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WAR DEPARTMENT

U.S. Dept. of Army

TECHNICAL MANUAL

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FUELS AND CARBURETION



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TECHNICAL MANUAL
FUELS AND CARBURETION

CHANGES }
No. 1 }

WAR DEPARTMENT,
WASHINGTON, October 13, 1941.

TM 10-550, December 27, 1940, is changed as follows:

21. **Bulk of gasoline compared with bulk of air.**—A cubic foot of air weighs 1¼ ounces, but a cubic foot of gasoline weighs about 48.5 pounds or 775 ounces. This means that a cubic foot of air must be multiplied by 620 to equal the weight of a cubic foot of gasoline. The ideal air-fuel ratio for an internal combustion engine is 15 parts air to 1 part gasoline by weight. Accordingly, to burn 1 cubic foot of gasoline, 15 times 620 or 9,300 cubic feet of air are needed. Converting this ratio to gallons, 1,240 cubic feet of air are needed to burn 1 gallon of gasoline; or ½ teaspoonful of gasoline must be mixed with 1 cubic foot of air to obtain the ideal 15 to 1 ratio.

[A. G. 062.11 (9-17-41).] (C 1, Oct. 13, 1941.)

BY ORDER OF THE SECRETARY OF WAR:

G. C. MARSHALL,
Chief of Staff.

OFFICIAL:

E. S. ADAMS,
Major General,
The Adjutant General.

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FUELS AND CARBURETION

Prepared under direction of
 The Quartermaster General

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SECTION I

CARBURETOR NOMENCLATURE

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Definitions.....	1

1. **Definitions.**—Because of the various names given to the many parts of the modern carburetor by manufacturers, the following general carburetor nomenclature will be used in this manual for purposes of clarity and uniformity:

- Accelerating pump.*—A device for injecting an additional amount of fuel in the main air-fuel stream when the throttle is suddenly opened.
- Air horn.*—That part of the carburetor air passage in which the choke valve is located.
- Body.*—The principal casting of the carburetor, usually including such parts as the mixing chamber, float chamber and bowl, throttle valve, fuel and air passages, jets and nozzles.
- Carburetor.*—A device for metering and mixing air and fuel in the correct ratios and amounts for all operating conditions of an Otto-cycle internal combustion engine.
- Choke valve.*—A valve placed in the carburetor air intake passage for the purpose of regulating the entrance of air.
- Compensation.*—The correction of unbalanced air-fuel ratios, which are caused either by changes in engine speeds or fuel requirements.
- Float.*—A device used in conjunction with a needle valve to maintain a constant fuel level in the float chamber.
- Float chamber.*—A small fuel storage space cast integrally with the carburetor body. It contains the float and float valve which automatically control the fuel level.
- Fuel passage.*—A cast or drilled opening in the body of the carburetor through which fuel flows. Parts of the passage are often threaded for the insertion of jets and nozzles.
- High speed adjustment.*—A means of adjusting the air-fuel ratio for high speeds. It is usually accomplished by a needle valve, metering rod, replaceable jet, or variable tension spring.
- Idling adjustment.*—A means of adjusting the air-fuel ratio for starting and low running speeds. It is usually accomplished by the idling adjustment screw and/or by replaceable jets having different sized openings. In many carburetors, the idling adjustment and the throttle stop screw adjustment are separate but related adjustments which must be balanced during any adjustment of the idling speed.
- Jet.*—A metered opening in an air or fuel passage to control the flow of air or fuel. It may be located anywhere from the entrance of the passage to the tip of the nozzle.
- Lean mixture.*—A mixture in which the proportion of air to fuel is greater than that required by the specific operating condition.
- Low speed adjustment.*—A means of adjusting the air-fuel ratio for low speed. It is usually accomplished by needle valves and/or replaceable jets having different sized openings.

- Metered.*—The controlled flow of fuel or air for purposes of carburetion.
- Metering rod (metering pin).*—A small rod having a varied diameter, operated within a jet to vary the flow of fuel through the jet.
- Mixing chamber.*—That part of a carburetor body between the venturi and the throttle valve in which fuel and air first mix.
- Needle valve.*—A small plain or threaded rod having a tapered point. Its position can be changed with respect to its seat to regulate the flow of fuel or air.
- Nozzle.*—That part of a fuel or air passage or jet which opens into the air or fuel stream of a carburetor. Some jets are placed so that their discharge ends act as nozzles.
- Rich mixture.*—A mixture in which the proportion of fuel to air is greater than that required by the specific operating condition.
- Throttle stop screw.*—An adjusting screw which stops the throttle valve from closing and thereby leaves sufficient opening for idling.
- Throttle valve.*—An adjustable plate (butterfly) or other type valve placed in the carburetor outlet to regulate the flow of fuel-air mixture from the carburetor. The throttle valve controls engine speed.
- Venturi.*—A throat type constriction placed in the carburetor body to increase the speed of the main air stream as it passes a fuel nozzle.

SECTION II

INTERNAL COMBUSTION ENGINE FUELS

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2. General.—*a.* A fuel is a substance composed principally of hydrogen and carbon in such proportions that it will burn in the presence of oxygen and liberate heat energy. By burning fuel in an internal combustion engine, this heat energy can be transformed into mechanical energy. Liquid fuels are ideal for internal com-

bustion engines because they can be economically produced, have a high heat value per pound, an ideal rate of burning, and can be easily handled and stored.

b. The most common internal combustion engine fuels are gasoline, kerosene, Diesel fuel oil, benzol, and alcohol. Gasoline, because of its many advantages, is used to a greater extent than any other fuel in internal combustion engines having spark ignition. It has a better rate of burning than other fuels and due to the ease with which it vaporizes, it gives quick starting in the coldest weather, smooth acceleration, and maximum power. Diesel fuel oil ranks next to gasoline in quantity used. It can be produced as economically as gasoline, but its use is limited to Diesel type engines. The use of kerosene as a fuel for internal combustion engines is usually limited to farm tractors and to marine and stationary engines which operate at a fairly constant speed. Its characteristics are such that it cannot be properly mixed with air and controlled in variable speed engines. In recent years, fuel and Diesel oil have for the most part taken its place. Gasoline can be produced in greater quantities and sold more cheaply than benzol or alcohol.

3. **Types of gasoline.**—In general, there are three common types of gasoline; straight run, cracked, and natural or casing head. Most commercial gasolines are blended from these three types in order to obtain a fuel that contains the desired characteristics of each.

a. *Straight run.*—(1) Straight run gasoline is manufactured by the fractional distillation of crude petroleum, the method first used for refining gasoline. In this method, crude petroleum is gradually heated in a still as shown in figure 1. The gasoline vapors are driven from the oil, collected, condensed, and led to receiving tanks. The still separates the light, medium, and heavy vapors into different condensing units so that a light, highly volatile gasoline distillate is led to one receiving tank, a medium weight less volatile distillate to another, and a heavy distillate with a low volatility to a third tank.

(2) About 20 gallons of straight run gasoline can be produced from 100 gallons of crude oil. Engineers seeking a greater yield of gasoline from crude oil developed the "cracking process."

b. *Cracked.*—(1) There are a number of methods of producing cracked gasoline, but the best known and most widely used are the Burton, Dubbs, and Cross processes, which obtain 45 to 60 gallons of gasoline from every 100 gallons of crude oil.

(2) Cracked gasoline is obtained by the destructive distillation method. A cracking unit is shown in figure 1. Gas oil, the third heaviest distillate, is directed to the cracking unit and heated under

pressure at a temperature of approximately 900° F. This cracks or partially decomposes the heavier hydrocarbons into light particles which are distilled to make gasoline.

c. *Natural or casing head.*—(1) This gasoline is obtained from natural gas that contains minute particles of gasoline in vapor form. The number of gasoline particles contained indicates the “wetness” of the gas. To make processing profitable, about 1,000 cubic feet of gas should be wet enough to produce at least 3 gallons of gasoline.

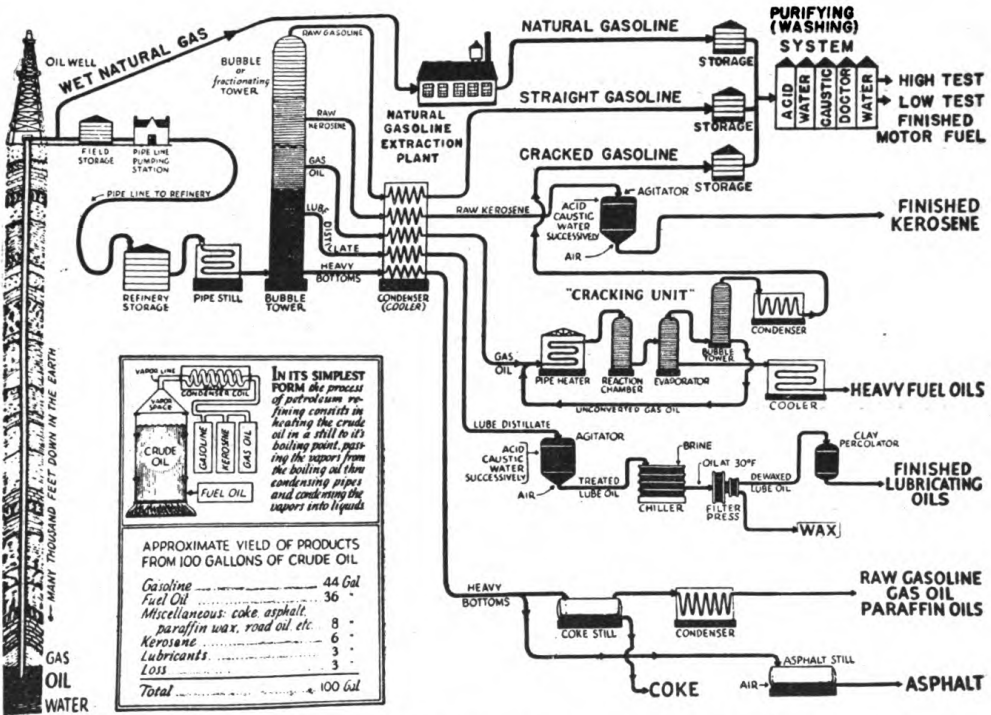


FIGURE 1.—Typical flow chart tracing crude oil from well to finished product.

(2) Certain grades of natural gasoline possess high antiknock qualities and are satisfactory engine fuels in themselves. However, because of their volatility, most natural gasolines are blended with straight run and cracked gasolines to make cold engines start easily.

(3) Propane and butane are byproducts of natural gasoline. These liquids can be collected and stored under pressure. They will turn into a gas when released into the atmosphere. Propane, the more volatile of the two, will gasify at a temperature of 43° F. below zero, and butane at 33° F. above zero. These very light volatile fuels are seldom used in internal combustion engines because they evaporate very rapidly and cannot be handled in open containers.

4. Composition of gasoline.—Gasoline is composed of fractions or parts, each having different physical characteristics; some are light and volatile and others heavy and less volatile. These fractions or parts will vaporize at temperatures ranging from 85° F. to 400° F. This range of temperatures, which measures the volatility of gasoline, is called the “chain of boiling points” or distillation range. The chain of boiling points is determined by distilling a given quantity of fuel in a standard apparatus used by the petroleum industry. The first drop of evaporated and condensed gasoline will fall into a graduated receiver at 98° F. to 124° F.; 20 percent of the sample will fall at approximately 212° F.; 50 percent at 290° F.; 90 percent at a temperature of not more than 395° F.; and the entire amount will be distilled at a temperature not over 440° F.

5. Energy contained in gasoline.—*a.* The heat energy contained in a fuel is its heat value, which is measured in British thermal units (B. t. u.’s). One B. t. u. is the heat required to raise the temperature of 1 pound of water 1° F. Therefore, 1,000 B. t. u.’s will raise the temperature of 1,000 pounds of water 1°, or 100 pounds of water 10°.

b. Power (energy) can be converted into heat and heat into power. The conversion of power into heat is illustrated by the frictional heat developed in brake linings as power is applied to the brakes. The conversion of heat into power is illustrated by the action of an internal combustion engine which converts the heat of burned fuel into the power that propels a motor vehicle.

c. The potential energy contained in a gallon of gasoline is 95,083,000 foot-pounds. If all this energy could be converted into work without any loss, the modern motor vehicle would go well over 450 miles on a gallon of gasoline. However, only about 5 percent of the heat energy of gasoline is converted into available power by the automotive engine. The power losses in a gallon of gasoline may be distributed as follows:

Engine:	<i>Percent</i>
Cooling system.....	35.8
Exhaust gas.....	35.6
Exhaust pipes.....	1.0
Muffler.....	1.2
Engine friction.....	5.6
Total.....	79.2

Power train:	<i>Percent</i>
Transmission friction-----	2.9
Rear wheels-----	3.7
Front wheels-----	1.7
Total-----	<u>8.3</u>
Miscellaneous: Wind resistance and others-----	<u>7.1</u>
Total-----	<u>7.1</u>
Total power losses-----	<u>94.6</u>
Net amount of power actually used-----	5.4

6. High and low test (gravity) gasoline.—Gasoline is sometimes spoken of as high or low test. This rating is based on the specific gravity of the fuel; that is, the weight of a quantity of gasoline compared with the weight of an equal quantity of water at 4° C. While specific gravity does have some bearing on the blending of fuels in the manufacturing process, it is now common commercial practice to classify fuels according to their octane rating.

7. Requirements of an ideal gasoline.—The following may be considered as some of the ideal properties of gasoline: volatility, including easy starting, minimum crankcase dilution, minimum vapor locks, quick and smooth acceleration, and good distribution; operating economy; purity, including minimum gum formation and minimum sulphur content; good antiknock qualities. Each of these properties has a definite effect on the performance of an engine in which the gasoline is used. However, other factors, such as engine and vehicle design, climate, terrain, types of highway, and altitude must be considered in determining the requirements of an ideal gasoline.

a. Volatility.—The volatility of a fuel affects starting ability, crankcase dilution, vapor locking, smoothness and quickness of engine acceleration, and fuel distribution. Volatility of fuels is determined and compared by the temperatures (chain of boiling points or distillation range) at which the fractions of the fuels can be distilled. This characteristic is controlled by the refiner to suit the climatic temperature in which the engine is to be operated.

(1) *Easy starting.*—If an engine is to start easily, it must have a burnable fuel mixture in the combustion chamber at the moment of starting. This is a mixture of about 15 parts of air to 1 part of fuel by weight. When an engine is cold, only a small part of the fuel normally supplied is vaporized. This makes it necessary to provide a greater quantity of fuel so that ultimately a sufficient amount of

vaporized fuel will be available for starting and continuing the operation of the engine. This is accomplished by closing the carburetor choke valve to reduce the air supply and increase the fuel supply and form a proper air-fuel mixture for combustion. Full choking decreases the air-fuel ratio until it is about $1\frac{1}{4}$ parts of air to 1 part of gasoline. Refiners increase the volatility of fuels during winter months to provide easier cold weather starting.

(2) *Minimum crankcase dilution.*—Cold weather operation and overchoking of the carburetor allow liquid (unvaporized) gasoline to seep past the piston and piston rings into the crankcase during the warming-up period. In order to minimize crankcase dilution, a fuel should completely vaporize at the lowest possible temperature.

(3) *Minimum vapor lock.*—Vapor lock, which blocks the flow of fuel, is caused by fuel vapors in the fuel system due to excessive heat in carburetors, fuel pumps, and fuel lines. To keep the fuel system cool, designers place it as far as possible from the exhaust pipe and manifold. Heat insulating material or baffles are sometimes placed between the carburetor and manifold or between the fuel lines and exhaust pipe. In order to lessen the tendency to vapor lock, summer grades of gasoline are blended from low volatility fuels.

(4) *Quick and smooth acceleration.*—Quick and smooth acceleration depends upon a fully vaporized accelerating mixture entering the combustion chamber.

