the two discharge holes. The throttle is relatively thick, so we have, in effect, a venturi at this point, thus aiding vaporization. A spiral is placed in the throat to help acceleration and to help keep the engine from dying when the throttle is opened suddenly.

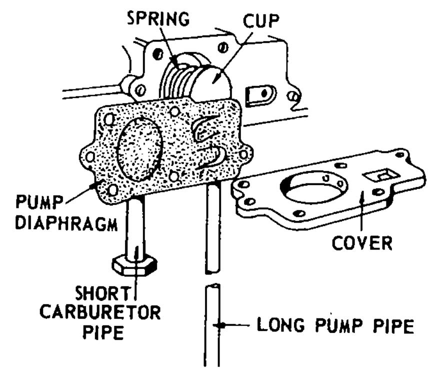
The amount of fuel at operating speed is metered by the needle valve and seat. Turning the needle valve in or out changes the setting until the proper mixture is obtained. This adjustment must always be done while the engine is running at operating speed, not at idle speed. While the needle valve may look like an idle valve due to its position, it is a true high speed mixture adjusting valve.



Adjustment of the load or high speed needle valve is made in a similar manner to the gravity feed system. For good acceleration a slightly rich mixture is needed.

There is no idle valve, but an idle speed adjusting screw. Idle speed mixtures are controlled by design of the carburetor throat and throttle. Examine the choke for its design and operation.

Some suction lift carburetors include a diaphragm fuel pump which fills an auxiliary fuel reservoir.



You should not confuse this diaphragm pump with the diaphragm-type carburetor. The *diaphragm-type carburetor* is a third kind which you will encounter as you continue to work with small engines. It will probably be less common than the float-type or suction-lift carburetor. It is especially adaptable to two cycle engines and permits or allows engines to be operated at any angle.

Gasoline and Oil

Fresh, clean, "regular" gasoline is recommended for use with your small engine. It is not necessary to use highly leaded premium fuels. Purchase small amounts of fuel so that it will be used in a short period of time. Stale gasoline can cause gum or varnish deposits in the fuel tank, carburetor, and combustion chamber.

Store gasoline in a closed marked metal container. Safety cans are excellent. Never use a glass jug or an old can that may leak or will spill its contents if upset. If using a plastic can be sure it is approved for gasoline storage.

When refilling the gasoline tank, always stop the engine and wait for it to cool. Do the filling outdoors in an open area where there is free air circulation.

The recommended oils are those identified as being "suitable for service MS". "MS" is an oil classification and identifies the oil which meets the requirements of an engine for severe service. For summer (over 40° F) use S.A.E. 30. If not available, use 10-W-30 oil. For winter (under 40° F) use SAE 5-W-20.

Clean air is needed for your engine. Large volumes are needed to mix with the fuel for good engine performance. Approximately 8000 gallons of air are needed for one gallon of fuel. Air cleaners are used on engines to insure clean air. Different types are used and each one requires regular and proper maintenance.

Activities and Demonstrations

1. Disassemble an old carburetor and identify the parts.

2. Start an engine and adjust the carburetor.

3. Explain the functions of the carburetor and its principles of operation. (Trace the fuel supply from tank to combustion chamber).

What type of carburetor is used on your engine? ______________________________

____

Why is fresh gasoline recommended? _____

____

____

What are two indicators of a too rich mixture?

____

____

____

____

AIR CLEANERS

A gasoline engine takes in more than 8000 gallons of air when it burns a gallon of fuel! The carburetor air cleaner filters the air going into your engine through the carburetor. Without a properly working air cleaner the dirt and dust in the air can ruin an engine. To give longer engine life, the engine must have an efficient air cleaner.

If the air cleaner doesn't function properly, dirt and dust which should be collected in the cleaner, may be drawn into the engine. There it becomes part of the oil film. It may choke the engine, causing an excessively rich mixture. Either condition is very detrimental to engine life. Dirt in the oil forms an abrasive mixture which wears the moving parts. A plugged air cleaner can cause raw gasoline to wash oil off the cylinder walls, thereby causing poor lubrication.

Type of Air Cleaners

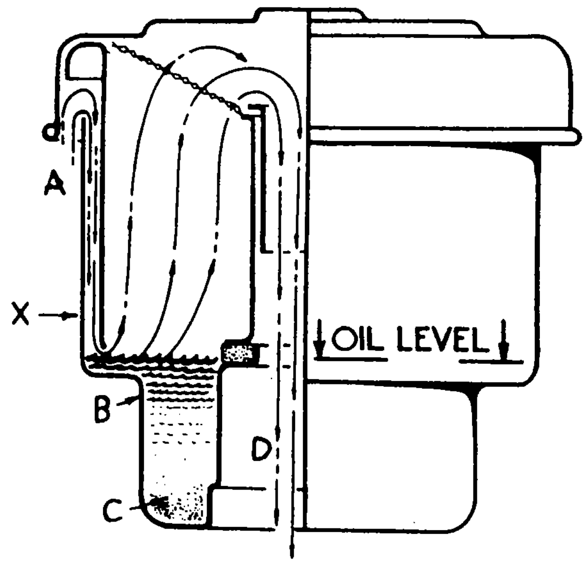
There are three types of air cleaners used on small gasoline engines. Oil-bath type is probably most common on older engines. The oiled-filter or foam type may be more common today. Dry filter types are used on some small engines and certainly are universally used on automobile engines.

Oil-Bath Type

Unfiltered air entering the cleaner passes through the surface of the oil in a small cup at the bottom of the cleaner. Some of the dust and dirt is deposited here.

Oil is picked up by the air and deposited on the filtering element. Oil-coated dirt particles lodge in the filtering element. Excessive oil and dirt drain back into the cup. The clean air flows out of the filter into the engine.

Air cleaners should be checked frequently, when using the engine under dusty conditions. It should be cleaned at least every 25 hours of operation or oftener if necessary.



Oil-Bath Air Cleaner

In servicing this air cleaner check your owner's manual and follow the recommendations.

1. Disassemble the cleaner.
2. Throw away the old dirty oil.
3. Clean cup, filter and other parts with petroleum solvent.
4. Refill the cup with recommended oil to the "oil level" mark.
5. Reassemble the cleaner, being sure the gaskets are in place and everything is tight.