(5) *Good distribution.*—If fuel is not distributed uniformly to all cylinders, the engine will run unevenly and the movement of the vehicle will be erratic. Good distribution requires that the fuel be almost completely vaporized and properly mixed before it passes into the cylinders.

b. Operating economy.—Cost per mile of operation is influenced by fuel economy. This involves two factors; cost per gallon, and miles per gallon.

c. Purity.—(1) *Gum.*—(a) Cracked gasoline has brought with it the problem of gum formation on the intake valves. Gum is a resinous, nonvolatile product formed by the oxidation of certain hydrocarbons during the cracking process. When gasoline evaporates, gum remains as a soft, sticky mass which, when subjected to high temperatures, forms a hard, baked deposit.

(b) The color of gasoline is no indication of its gum content. A gasoline may have a yellow color and still be comparatively free from gum, whereas a water-white gasoline may have a high gum content.

(2) *Sulphur.*—(a) Almost all known crude oils have a sulphur content varying from slight traces to as high as 4 percent. During

distillation, the sulphur in a crude oil is distributed to all fractions of the distillate, some of it going into the gasoline fractions.

(b) When gasoline is completely burned, two products are formed; carbon dioxide, and water in the form of superheated steam. If any sulphur is present in the gasoline, it too is burned and combined with the oxygen in the air to form sulphur dioxide. This unites with the steam vapor to form sulphurous acid first and then, under pressure, sulphuric acid. Sulphuric acid corrodes all metal parts of the engine with which it comes in contact.

(c) So exact are modern refining processes that sulphur has caused very little trouble in recent years. At the present time, the generally accepted maximum sulphur content is 0.01 percent.

d. Antiknock value.—(1) *Combustion.*—The burning of a fuel in the presence of oxygen is called combustion.

(a) A gallon of gasoline weighs about 6.1 pounds, of which 5 pounds is carbon and the remainder hydrogen. The air necessary to burn a gallon of gasoline is composed of about 19 pounds of oxygen and 72 pounds of nitrogen and other gases. In burning a gallon of gasoline, about 11 of the 19 pounds of oxygen from the air combine with the 5 pounds of carbon in the fuel to form carbon monoxide and carbon dioxide gases. Complete combustion converts all the carbon into carbon dioxide gas. However, complete combustion is never obtained in an engine, and as a result, carbon monoxide is also formed. While the carbon and oxygen are uniting to liberate heat, which is converted into energy to run the engine, the hydrogen in the fuel unites with the remaining oxygen in the air to form about 6.9 pounds of water; that is, about .83 gallons of water is formed for every gallon of gasoline burned. The water passes off with the burned exhaust gases in vapor form. In hot weather it is not of great importance, but in cold weather the water vapor partially condenses, which usually causes rust and corrosion in the muffler. The nitrogen in the air is not affected. It remains stable and acts as a cooling agent, reducing the maximum burning temperature that could be obtained if pure oxygen were supplied instead of air.

(b) A Diesel engine differs from a gasoline engine. Operating on an excess amount of air, a Diesel engine burns the fuel more completely and the exhaust is ordinarily free from carbon monoxide gas, which is, however, given off when the combustion in a Diesel engine is incomplete, usually due to faulty engine operation.

(c) When fuel burns inside the cylinders of an internal combustion engine, the temperature of the mixture is raised by the heat given off. Actual burning temperatures of 4,000° to 4,500° F. have been recorded in operating engines.

(2) *Compression pressure.*—Within practical limits, the more a fuel is compressed in the combustion chamber (compression pressure), the more efficient it is and the more power it produces. As a fuel burns, the pressure it creates (combustion pressure) is about four times greater than the compression pressure. A fuel subjected to a compression pressure of 100 pounds per square inch will develop about 400 pounds per square inch combustion pressure as it burns. Should the compression pressure be raised to 120 pounds per square inch, the power produced by the engine will be greatly increased because the combustion pressure will have been raised to about 480 pounds per square inch.

(3) *Detonation.*—(a) When the compression pressure is very high, the fuel mixture tends to ignite spontaneously instead of burning uniformly and slowly, causing detonation, knock, or ping. Fuel knock, besides being an annoying sound, results in loss of power, overheating, increased fuel consumption, and severe shock to spark plugs, pistons, connecting rods, bearings, and crankshafts. It has been known in extreme cases to chip porcelain from spark plugs and crack cylinder and valve heads.

(b) Detonation occurs in an engine as the fuel is burning in the combustion chamber. A special engine has been built permitting motion pictures to be made which clearly show the combustion process and when detonation occurs. The spark from the spark plug starts the fuel mixture burning and the flame spreads evenly from layer to layer of the fuel, compressing and heating the unburned portion. Eventually the last of the unburned portion is so compressed and heated that it explodes before the moving flame has reached it, generating extremely high pressure. This explosive pressure striking piston head and the walls of the combustion chamber with hammer-like blows causes the knock and ping sometimes heard in engines.

(c) Improvements in combustion chamber design have helped to reduce detonation. When the temperature of an unburned fuel can be kept below the detonation temperatures by engine cooling, the increased compression pressures result in increased combustion pressures. Hot areas, like the exhaust valve, radiating heat to the unburned charge may cause detonation. By placing the spark plugs close to these hot areas so that the fuel starts to burn near them and then moves away from them, the tendency toward engine knocking can be minimized.

(d) Carbon formation in a combustion chamber increases the tendency of a fuel to knock because, being an excellent heat insulator, it reduces the effective cooling surface in the region of the last-to-burn portion of the fuel charge.

(4) *Octane rating.*—(a) The ability of a gasoline to resist detonation is called its octane or antiknock rating. A straight run gasoline from asphaltic base crudes has better antiknock value than one from paraffinic base crudes. Cracked gasoline generally has less tendency to knock than straight run gasoline. All marketed gasolines are a blend of straight run and cracked gasolines, so unless their blending is controlled, their antiknock qualities will vary.

(b) Engineers and refiners have devised a method of determining and comparing the antiknock qualities of gasolines by using a special one-cylinder engine, known as the C. F. R. (Cooperative Fuel Research Committee) fuel testing engine, in which the compression pressure can be raised or lowered. A device records and measures the knocking effect of the fuel being tested. A mixture of iso-octane, which has a very high antiknock rating, and heptane, which produces a pronounced knock, is used as a reference fuel to establish an antiknock standard. The antiknock value or octane number of a gasoline being tested is represented by the percentage by volume of iso-octane that must be mixed with normal heptane in order to duplicate the knocking of the gasoline being tested. Octane numbers range from 50 in third-grade gasolines to over 100 in aviation gasolines. Since an octane number of 100 indicates a fuel having an antiknock value equal to that of iso-octane, a number higher than 100 indicates that the antiknock value is that much greater than that of iso-octane.

(c) If the octane rating of a gasoline is naturally low, the fuel will detonate as it burns and power will be applied to the pistons in hammer-like blows. The ideal power is that which pushes steadily rather than hammers against the pistons as shown in figure 2. The octane rating of a gasoline can be raised in two ways; by mixing it with another fuel, or by treating it with a chemical.

1. By the first method, gasoline is mixed with benzol or alcohol. It takes from 30 to 40 percent of benzol to get a good antiknock rating and an even greater percentage of alcohol. Alcohol absorbs moisture from the air and the water formed has a tendency to collect in the fuel system. Neither alcohol nor benzol have the ability to produce as much heat as gasoline, so a richer mixture is necessary to give good combustion when this blend of fuels is used. In this country, no fuel mixed with alcohol is sold. However, some fuel mixed with benzol is sold, especially in territories which are close to coke ovens, the principal source of benzol.

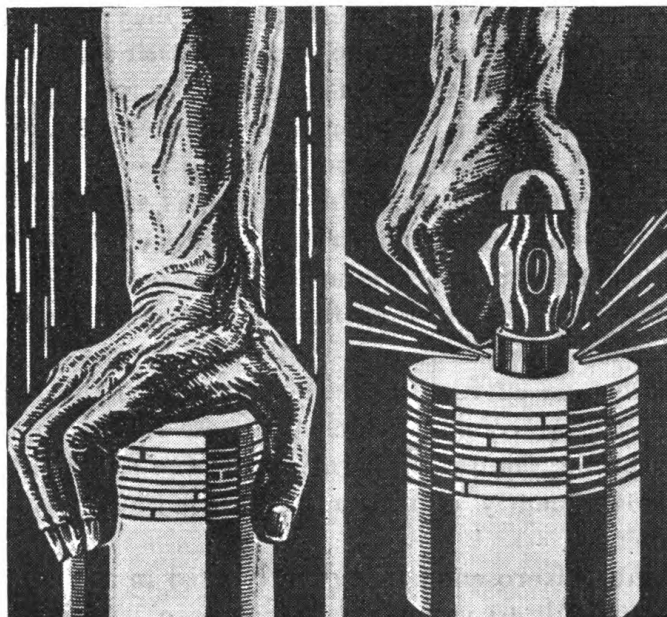


FIGURE 2.—Ideal power is that which pushes instead of hammers against the pistons.

2. A treated fuel is one which contains a chemical that is not a fuel. Iodine is effective but it is detrimental to the metal of the engine. The most satisfactory chemical known is tetra-ethyl lead compound, which is added to gasoline in the proportion of about 1 to 1,200 by volume, depending on the fuel and the antiknock value desired. The chemical commonly used contains tetra-ethyl lead (produced from alcohol and lead), ethylene dibromide, ethylene dichloride, and aniline dye. Tetra-ethyl lead is a liquid which mixes thoroughly with gasoline and vaporizes completely. Ethylene dibromide prevents the tetra-ethyl lead from forming lead oxide deposits on spark plugs and on valve seats and stems. Dye is added to identify an ethyl treated gasoline and to warn against its being used as anything but an engine fuel. Ethylene dichloride assists the ethylene dibromide in eliminating deposits.

(d) An engine which does not knock on a low octane fuel does not increase in efficiency when operated on fuel with a higher octane rating. An engine which knocks on a given fuel should use one of a higher octane rating. If the knock does not stop, some mechanical adjustments are probably necessary. By adjusting the spark of an engine using a low antiknock gasoline so that it will fire later (retarding the spark) eliminates knocking, but fuel consumption will be

increased and the engine will overheat. It may be less expensive to use a higher priced, high octane gasoline with an advanced spark than to use a cheap, low octane gasoline with a retarded spark.

(e) The Quartermaster Corps normally purchases for motor vehicle use three standard commercial types of gasoline with octane ratings of 70, 77, and 92. The octane 70 gasoline is used under ordinary conditions when engine design and compression do not require a fuel with a higher anti-knock quality. The octane 77 fuel is used for emergency vehicles, such as fire engines and ambulances, and when compression ratios require a fuel with higher antiknock octane rating. The octane 92 fuel is used essentially in the radial engines of tanks and similar combat vehicles. These radial engines usually have a much higher compression ratio than the average car or truck engine and consequently require a fuel with an exceptionally high antiknock rating.

8. Kerosene.—Kerosene is not greatly used in automotive engines because it is difficult to vaporize. It has been used with success in low speed tractor engines and in many low speed stationary engines which have constant loads. In all cases, the engines must be started on gasoline and run until the operating temperature is reached before the kerosene supply can be switched on and the gasoline turned off.

9. Benzol.—Benzol, a byproduct obtained in the manufacture of coke, is blended with gasoline to give it very high antiknock qualities. Benzol can be burned alone; however, its exhaust is highly objectionable and in the pure state it freezes solid at about 36° to 40° F. Commercial benzol, a product of additional refining and available as an internal combustion engine fuel, freezes at 23° F. Benzol has a tendency to form carbon, and if not carefully refined, the free sulphur and sulphur compounds in it cause corrosion and unnecessary wear in engines.

10. Alcohol.—Ethyl (grain) alcohol and methyl (wood) alcohol are also used as internal combustion engine fuels. Alcohol differs from gasoline or benzol in that it is not a true hydrocarbon but contains a large amount of oxygen. Neither does it have the heat value (British thermal units) of the other two fuels. It makes cold starting more difficult because it is not easily vaporized, but this same property permits higher compression ratios which give more power. It burns without leaving objectionable odors, gives off no smoke, and leaves no carbon deposits inside the engine. Alcohol can be produced without drawing on crude petroleum resources and there is no limit to the supply. Its high production cost restricts its use as an engine fuel.

11. Diesel fuels.—*a.* Fuels used for Diesel and semi-Diesel engines are generally of the heavy fuel oil type. These have a higher specific gravity than gasoline fuels and are much less volatile. Viscosity, flash point, cleanliness, residue, distillation, and other characteristics are quite important in Diesel fuels. Perhaps the most important characteristic is cetane rating, or ignition quality. This ranges from 30 to 80, depending on the grade and type of the fuel. Fuels with a cetane rating of 30 to 50 are classed as rough Diesel fuels and those of 50 to 80 as smooth Diesel fuels.

b. Further discussion of Diesel fuels will be found in TM 10-575.

SECTION III

THE FUEL SYSTEM

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12. General.—The fuel system in a modern automotive vehicle usually consists of a tank for storing the fuel, a fuel gage, pipes for conveying the fuel from the tank to the engine, filters and cleaners for straining and cleaning the air and fuel, and a fuel pump for transferring fuel from the tank to the carburetor. (See fig. 3.)

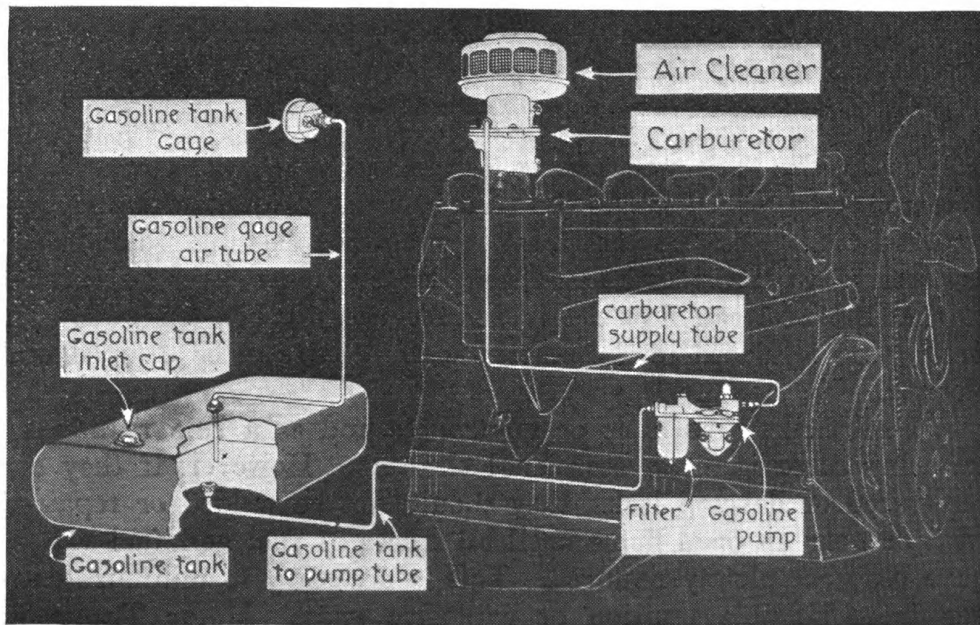


FIGURE 3.—Fuel system for an automotive engine.

13. **Fuel tanks.**—*a.* The main fuel tank in passenger vehicles is generally in the rear of the chassis. Trucks have them mounted under the driver's seat, on the sides, or at any other convenient place on the vehicle. Most modern vehicles have fuel pumps, consequently the position of the tank has little effect on the quantity of fuel supplied to the carburetor.

b. As shown in figure 4, the tank is usually made of thin gage tinned metal or of lead and tin alloy covered sheet steel known as "terne plate." It has an inlet or filler pipe and an outlet. This outlet, with a fitting for the fuel line connection, may be in the top or side of the tank. The lower end of the outlet pipe is placed about $\frac{1}{2}$ inch from the bottom of the tank so that any sediment which

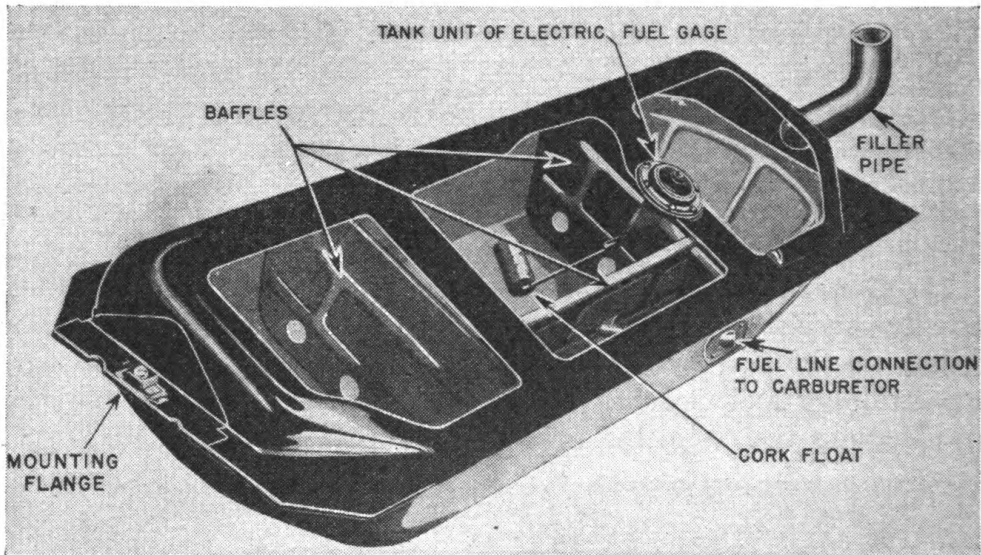


FIGURE 4.—Main fuel tank with top cut away.

collects in the tank will not be carried to the carburetor. Baffle plates may be placed inside the tank to reinforce the sides and bottom and to prevent the fuel from surging or splashing. The baffles are welded to the sides and bottom and are notched or perforated so that the fuel can flow freely from one section to the other. A drain plug is placed in the bottom so the tank can be drained and cleaned.

c. Fuel tanks give little or no trouble and as a rule require no servicing other than an occasional cleaning. However, if they are punctured or develop leaks, they should not be welded or repaired with or near an open flame until all traces of fuel and fuel vapors have been completely removed. This is necessary to minimize danger from possible ignition or explosive gases. Motor Transport

School Technical Service Bulletin Z-11 and TM 10-450 give complete instructions on cleaning fuel tanks preparatory to welding and repairing them.

14. Fuel filters.—*a.* These may be located any place between the main fuel tank and the carburetor. They may be found in the main fuel tank, vacuum tank, fuel pump, or carburetor. Types of filters connected in the fuel line are shown in figure 5.

b. The most common type of fuel filter (figs. 7 and 8) is placed between the fuel tank and a mechanical fuel pump. In this type, the fuel enters the glass bowl and passes up through the filter screen and out through the outlet. Any water and solid matter caught by the filter falls to the bottom of the filter bowl where it can be readily seen and removed. Dirt in fuel generally comes from rust scales in tank cars, storage tanks, and drums. Water comes from

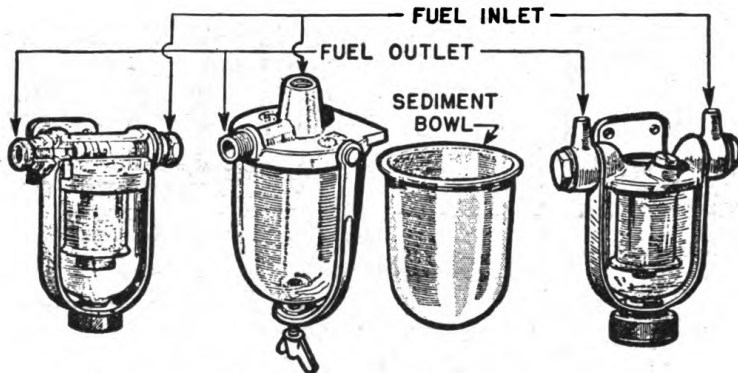


FIGURE 5.—Types of fuel filters used in the fuel line.

the condensation of moisture in metal containers or tanks. The filter element is usually a metal screen. However, a recently developed fuel filter is fitted with a clay filter element.

15. Fuel systems.—Fuel systems are of the following types: gravity fed, pressure fed, and pump fed.

a. Gravity fed.—(1) In a gravity fed fuel system, the fuel moves directly from the vehicle storage tank to the carburetor by gravity.

(2) Another method involves the use of vacuum tanks which draw fuel from the vehicle's storage tank by the vacuum action of the intake manifold. The vacuum tank then becomes a secondary storage tank, usually located under the engine hood, from which fuel flows to the carburetor by gravity.

(3) The gravity method of supplying fuel to the internal combustion engine is seldom used on the modern motor vehicle; therefore, its details will not be discussed here. In the older type vehicles where

this method of fuel supply is found, reference should be made to the manufacturer's manual.

b. Pressure fed.—In a pressure fed system, the tank, which must be airtight, can be placed at the most convenient point in the chassis. A small hand-operated air compressor is used to maintain a constant pressure of about 1/2 pound per square inch on the fuel, forcing it through the fuel lines to the carburetor. A gage mounted on the dash indicates the air pressure. A safety valve relieves the air pressure when it becomes excessive. This system is seldom used.

c. Pump fed.—In a pump fed system (fig. 3), the supply tank may be located at the most convenient point on the vehicle.

(1) *Mechanical fuel pumps.*—Mechanical fuel pumps are generally of the diaphragm type shown in figures 6 and 7. The type

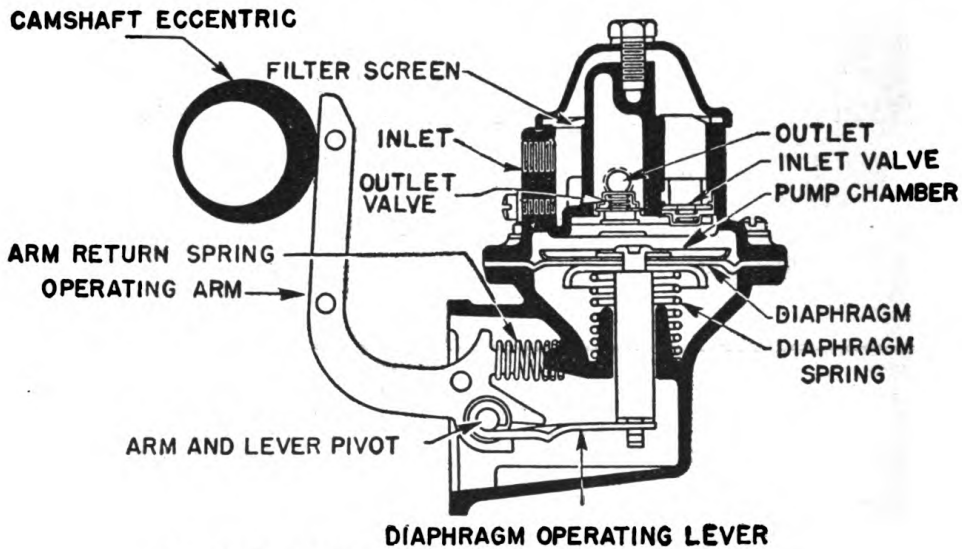


FIGURE 6.—Mechanical fuel pump with built-in fuel filter.

shown in figure 8 differs in that the pump has a vacuum booster section. This booster section has nothing to do with the fuel system, except that it is operated by the fuel pump arm. As shown in figure 6, the inlet valve and the filter are built in the body of the pump, and in the other two types (figs. 7 and 8), the inlet valve and the filter are separate from the pump body but are part of the assembly.

(a) During the first or suction stroke, the rotation of an eccentric on the camshaft actuates the pump operating arm, which pulls the lever and diaphragm downward against the pressure of the diaphragm spring, producing a vacuum in the pump chamber. The vacuum holds the outlet valve closed and pulls the inlet valve open making the fuel flow from the supply tank through the inlet up

through the filter screen and down through the inlet valve into the pump chamber. During the return stroke, the diaphragm is forced up by the diaphragm spring, the inlet valve closes, and the outlet valve is forced open allowing the fuel to flow through the outlet to the carburetor.

(b) The operating lever is hinged to the pump arm so that it can be moved down but cannot be raised by the pump arm. The pump arm spring makes that arm follow the cam without moving the lever. The lever is moved upward only by the diaphragm spring. The pump, therefore, delivers fuel to the carburetor only when the fuel pressure in the outlet is less than the pressure maintained by the diaphragm spring. This condition arises when the fuel passage from the pump into the carburetor float chamber is open and the float needle valve is not seated.

(c) Figure 7 shows a type of fuel pump which is now commonly used. Its method of operation can be followed from the above description.

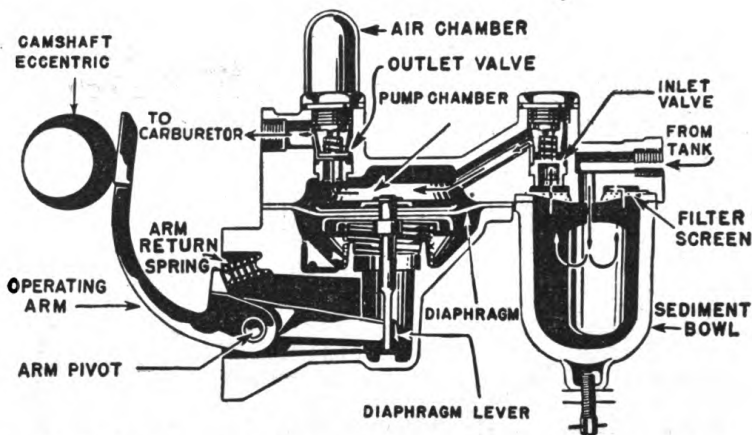


FIGURE 7.—Mechanical fuel pump with a separate fuel filter built integrally with the pump.

(d) *Vacuum sections in mechanical fuel pumps.*—Many mechanical fuel pumps have a vacuum booster section which operates the windshield wiper at an almost constant speed (fig. 8). The fuel section (upper) functions in the same manner as that in ordinary fuel pumps. However, the rotation of the camshaft eccentric in this special type pump also operates the vacuum booster section by actuating the pump arm which pushes a link and the bellows diaphragm assembly downward expelling the air in the lower chamber through its exhaust valve out into the intake manifold. On the return stroke of the pump arm, the diaphragm spring moves the bellows diaphragm upward producing a suction in the vacuum chamber.

This suction opens the intake valve of the vacuum section and draws air through the inlet passage from the windshield wiper.

1. When the windshield wiper is not being used, the intake manifold vacuum holds the diaphragm downward against the diaphragm's spring pressure so that the diaphragm does not function with every stroke of the pump arm. When the manifold vacuum is greater than the vacuum produced by the pump, the air flows from the windshield wiper through the inlet valve and the vacuum chamber of the pump and out the exhaust valve outlet to the manifold, leaving the vacuum section inoperative. With a high vacuum in the intake manifold, the operation of the windshield wiper will be the same as if the pump were not installed. However, when the intake vacuum is low, as it is when the engine is accelerated or operated at high speeds, the vacuum produced by the pump is greater than that in the manifold and the vacuum section operates the windshield wiper at a nearly constant speed.
2. Some mechanical pumps have the vacuum section placed in the top of the pump instead of in the bottom as shown in figure 8, but the operation is basically the same.

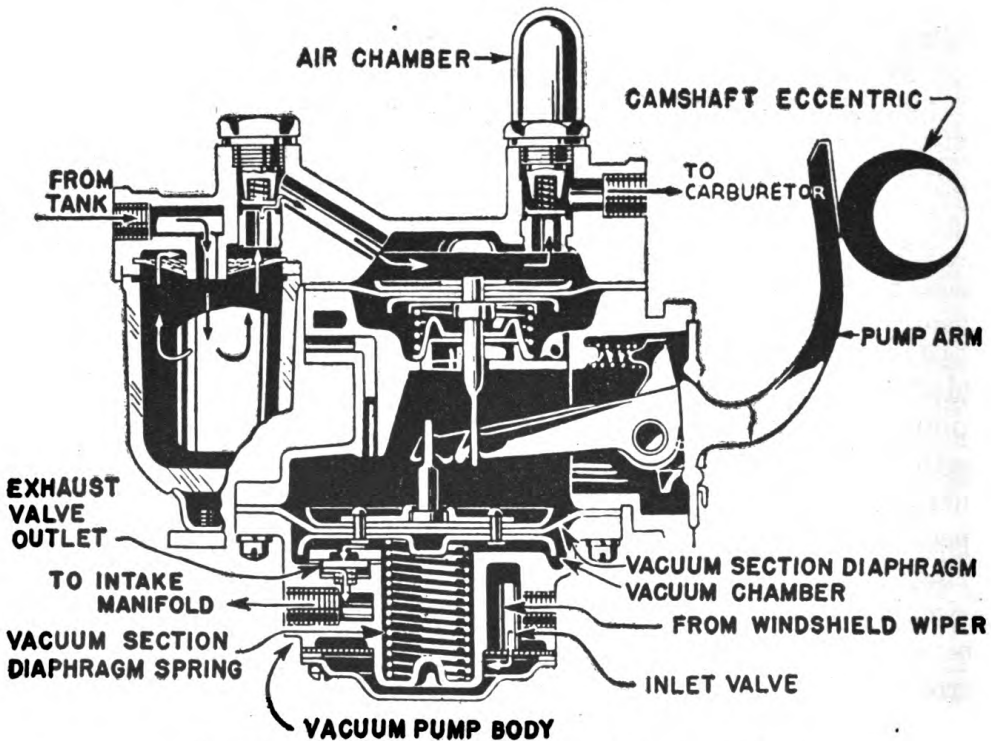


FIGURE 8.—Mechanical fuel pump with vacuum section.

(2) *Electric fuel pumps.*—(a) This type of pump is designed to supply gasoline to the carburetor regardless of the climate, terrain, speed, or location of the tank, and to operate independently of any vacuum in the intake manifold. Figure 9 shows the principal parts of an electric fuel pump.

(b) The pump, connected between the carburetor and the fuel tank, is operated by an electric current controlled from the coil side of the ignition switch. When the ignition switch is turned on, the pump will operate before the engine starts, drawing gasoline from the main supply tank and delivering it to the carburetor under pressure.

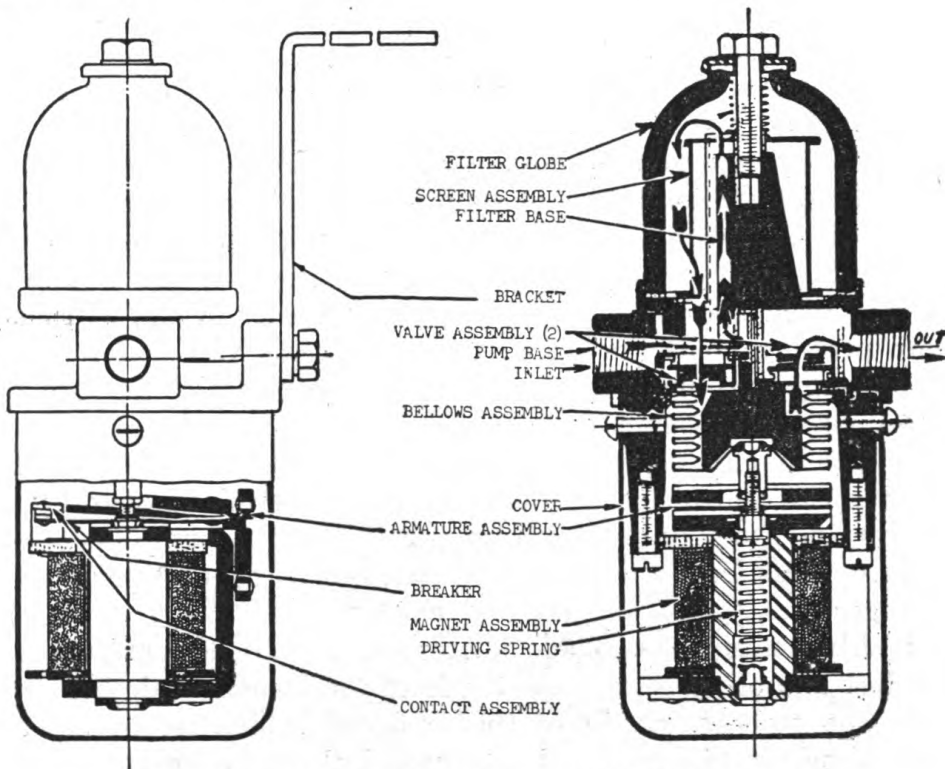


FIGURE 9.—Electric impulse fuel pump with built-in fuel filter.

1. The metal bellows, expanded by the downward pull of the electromagnet on the armature, draws gasoline from the main supply tank through the inlet suction valve into the pump chamber.
2. During this downward stroke of the armature, the electric contact breaker opens the circuit and demagnetizes the electromagnet, thus freeing the armature. The inlet suction valve then closes and the driving spring pushes on the bellows and forces gasoline through the outlet valve

into the fuel line to the carburetor. When the contact points of the breaker come together again on the upstroke of the armature assembly, the electric circuit is closed and the cycle is rapidly repeated.

(c) As soon as fuel fills the carburetor to the correct level, the carburetor needle valve closes and the pressure built up within the bellows prevents further pumping by holding the electric contact points apart. With the contact assembly open, there is no current flowing and therefore no drain on the battery. When the level of the fuel falls in the carburetor float chamber, the needle valve is unseated, relieving the pressure on the bellows, so that the electric fuel pump again functions until the carburetor needle valve is returned to its seat by the rising gasoline level in the carburetor float chamber. The suction in this type of pump is so great that it rarely needs priming.

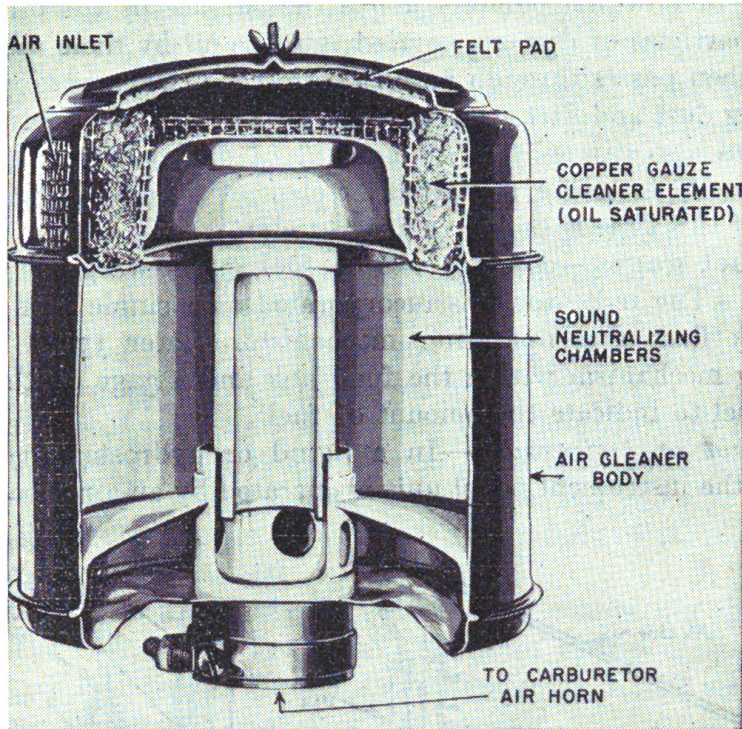
(3) *Fuel pump performance.*—(a) It is essential that the fuel pump deliver sufficient fuel to supply the requirements of the engine under all operating conditions and that it maintain sufficient pressure in the line between the fuel pump and carburetor to keep the fuel from boiling and to prevent vapor lock. Excessive fuel pump pressure holds the carburetor float needle valve off its seat, causing high gasoline level in the float chamber which in turn increases gasoline consumption.

(b) The pump, depending upon fuel pump pressure and carburetor float control, usually delivers a predetermined quantity of fuel varying from 10 to 55 gallons per hour. The pump operating pressure varies from 2 to 4 pounds; with an average of 3 pounds for passenger cars, 1/2-ton, and 1 1/2-ton vehicles.

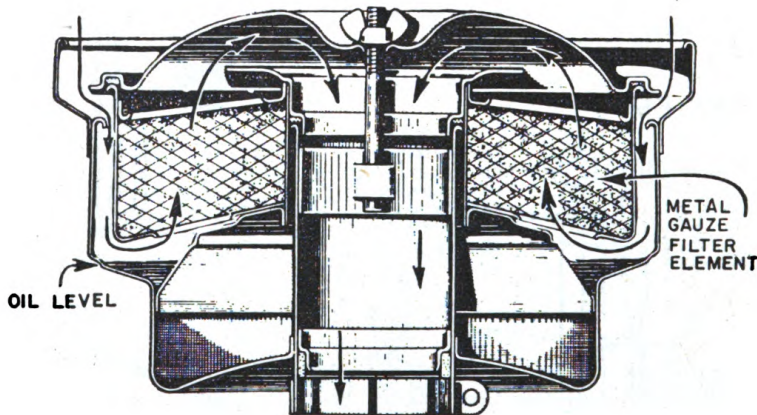
16. *Air cleaners.*—a. These devices (fig. 10) are designed to separate dust and other foreign matter from the incoming air before it enters the carburetor. Since thousands of cubic feet of air are drawn from within the hood and passed through the engine cylinders, it is important that this air is clean. When driving along dusty roads, dust is drawn through the radiator and ultimately finds its way into the engine unless the air is filtered or cleaned. Foreign matter in the engine causes excessive wear and operating troubles.

b. The filtering element is usually made from copper gauze or copper wool saturated with oil and packed into position between wire or other openwork sections of the cleaner body. Air entering the engine passes through the filtering element which traps the dust and dirt. The filter element should be washed in gasoline or kerosene approximately every 1,000 miles, or oftener if operating conditions

warrant. After washing out old oil and dirt, treat the filter element by dipping it into a pail of SAE No. 50 engine oil (Navy symbol No. 3100). After cleaning and draining, the filter is reassembled.



① Oil saturated type.



② Oil bath type.

FIGURE 10.—Air cleaners.

The gauze (or wool) in the filter also acts as a flame arrester during a severe flash-back or backfire. The filter shown in figure 10 ① contains a silencing unit consisting of intake passages designed to muffle air noises and a felt pad which acts as a gasket and absorbs engine intake noises.

c. The oil bath type of air cleaner is installed on the engines of most military motor vehicles. A cavity in the base of this cleaner contains a quantity of oil. The incoming air is forced to reverse its direction of flow immediately above the surface of the oil and the heavier particles of dirt are carried into the oil by their momentum. The air then passes through an oil saturated copper gauze where the remaining dust and dirt are trapped. The change in direction of the air stream also carries a small amount of oil vapor with it which keeps the copper gauze (mesh) filter element saturated with oil. A cleaner of this type is shown in figure 10 ②.

17. Fuel gages.—Early types of fuel gages were mechanically operated. The indicator was incorporated as a single unit with the fuel tank float and operating mechanism. Later types have an operating mechanism within the fuel tank and a gage on the instrument panel to indicate the amount of fuel.

a. *Liquid or hydrostatic.*—In a liquid or hydrostatic type gage (fig. 11) the instrument panel unit is operated by an air tube running

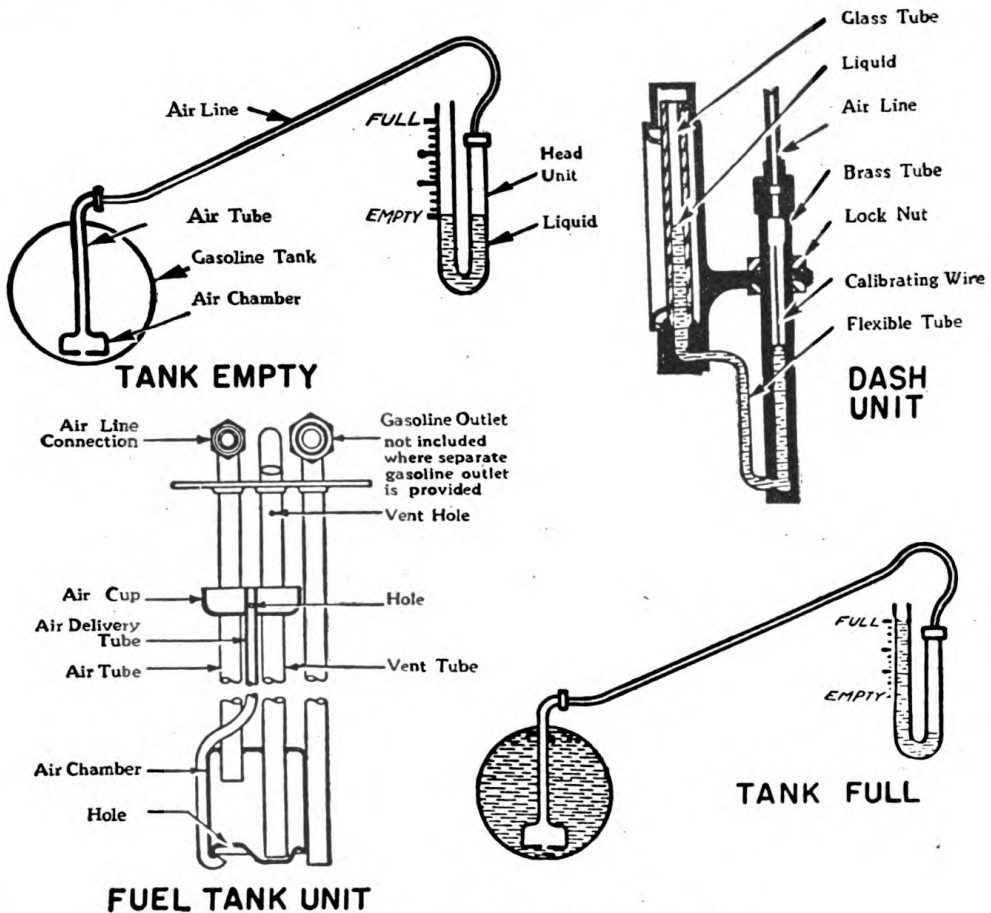


FIGURE 11.—Liquid or hydrostatic type fuel gage.

between the tank unit and the instrument panel unit. The end of the air tube at the instrument panel is fitted with a U-shaped unit having a calibrated glass tube containing a colored liquid. The end of the tube in the fuel tank is fitted with an air chamber. When the fuel tank is empty, there is no pressure in the air chamber and therefore no pressure is applied to the liquid in the U-shaped glass tube on the instrument panel. As the fuel tank is filled, air is trapped in the air chamber and the pressure thus built up is transferred by the air tube to the top of the liquid in the U-tube, making it move around the bend and rise in the glass tube to indicate the amount of fuel in the tank. As the fuel is withdrawn from the tank, the air pressure is gradually reduced and the colored liquid in the gage flows down and back around the bend in the glass tube. Hydrostatic (liquid) fuel gages are generally being replaced by electric gages.

b. Electric.—Most motor vehicles are now equipped with fuel gages which are operated in conjunction with the vehicle's electrical system. The two principal types are the electric meter and rheostat type and the bimetal and resistance wire type. The details of their operation are discussed in TM 10-580.

18. Fuel lines and fittings.—Fuel lines connecting the various units of the fuel system are usually made of drawn copper tubing. However, copper tubing is being supplanted by rolled steel tubing usually rust-proofed by copper or zinc plating.

a. Fuel lines are placed away from exhaust pipes, mufflers, and manifolds so that the excessive heat will not cause vapor lock. They are attached to the frame, engine, and other units so that the effect of vibration is minimized and so they are free of contact with sharp

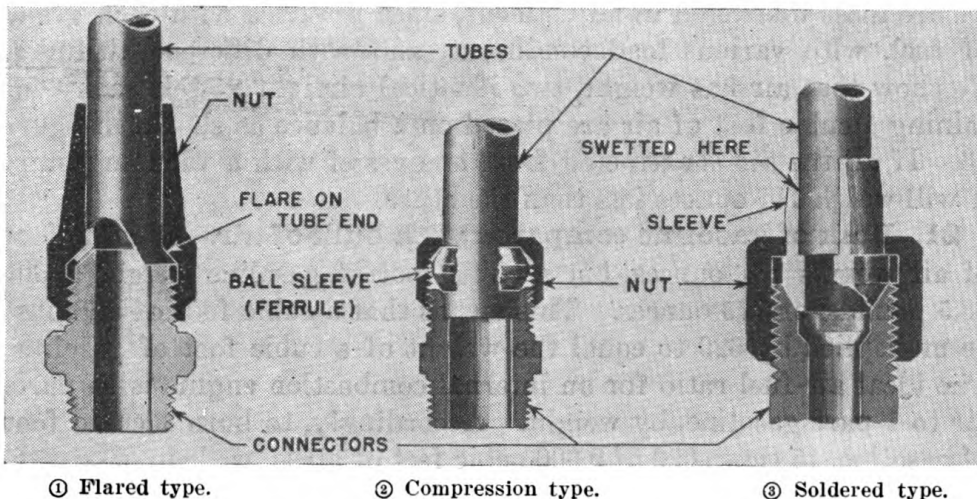


FIGURE 12.—Three types of tube fittings used on fuel and oil lines.

edges which might cause wear. In places of excessive movement, as between a vehicle frame and a rubber mounted engine, short lengths of gasoline resistant flexible tubing are used.

b. Three principal kinds of tube fittings (flared, compression, and soldered types) are shown in figure 12. Of the three, the flared fitting, sometimes referred to as a refrigerator or marine fitting, is probably the most popular.

SECTION IV

PHYSICS OF CARBURETION

	Paragraph
General.....	19
Weight of air.....	20
Bulk of gasoline compared with bulk of air.....	21
Vaporization.....	22

19. **General.**—All internal combustion engines require a fuel charge in the engine cylinders. In the spark ignition type engine, this fuel charge is a mixture of air and the vapor obtained from a volatile liquid fuel. A liquid fuel is atomized (broken up), partially vaporized, and mixed with the correct proportion of air in a carburetor. To understand the mechanics of a carburetor, it is first necessary to understand the principles of carburetion. There are a number of methods by which a fuel mixture may be made, each one requiring a different type of carburetor.

20. **Weight of air.**—It is not generally appreciated that air has weight and that this weight decreases as the height above sea level increases. The weight of air (atmospheric pressure) has a definite bearing on carburetor design, construction, and adjustment. Mechanics are most interested in adjustment, since it varies with each grade of fuel, with various load conditions, and with different altitudes. To show that air has weight, two identical airtight vessels each containing 1 cubic foot of air are placed on a balance as shown in figure 13. If all the air is extracted from one vessel with a vacuum pump, it will weigh 1¼ ounces less than the other.

21. **Bulk of gasoline compared with bulk of air.**—A cubic foot of air weighs 1¼ ounces, but a cubic foot of gasoline weighs about 48.5 pounds, or 775 ounces. This means that a cubic foot of air must be multiplied by 620 to equal the weight of a cubic foot of gasoline. The ideal air-fuel ratio for an internal combustion engine is 15 parts air to 1 part gasoline, by weight. Accordingly, to burn 1 cubic foot of gasoline, 15 times 620 or 9,300 cubic feet of air is needed. Converting this ratio to gallons, 1,240 gallons of air is needed to burn 1 gallon

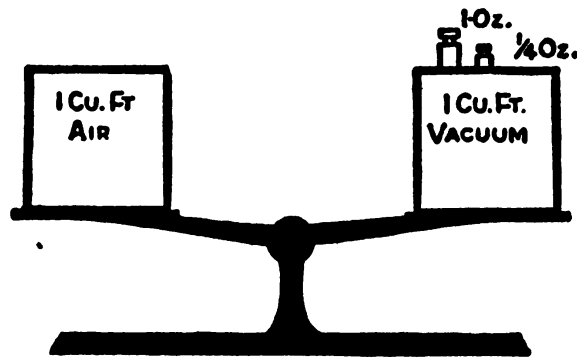


FIGURE 13.—One cubic foot of air balanced by $1\frac{1}{4}$ ounces, demonstrating that air has weight.

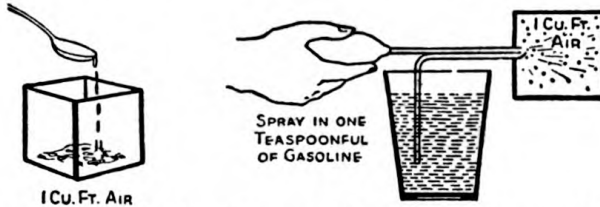
of gasoline; or, $\frac{1}{2}$ teaspoonful of gasoline must be mixed with 1 cubic foot of air to obtain the ideal 15 to 1 ratio.

22. Vaporization.—*a. General.*—(1) In order to secure a good air-fuel mixture, gasoline must first be atomized (broken up) and vaporized. If $\frac{1}{2}$ teaspoonful of gasoline is poured into a cubic foot of air (fig. 14 ①), the gasoline simply drops to the bottom of the vessel and remains there without mixing with the air except by the slow process of evaporation.

(2) Vapor is a gasified liquid. When a liquid vaporizes, it occupies more space and it will also float in air. Evaporation occurs at all temperatures but it is usually more rapid in hot weather. All volatile liquids placed in contact with the air will start to evaporate and in this vapor form may present extremely dangerous fire and explosion hazards. The loss from evaporation is considerable, especially in extremely warm weather, and must be considered when handling fuels in bulk. As a rule, the evaporated particles are not visible, but in most cases the vapors from an evaporated liquid fuel give off an odor which may aid in detecting abnormal evaporating conditions.

(3) It is possible to accelerate vaporization of a fuel by a number of methods. The vaporization of gasoline in an internal combustion engine is carried out progressively. The breaking up of a fuel is started by the action of the needle valve and the venturi tubes. It is partially vaporized and atomized by the vacuum produced in the top of the venturi tube. It is further vaporized, as it passes through the intake manifold, by the heat transferred to the manifold from the engine and it is almost completely vaporized during the compression stroke of the piston by the heat of compression and the heat left by the previously burned fuel. In carburetor design, the trend is to start vaporization as soon as possible.

b. Vaporization by spraying.—If an atomizer is used for vaporizing a fuel (fig. 14 ②), it is possible to spray $\frac{1}{2}$ teaspoonful of gasoline into a cubic foot of air very quickly and have it mix fairly well, since it enters the air in the form of a mist. The use of an atomizer represents one of the most important principles of carbure-



① Pouring $\frac{1}{2}$ teaspoonful of gasoline into a cubic foot of air does not mix them. ② Spraying $\frac{1}{2}$ teaspoonful of gasoline into a cubic foot of air mixes them fairly well.

FIGURE 14.

tion. When the bulb is pressed, the suction created at the nozzle by the expelled air draws portions of the gasoline up through the tube. As it draws the gasoline out, the air from the bulb strikes it and breaks it up into small particles; that is, atomizes it. "Atom" is a

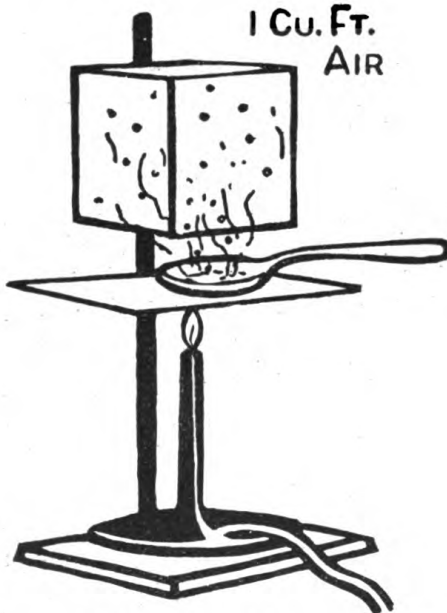


FIGURE 15.—Demonstrating use of heat to vaporize fuel and mix it with air.

term applied to very small parts of any element and atomization means breaking into small particles.

c. Vaporization by heat.—(1) A liquid can be vaporized by applying heat. The greater the heat, the more rapid the vaporization. If heat is applied to $\frac{1}{2}$ teaspoonful of gasoline (fig. 15), the gasoline will be driven off quickly in the form of gasoline vapor. This vapor

rises, and if the vessel containing the cubic foot of air is immediately above it, the air and vapor mix fairly well.

(2) This heating principle is made use of in carburetors by several methods. The older method was to make use of a "stove" built around the exhaust manifold at a point close to the carburetor so that the air being drawn into the carburetor was first passed around the manifold and heated. While stoves are still used, the more modern practice is to use the "hot spots" around the manifold passages. The atomized gasoline, as it passes from the carburetor into the manifold, comes in direct contact with a heated surface and vaporizes rapidly.

d. Vaporization by vacuum.—(1) The earth is surrounded by an ocean of air, many miles in height, that presses upon the earth with a pressure of 14.7 pounds per square inch at sea level. Atmospheric pressure is exerted in all directions. Air is continually forcing its way into any place that contains no air; that is, air will always try to fill a vacuum.

(2) Air can be exhausted from a bottle half filled with water by connecting it to a vacuum pump (fig. 16). As pressure is lifted from the water, it begins to vaporize and it will then boil at 80° to

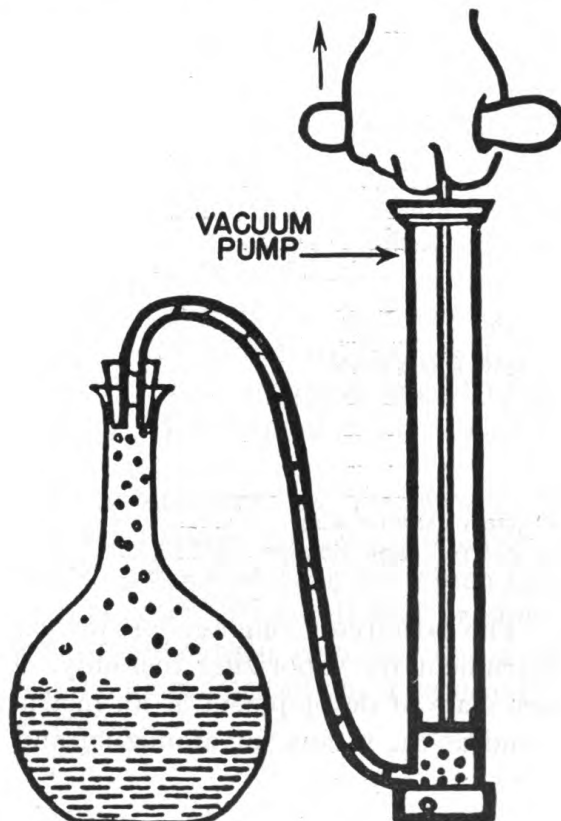


FIGURE 16.—Vaporization of fuel by vacuum.

90° F. instead of the normal 212° F. If half the air is removed from a sealed container, the air left will expand as the pressure is removed, leaving the air pressure within the container only about half that of the atmospheric pressure on the outside of the bottle. This unequal pressure speeds up the vaporization action.

(3) Vaporization by vacuum has a very important place in carburetor operation. A vacuum is the principal means of drawing fuel into the mixing chamber of a carburetor. A venturi tube, which is located just ahead of the mixing chamber, is used in combination with the suction of the engine to increase the vacuum. The lowered pressures due to the vacuum in the venturi allow the atomized fuel to expand and vaporize more quickly.

(4) The vacuum created in the intake manifold is also used to operate windshield wipers, clutch operating mechanisms, power brakes, and gear shifting devices.

SECTION V

PRINCIPLES OF CARBURETION

	Paragraph
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Elementary carburetors	26
Elementary type carburetor with venturi	27
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Venturi action	29
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Air bleed	31
Choke valve	32
Throttle valve	33
Compensation	34
Starting, idling, and slow speed device	35
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Metering rods	37
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Accelerating device	39
Ratio of carburetor size to engine size	40
Accelerator, throttle controls, and linkage	41
Automatic choke	42

23. General.—The carburetor long ago lost its originally intended function as an instrument for vaporizing fuel only. It has reached a comparatively high state of development as an instrument for metering fuel and air, and as the means for atomizing and vaporizing the fuel charge.

24. Action of carburetor.—*a.* When the engine piston descends on the intake stroke, it creates a partial vacuum within the cylinder and air tries to get in to fill this partial vacuum. The only entrance to the cylinder is through the carburetor. As the air rushes through the venturi tube, it creates a partial vacuum at the carburetor nozzle. In some carburetors, the float bowl is opened to the atmosphere so that atmospheric pressure is exerted on the fuel in the bowl; in others, the float bowl is vented to the carburetor horn and the pressure in the bowl is the same as that in the horn. Since this horn pressure is greater than the pressure at the carburetor nozzle, fuel is drawn from the float bowl to the nozzle and out into the passing air stream. As the fuel is drawn from the tip of the nozzle, it is struck by the rapidly moving air stream and carried with it into the engine cylinder. The force of the air stream striking the fuel atomizes it into a mist, which is the first step toward vaporization and the mixing of the air and fuel.

b. The delivery of fuel at the nozzle is controlled by a needle valve, jet, or metering rod. These may operate anywhere and in any combination along the fuel passage from the float bowl outlet to the tip of the nozzle. For convenience in servicing, they are generally placed at the float bowl outlet.

25. Puddle type carburetor.—In the original type of carburetor, known as the puddle type, vaporization was completed before the air-fuel mixture entered the intake manifold. An air stream directed across the surface of the fuel collected the vapor off the top. This was a fairly acceptable method of carburetion because prior to 1903 commercial gasolines were extremely volatile. It was necessary to drain the bowl at frequent intervals because the air stream picked up only the lightest particles of the fuel and left the heavy ones. Eventually, when the bowl contained nothing but the heavy non-volatile parts of the fuel, the carburetor ceased to function and the engine stopped running. This type in itself is no longer in common use.

26. Elementary carburetors.—*a.* The simplest form of carburetor consists of an air passage containing a choke valve, fuel jet, and butterfly throttle, and a float chamber which maintains the fuel in the jet at a constant level. Since all fuel passing through a carburetor of this type is discharged from the one nozzle without the influence of any means of compensation, it is usually referred to as a plain tube carburetor.

b. (1) Figure 17 ① shows an elementary type carburetor in which the gasoline supply tank is placed below the carburetor and the fuel is pumped up through the fuel line to the fuel chamber. The overflow pipe maintains the level of the fuel at a constant height. The fuel supply to the nozzle is controlled by the needle valve. The gasoline level in the nozzle is always just below its tip. The carburetor flange is fastened to the intake manifold of the engine. The suction of the engine pistons draws air through the air passage and up past the choke valve and the nozzle. A spray of gasoline is drawn into the air from the nozzle and mixes with the air. This atomized mixture forms the fuel charge for the engine cylinders.

(2) When the engine is being started, the suction or vacuum is at its lowest point. In order to increase the suction on the fuel in the nozzle, the choke valve should be partially if not entirely closed.

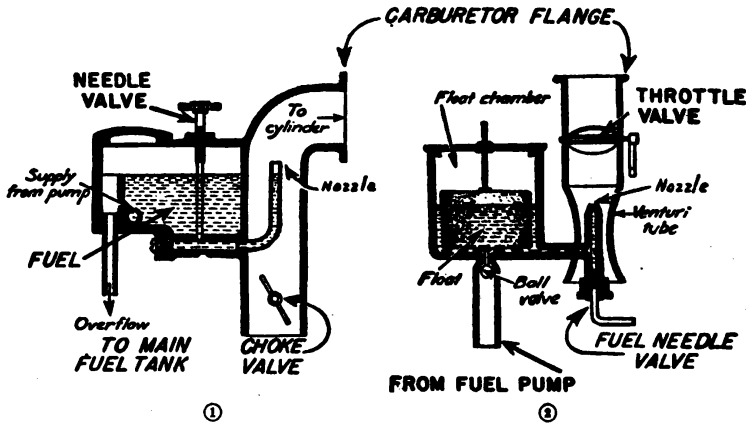


FIGURE 17.—Two elementary types of plain tube carburetors.

When the engine is running, it should be completely open to admit sufficient air to the cylinders. The adjustment of the choke valve, used on all modern engines, is controlled either by hand from a control mounted on the dash or by an automatic mechanism.

(3) This type carburetor can be used on only a constant speed engine, because there is no method included for increasing or decreasing the air supply at varying engine speeds.

27. **Elementary type carburetor with venturi.**—Figure 17 ② shows another elementary type of carburetor and the application of two fundamentals, the constant level float and the venturi tube, which are explained in paragraphs 28 and 29 below. In this type carburetor, the fuel is kept at a constant level in the supply or float chamber by a hollow metal float operating a ball valve.

28. **Float chamber.**—*a. Types.*—When the float chamber surrounds the nozzle (fig. 18), it is concentric. When the float chamber is at the side of the nozzle (fig. 19), it is eccentric.

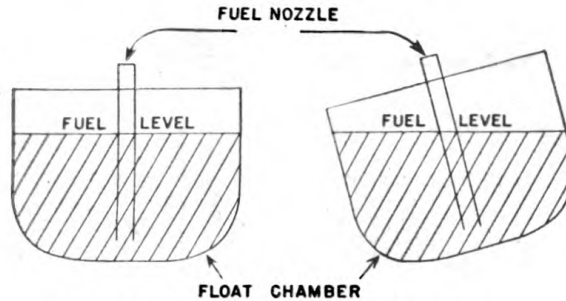


FIGURE 18.—Concentric float chamber.

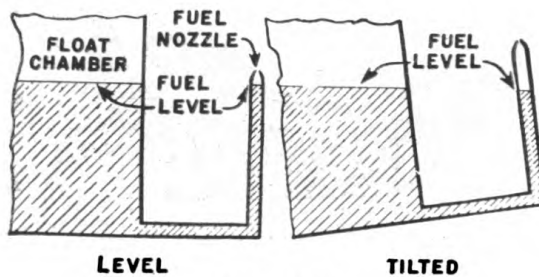


FIGURE 19.—Eccentric float chamber.

b. Float mechanisms.—(1) There are two general types of float-control mechanisms. In figure 20, the needle valve passes through the float. It is controlled by the float rising against two weighted

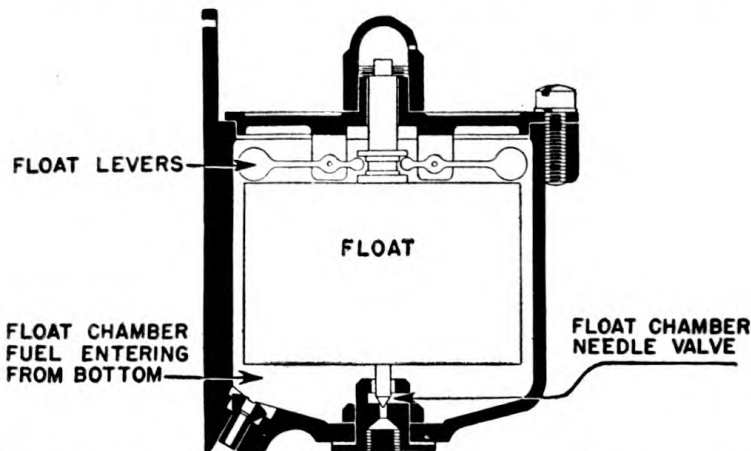
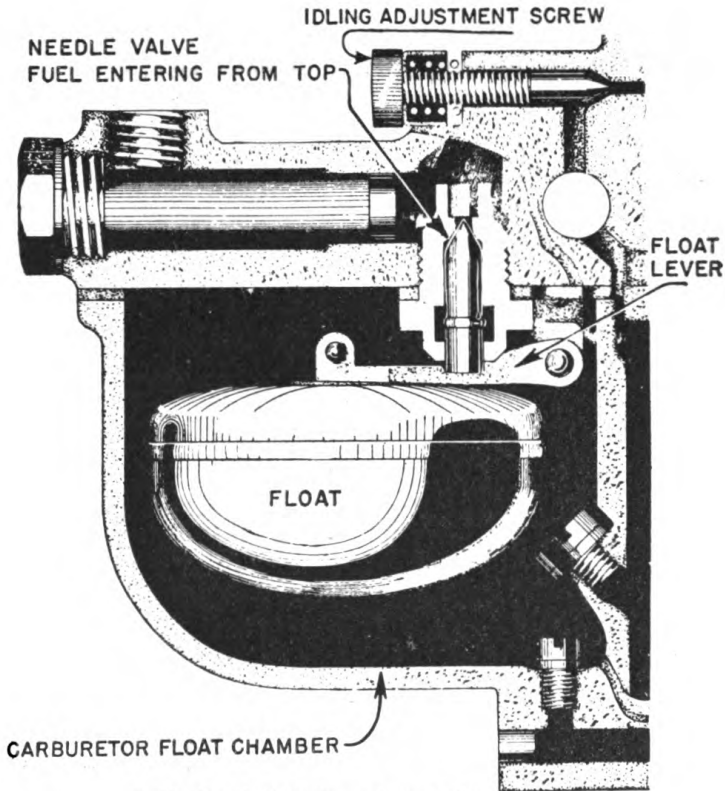
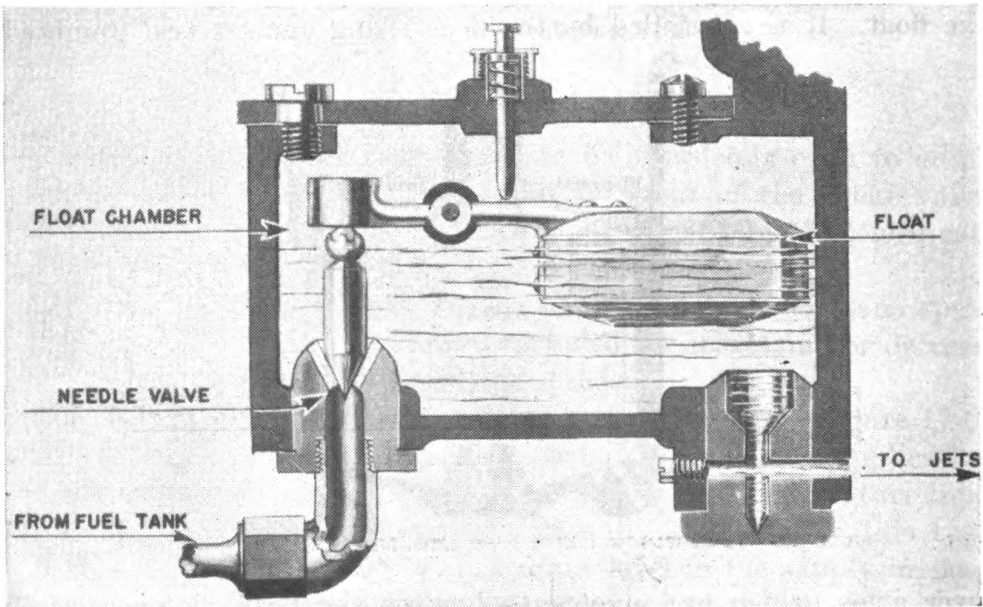


FIGURE 20.—Float with weighted lever arms operating the needle valve.

lever arms, which are pivoted to lugs on the float chamber cover. With this type, the fuel entrance to the float chamber must be placed in the bottom.



① Fuel entering from top of float chamber.



② Fuel entering from bottom of float chamber.

FIGURE 21.—Level type float.

(2) Figure 21 ① shows a lever type of float mechanism with the fuel entering from the top of the float chamber and figure 21 ② shows one with fuel entering from the bottom. It is considered advantageous for the fuel to enter from the top because the needle is less likely to be held off its seat by small particles of dirt and any accumulation of water in the float chamber.

(3) Floats were formerly made of shellacked cork but difficulty was experienced because the float finally absorbed moisture, became heavier, and caused a change in float level position and the level of the fuel in the float chamber. Most floats are now made of metal.

29. Venturi action.—*a.* If a constriction (venturi) is placed in a pipe as shown in figure 22, and water is forced through the pipe, the water in the constriction will flow faster than the water in other

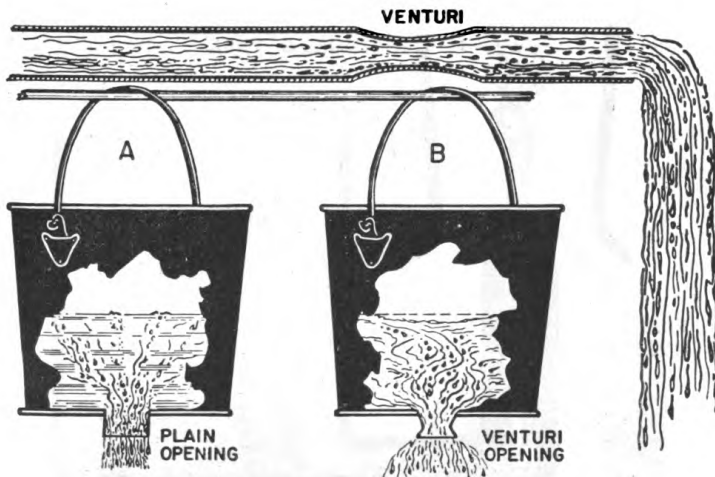


FIGURE 22.—The principle of the venturi tube.

parts of the pipe. This is caused by the spreading tendency of the water as it leaves the constriction. Similarly, if two buckets are placed side by side, both filled with water, one with a 1-inch plain opening in the bottom as shown at A (fig. 22), and one with a 1-inch venturi or bellmouth opening as shown at B (fig. 22), the water will flow out of the venturi opening at a faster rate than out of the plain opening. This same accelerating action takes place as air flows through the venturi of a carburetor.

b. (1) The venturi principle has long been known, and a venturi tube in a carburetor (fig. 23) will develop increased air flow and a higher vacuum within the venturi throat. A problem in carburetion is to secure the correct amount of suction around the needle valve at slow engine speeds and still allow enough air to enter at high engine speeds to maintain the desired ratio of air and fuel. The venturi tube lends

itself to these extremes by increasing the vacuum at low speeds without restricting the flow of air at high speeds.

(2) As the piston within the engine cylinder moves downward on the intake stroke, a suction is created around the fuel nozzle in the narrowest part of the venturi and air enters and picks up the gasoline as it passes. After passing the venturi, the partially atomized air or gasoline enters a mixing chamber and completes atomization. In updraft carburetors, the mixing chamber is always located above the gasoline fuel nozzle and near the upper part of the venturi. A partial vacuum exists in a mixing chamber and just as water boils more readily in a vacuum than it does under normal air pressure, so gasoline tends to vaporize more readily in this partial vacuum.

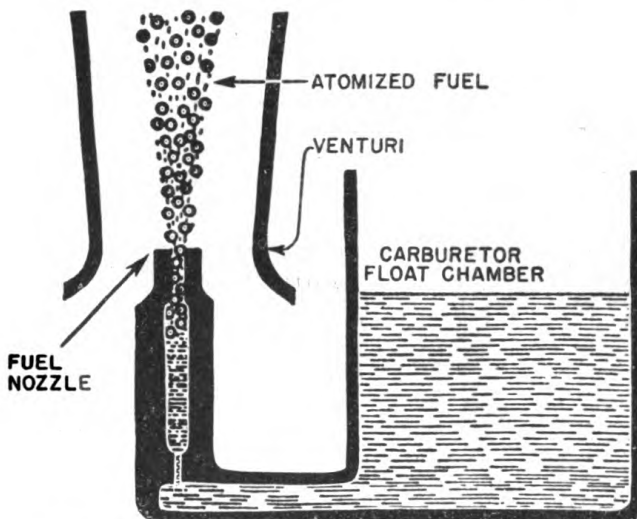


FIGURE 23.—Venturi principle applied to a carburetor.

c. Some carburetors contain two or even three venturi tubes. Figure 24 shows one with two tubes. The use of two or more tubes greatly increases the air speed at the mouth of the fuel nozzle. This increased speed is of great value under light loads (small throttle opening) because better atomization is obtained, giving better low speed performance.

30. Fuel spray nozzles.—These constitute a very important part of the carburetor. It is necessary to have more than just an ordinary opening by which the fuel can enter the mixing chamber. In addition to being a passage for fuel, it must also assist in breaking the fuel into small particles or mist, so that they can be more easily picked up by the inrushing air and more easily converted into a vapor. The most efficient opening is that which will atomize the fuel into the

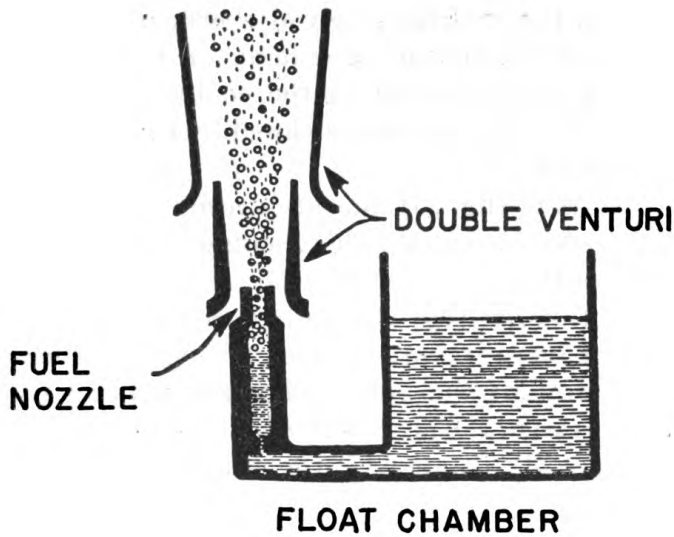


FIGURE 24.—Elementary double or compound venturi tube principle applied to a carburetor.

smallest particles. Designers differ in their opinion as to which shape is the most efficient. Therefore, fuel spray nozzles of different shapes are used in the various makes of carburetors. They can be placed in four general groups as shown in figure 25.

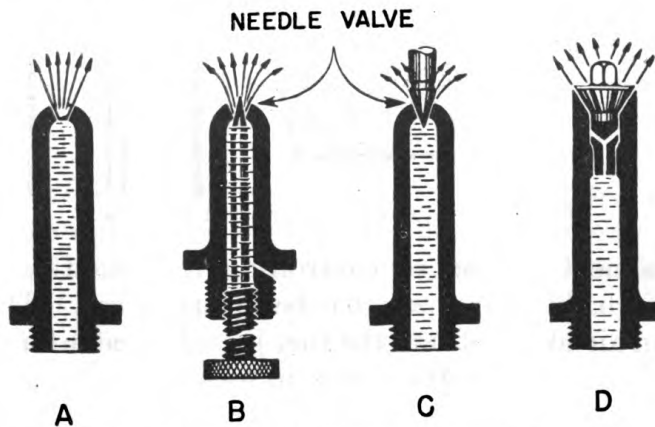


FIGURE 25.—Different designs of fuel spray nozzles used in modern carburetors.

a. The fuel spray jet, type A (fig. 25), is a round tube with an opening at the top through which the fuel passes. The size of the opening being fixed, it delivers fuel on a constant basis.

b. Type B (fig. 25) is the same as type A except for an adjustable needle valve inside. This needle valve, which is manually adjusted, changes the flow of fuel by controlling not only the quantity but also

the shape. When the knurled screw is down, only the needle point enters the hole and the stream or column of fuel passes through it in the form of a spray, hollow in the center. When the screw is raised so that most of the opening is closed by the point of the needle, the stream is reduced.

c. The third type, C (fig. 25), has an inverted, external needle valve which descends from above into the opening. It produces much the same effect as type B.

d. The fourth type, D (fig. 25), is like type C except that instead of having a solid screw point, a series of separated small channels break up the surface of the point. The screw point can be moved up and down to change the size of the channel openings.

31. **Air bleed.**—By comparing the simple carburetors shown in figure 17 with the diagram of the form shown in figure 26, it will be

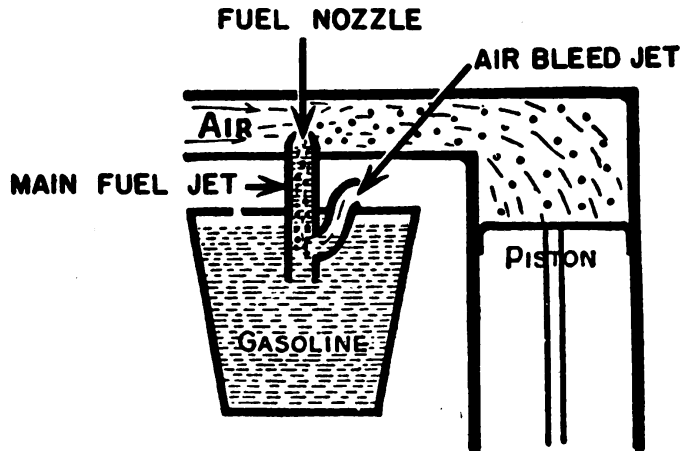


FIGURE 26.—Elementary air bleed principle.

noted that a new method of controlling the quantity of gasoline flowing through the fuel nozzle has been introduced. This is an air opening or an air bleed jet into the fuel jet. Instead of a solid stream of fuel being drawn from the nozzle to mix with the air, air bubbles are first mixed with it. These air bubbles break the fuel into small particles before it reaches the nozzle so that the further action of the main air stream upon the fuel particles results in a better atomized fuel charge.

32. **Choke valve.**—a. (1) An excessively rich mixture is required to start a cold engine because the only heat available for vaporization comes from the heat of compression within the cylinders. Since only about 10 percent of the fuel will be vaporized within a cold engine under average conditions, about ten times the usual amount of fuel must be taken into the cylinders in order to provide sufficient vaporized fuel to obtain a correct burning mixture.

(2) This is usually accomplished by means of a choke valve in the air inlet or carburetor horn (figs. 28 and 29). The position of this valve may be regulated either manually by the operator or automatically by a thermostat controlled by the temperature of the exhaust manifold. Closing the choke valve restricts the air supply and greatly increases the suction at the fuel nozzle. Much more fuel is drawn into the mixing chamber than would be if the choke valve were open. As soon as the engine starts, the choke must be partly opened or the overrich mixture will "kill" the engine.

b. While the choke valve is an effective aid in starting, it should be sparingly used. If it is left partly closed, the carburetor will deliver an overrich mixture which will lead to incomplete combustion. This will leave liquid fuel in the cylinder, which washes lubricant from the cylinder walls, causes crankcase dilution, fouled plugs, and other defective conditions.

33. Throttle valve.—Engine speed is controlled by the position of the throttle valve (fig. 27). As the throttle is opened wider, a larger fuel-air charge is admitted to the cylinder.

34. Compensation.—*a.* A simple carburetor can deliver a correctly proportioned mixture of fuel and air at only one engine speed. Since the rate of the fuel flow varies if the air speed is increased or decreased, some means of compensation is necessary during these variations to prevent too lean or too rich a mixture. The correct mixture generally occurs when the air velocity allows about 200 cubic feet of air per minute to pass through a carburetor having a correct balance between the size of the venturi and the jets involved. Air delivery begins just above the zero point of suction, whereas fuel delivery begins only after suction has been considerably increased. This is due to the fact that the fuel must be lifted to the top of the nozzle before it can flow into the mixing chamber. Once started, the rate of fuel delivery increases faster than the rate of air delivery, and in all simple spraying types of carburetors the mixture is too lean at a low suction, becomes correct at some higher suction, and as the suction becomes still higher due to the increased air speed, the mixture becomes too rich.

b. There are two general methods of overcoming this inherent defect in the simple carburetor. The first is to increase the air speeds around the nozzle at slow engine speeds and the second is to decrease or restrict the flow of fuel at high engine speeds. The balancing of the air-fuel ratio in the carburetor under various throttle positions is known as compensation. There are five basic compensating devices used in modern carburetors: A starting, idling, and slow speed

device; auxiliary air valves; metering rods; compensating jets; and accelerating devices. These may be used singly or in combinations.

35. Starting, idling, and slow speed device.—*a.* Engine speed depends on the forces developed during the power stroke. This is controlled by the throttle valve which regulates the amount of fuel and air admitted to the cylinders. A suction of about $\frac{1}{2}$ pound per square inch below atmospheric pressure at the mouth of the nozzle must be reached in order to lift fuel from the passage into the mixing chamber. It is difficult to obtain this suction in carburetors with a fixed air passage at cranking or low engine speeds with the throttle nearly closed. To overcome this difficulty, a second nozzle is required at the edge of or above the throttle to feed the fuel. Such a nozzle may be called a starting, idling, and slow speed device. (See fig. 27.) After the engine is started and as the throttle is opened to increase engine speed, the vacuum above and below the throttle is equalized and the suction on the idling nozzle becomes less until fuel is no longer pulled from it. As engine speeds increase, due to the

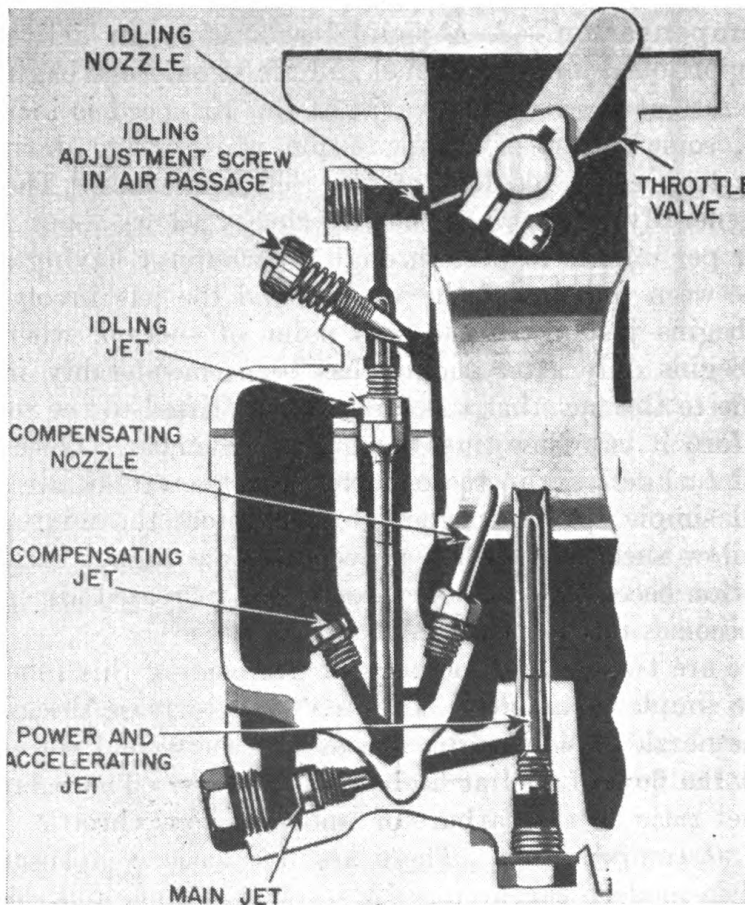


FIGURE 27.—A starting, idling, and slow speed device.

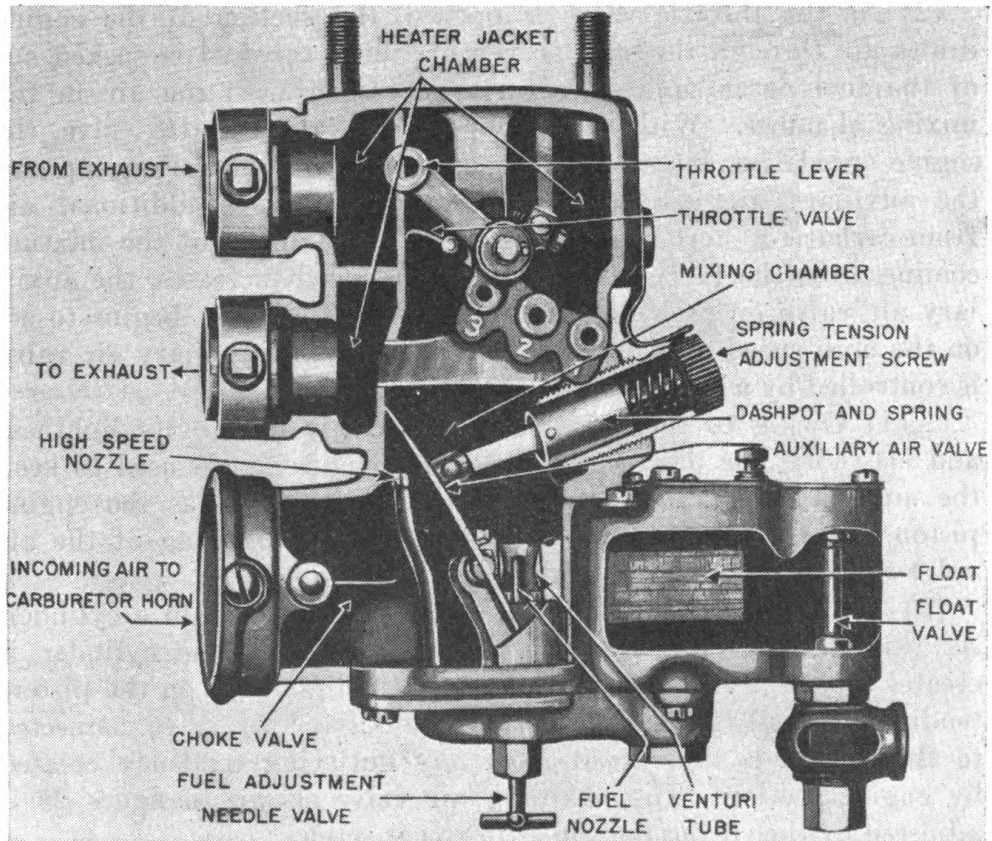


FIGURE 28.—Use of an auxiliary air valve to control fuel mixture in a carburetor.

throttle valve being opened wider, the main supply of fuel begins to come from the main jet.

b. The idling device will become inoperative at a vehicle speed of about 20 miles per hour. The starting and idling mixture is controlled by an adjustable screw in an air opening in the passage to the slow speed jet somewhere above the normal fuel level in the float chamber.

36. Auxiliary air valves.—*a.* (1) Some carburetors are equipped with a device that will automatically maintain the mixture of air and fuel within the limits of approximately 15 to 1, irrespective of engine speed or load. If this is not done, an engine could only run at one speed and with a fixed load.

(2) If an attempt is made to increase the engine speed without increasing the air volume, the increased suction enriches the fuel mixture out of all proportion to the demands of the engine.

b. (1) An auxiliary air valve located between the high speed nozzle and the throttle automatically controls the volume of air required for correct fuel mixture. A valve of this type is shown in figure 28.

(2) As the throttle valve is opened, the suction of the engine draws air through the smaller venturi tube; the fuel is sucked out of the fuel nozzle in the venturi and mixed with the air in the mixing chamber. With further opening of the throttle valve, the engine speeds up, increasing the suction within the carburetor and the auxiliary air valve is sucked open admitting additional air from carburetor horn which cuts down the richness of the mixture coming from the fuel nozzle. As engine speed increases, the auxiliary air valve opens wider and the increased air flow begins to act on the high speed nozzle. The movement of the auxiliary air valve is controlled by a spring and dash pot arrangement.

c. (1) Owing to the peculiar action of air due to its lightness and elasticity, the dash pot, as shown in figure 28, is used to keep the auxiliary air valve from fluttering in and out as the engine pistons deliver their suction impulses to it. Fluttering of the air valve would cause uneven operation of the engine.

(2) This type dash pot has a piston operating within a cylinder. As this piston moves away from the bottom of the cylinder it creates a partial vacuum which produces a slight pull on the piston, tending to steady its movement. The auxiliary air valve connected to this piston is thus freed from any fluttering tendency created by engine suction. The auxiliary air valve shown in figure 28 is adjusted by the spring tension adjustment screw.

37. Metering rods.—*a.* As varying engine speeds demand varying quantities of fuel, the high speed main jet opening on metering rod type carburetors is increased or decreased by the movement of a metering rod. The metering rod varies the fuel flow as the engine speed changes, supplying a correctly proportioned fuel mixture for all speeds above that at which the main jet becomes operative.

b. Metering rods are controlled by the opening and closing of the throttle mechanism or by air suction through an automatic air valve. A throttle controlled metering rod type carburetor is shown in figure 45, and is discussed in detail in paragraph 46.

38. Compensating jets.—*a. General.*—The compensating jet (fig. 29), sometimes referred to as a supplementary jet, is used in some carburetors in conjunction with the main jet to control the richness of the fuel mixture at variable speeds. This type of jet is usually connected with the float chamber and has its nozzle placed in the air stream in such a position that it is least affected by changes in suction within the venturi. Since its fuel flow is fairly constant, it tends to make the mixture lean at high speeds. It acts with the main jet to give an average mixture of air and fuel throughout the driving speed range.

FUELS AND CARBURETION

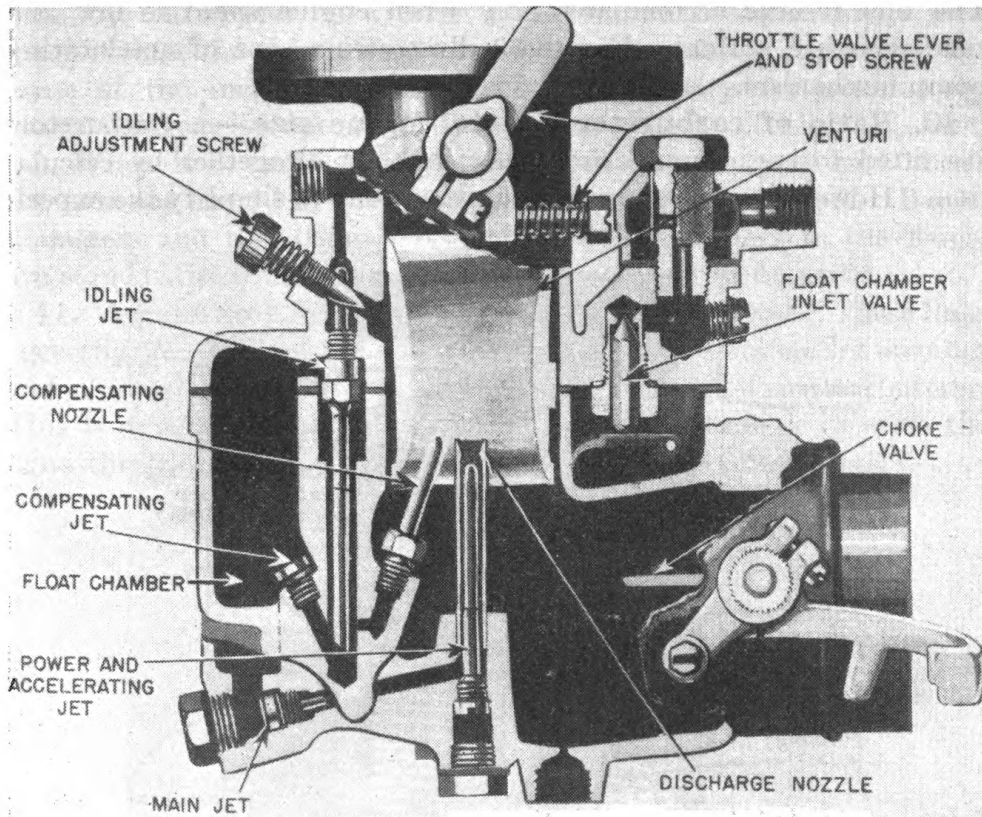


FIGURE 29.—Compensating compound nozzle type updraft carburetor (section through the body).

b. Full throttle compensating valve.—(1) This device, sometimes referred to as an economizer valve, is used in some makes of carburetors to provide an additional amount of fuel for three-quarter to full throttle operation. A valve of this type (fig. 30) is operated by the accelerating pump piston. It is located in the bottom of the accelerating well in such a position that the accelerating pump piston will push it open at about three-quarter open throttle.

(2) This fuel compensating effect is similar to that produced by the mechanically or vacuum operated metering rod discussed in paragraph 37.

39. Accelerating device.—*a.* When the throttle is opened suddenly from an idling speed, the carburetor should deliver a richer mixture to meet the increased demand for power.

b. Quick acceleration is made possible by maintaining a reserve of fuel near the outlet of the main nozzle in an accelerating well. When the engine is accelerated to meet high speed or heavy load demands, the reserve fuel in the well may be either drawn out by increased air movement or pumped out by action of a piston within the well.

The fuel reserve accumulates only when engine speed is low and conditions are normal. Figure 30 illustrates a type of accelerating pump mechanism.

40. Ratio of carburetor size to engine size.—*a.* Carburetors are fitted to engines experimentally and not altogether by calculation. However, a few simple calculations help to simplify the experi-

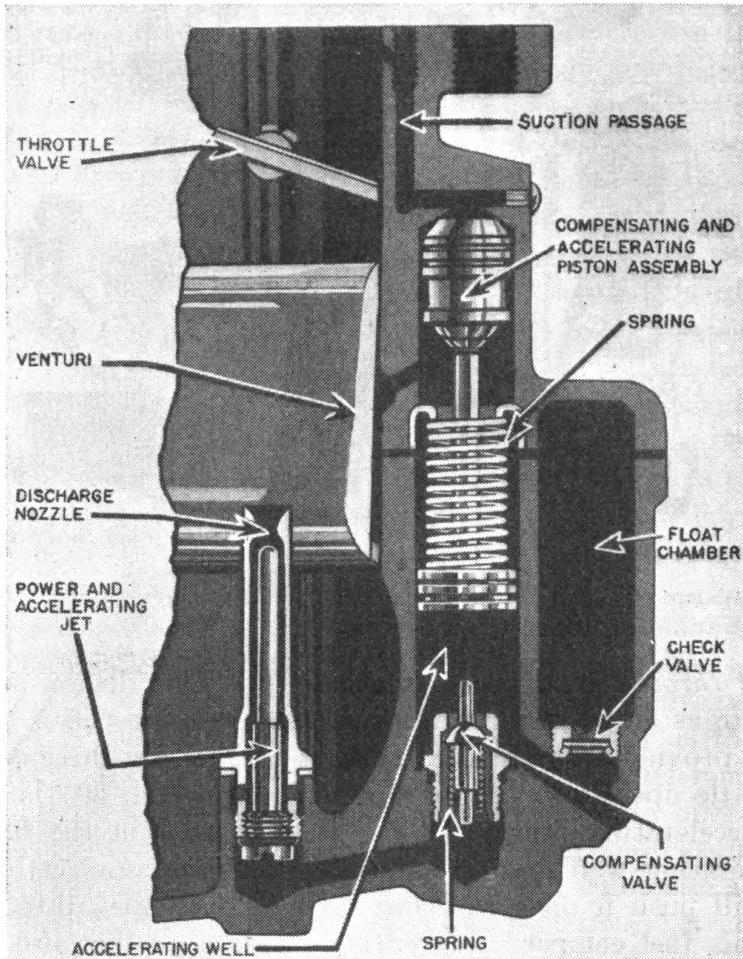


FIGURE 30.—Section through a compound nozzle type carburetor, showing accelerating pump and full throttle compensating valve assembly.

mental work. Modern automotive engines under full load consume about 0.6 pounds of fuel per horsepower hour and use an air-fuel mixture of approximately 15 to 1 by weight. Hence, the air consumption is 15 times 0.6 pounds or about 9 pounds of air per horsepower hour; or, 9 divided by 3,600, which is 0.0025 pound of air per horsepower per second (3,600 being the number of seconds in 1 hour). On most carburetors, the maximum amount of air that will pass a 1 square inch throat is about 0.29 pound per second.

b. The carburetor in a large truck engine needs a throat area greater than the throat area of a passenger vehicle carburetor because of the increased quantity of air necessary for satisfactory heavy duty engine operation.

c. When it is necessary to procure and install a new carburetor, the new one should be of the same size and type as the old. Barrel diameters and the distance between bolt hole centers in the flange are standardized. These are measured as shown in figure 31.

41. **Accelerator, throttle controls, and linkage.**—*a.* These linkages (fig. 32) control the speed of an automotive engine by opening and closing the throttle valve (fig. 27 and 28) on the carburetor. This is done with the foot-operated accelerator linkage or with the hand throttle which is usually located on the instrument panel.

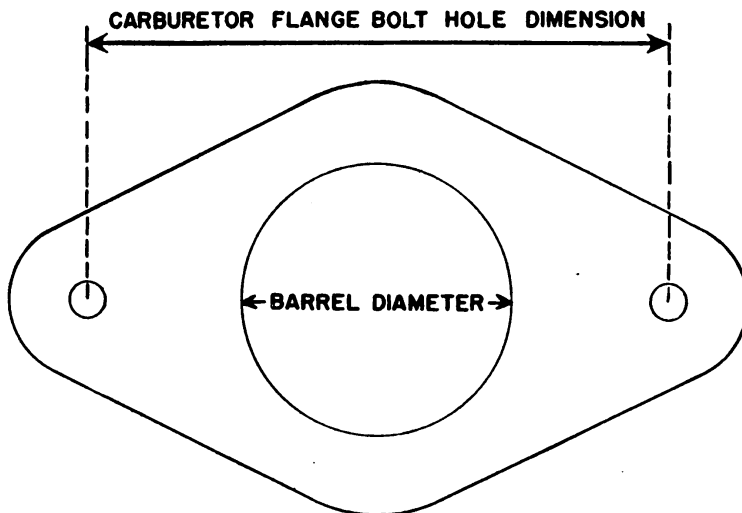


FIGURE 31.—How to measure the barrel diameter of a carburetor and the distance between flange bolt holes.

b. The accelerator consists of a foot pedal and connecting linkage which opens and closes the throttle valve independently of the hand throttle control (fig. 32). When the foot accelerator pedal is depressed, the throttle rod is moved by the linkage and opens the throttle valve to increase the speed of the engine. When the pressure on the pedal is released, the accelerator return spring returns the throttle valve to the idling position, reducing the engine speed. The hand control on the instrument panel is connected to the hand throttle connection on the opposite side of the carburetor as shown in the insert in figure 32. When the hand control is pulled out from the panel, the throttle is opened, and when it is pushed in, the throttle is partially closed to the idling position. When the choke is com-

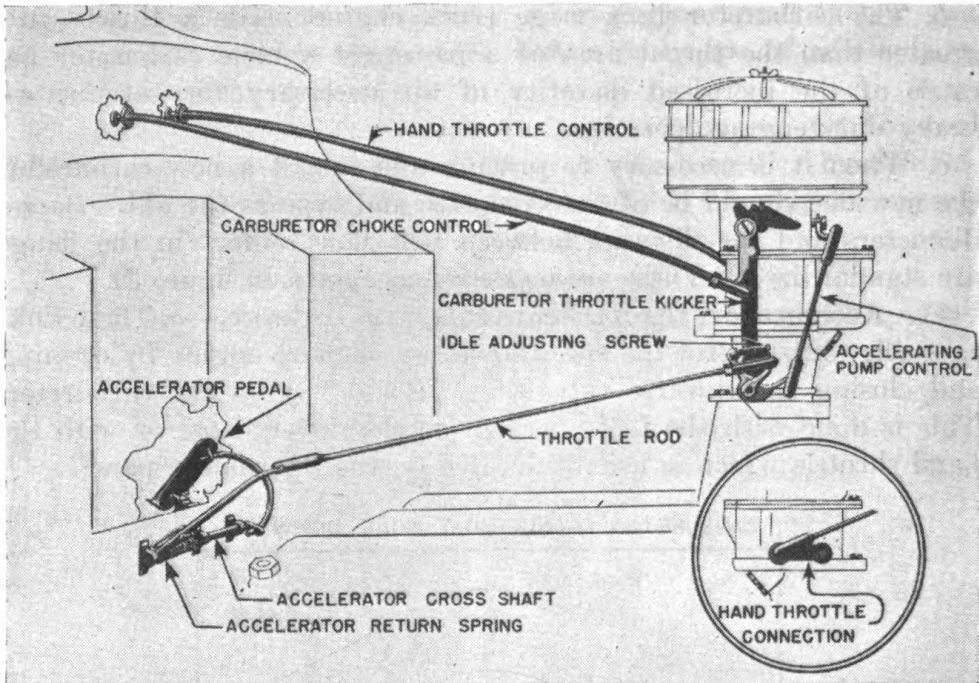


FIGURE 32.—Controls and linkages for the accelerator, throttle, and choke valve.

pletely closed, when starting a cold engine, the carburetor throttle kicker opens the throttle a trifle in order to increase the idling speed.

42. Automatic choke.—*a.* This control unit replaces the conventional hand choke and not only controls the fuel-air ratio for quick starting at any temperature but also automatically provides the proper amount of choking to enrich the fuel mixture for all conditions of engine operation during the warm-up period. (See fig. 33.)

b. (1) This carburetor choke unit is mounted on the intake manifold where its operation is governed by changes in manifold temperature, manifold vacuum, and carburetor inlet air velocities. A short, positive linkage connects the control lever with the carburetor choke valve. The choking action is regulated by a spiral bimetal thermostat and an internal bellows. Engine vacuum, immediately after starting, collapses the bellows and rotates the thermostatic spring to relieve the tension on the choke valve, which makes the mixture lean. The spiral thermostat spring, connected between the choke and the bellows linkage, controls the tension on the choke valve according to the temperature. It gradually decreases the choking action during the warm-up period until it is completely eliminated when the engine has reached a normal operating temperature.

(2) When the engine has stopped running and the temperature has dropped to about 70°, the thermostat coil spring again moves the choke valve in the carburetor to the closed position.

c. Another automatic choke is shown in figure 47. Its operation, which is similar to that discussed in this paragraph, is described in detail in paragraph 46.

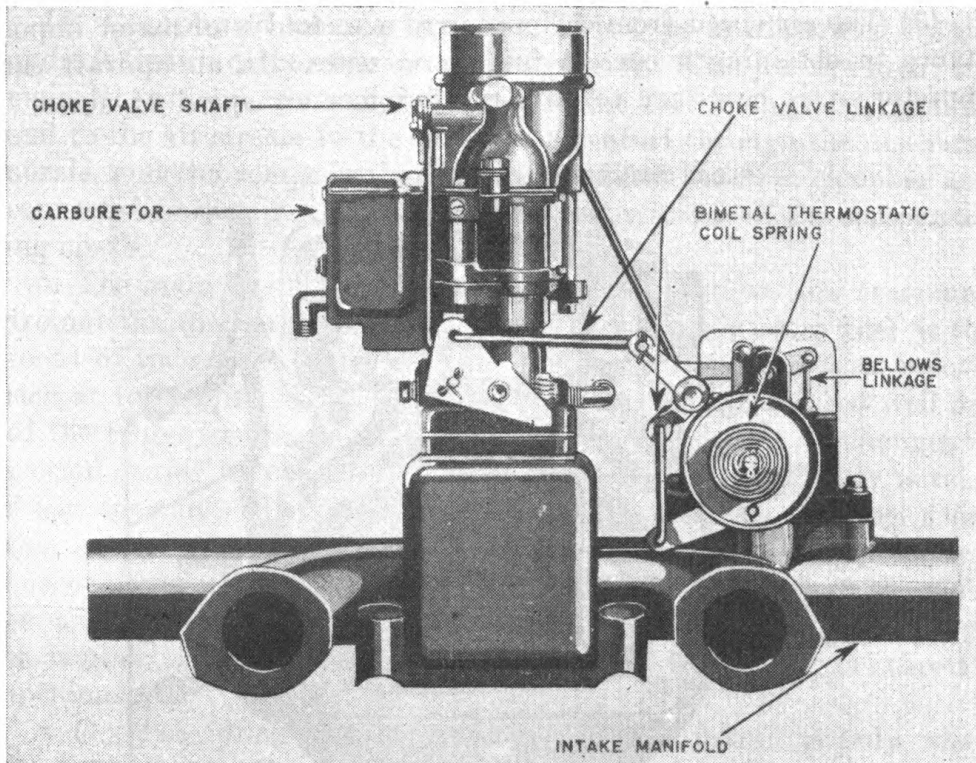


FIGURE 33.—Automatic choke mechanism mounted on intake manifold and connected to the carburetor.

SECTION VI

CARBURETORS

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43. General types.—*a. Updraft and downdraft.*—(1) Carburetors are classified as updraft or downdraft, according to their position with respect to the intake manifold. If the carburetor is

located below the manifold, it is an updraft (fig. 35) and if placed above the manifold, it is a downdraft (fig. 33).

(2) In all early fuel systems, the necessity of having fuel flow by gravity to the float chamber made the use of an updraft carburetor necessary because of its low position. However, with the advent of the mechanical fuel pump, it is possible to locate the carburetor in any position with reference to the intake manifold.

(3) The air speed from carburetor to manifold is of major importance in obtaining a correct fuel-air mixture. In an updraft carburetor, it is necessary to have a minimum air speed of about 40

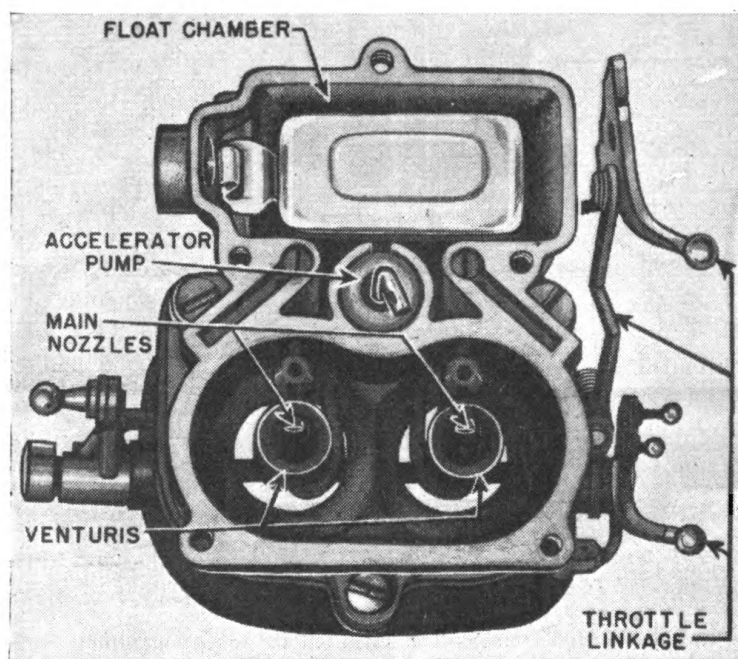


FIGURE 34.—Top view of duplex carburetor with horn and cover removed showing float chamber and two individual venturis.

feet per second through the air horn, venturi, and mixing chamber in order to break up, mix, and lift the fuel charge. Should the air speed be less than this minimum, incorrect carburetion will result. In order that this minimum air speed may be obtained at low engine speed, an updraft carburetor must have a small venturi. However, this is apt to restrict the fuel flow during wide open throttle operation. With the downdraft type, the fuel, once started from the nozzle, will flow by gravity to the intake manifold.

b. Duplex.—This design includes two carburetors within a single body unit (fig. 34). Both carburetor units draw their fuel from a single float chamber and their throttle valves operate on a common shaft connected through linkage to the accelerator foot pedal and the hand throttle on the vehicle's instrument panel. Each carburetor unit is adjusted separately. This type carburetor is used, as a rule, on eight-cylinder engines and occasionally on six-cylinder engines.

44. Compound nozzle type.—*a.* This type is illustrated by the updraft Zenith carburetor shown in figure 29. Two jets are used; the main jet, which is connected directly to the fuel in the float chamber and to the air stream in the carburetor venturi through the discharge nozzle, and the compensating jet opening into the float chamber and connected to the air stream in the venturi by means of the compensating nozzle.

b. The main jet flow varies with the changes in suction (vacuum) around the discharge nozzle (fig. 29) and delivers more fuel as the speed of the engine increases; thus the fuel mixture tends to become rich at top engine speed. The compensating nozzle, located well out of the center of the air stream, is not greatly affected by changes in suction caused by changes in engine speed so the fuel supply is relatively constant. This tends to create an insufficiency of fuel from this nozzle at top engine speeds. The action of the compensating nozzle offsets the excessive richness of the fuel mixture from the main jet and the combination results in the required average fuel charge at engine speeds between one quarter and three quarter throttle openings.

c. (1) The idling system (figs. 27 and 29) functions only when starting an engine and during low speed operation (up to about 20 miles per hour). This idling nozzle action is controlled and regulated by an idling adjustment screw in the air passage from behind the venturi, an idling jet (fuel passage from float chamber) and a throttle stop screw. The desired idling fuel supply is fixed by the size of the opening in the idling jet. To provide proper air-fuel mixture, the idling adjustment screw is used to vary the quantity of air. When a correct idling mixture is obtained, the throttle stop screw is then adjusted to provide the final desired idling speed.

(2) When the throttle is slightly open, a very strong suction (vacuum) is produced on the idling nozzle. The fuel drawn out of this nozzle passes over the edge of the throttle valve at high velocity

and is atomized. The high vacuum aids in vaporizing the fuel and mixing it with air. This gives the first few fuel charges needed for starting the engine. When the throttle is opened past the slow speed position (about 20 miles per hour), the idling system automatically goes out of operation and fuel is then supplied through the main and compensating jets.

d. (1) Wide open throttle, either for top speeds, accelerating or hard pulling, requires an increase in fuel delivery in addition to that supplied through the main jet. This increased fuel is provided by the accelerating piston assembly, the accelerating well and its valve, and the changes in suction developed during engine acceleration. (See fig. 30.)

(2) No adjustments, other than changing the size of the power and accelerating jet, can be made to the accelerating assembly.

(3) This accelerating piston assembly operates only when a sudden and heavy demand for additional power is made. When the throttle is partially closed, the vacuum above the throttle is high and holds the piston assembly in place at the top of the well against the spring pressure and no accelerating action takes place. As the throttle is opened wider, the vacuum in the suction passage decreases and the spring in the accelerating piston assembly pushes the piston downward in the well. The moving piston presses on the fuel in the well and creates a pressure. This pressure forces the check valve to its seat, preventing the fuel in the accelerating well from being forced back into the float chamber. As the piston goes down, it pushes open the compensating valve and fuel is forced into the venturi at the discharge nozzle from the power and accelerating jet. This provides the additional fuel required for acceleration. If the throttle valve is held wide open after the accelerating charge has passed into the venturi, the vacuum in the suction passage above this valve is still low and the accelerating piston will remain at the well bottom, holding the compensating valve open. Immediately after the fuel has left the accelerating well and passed into the venturi, the pressure on the check valve into the float chamber is relieved. It opens and fuel flows from the float chamber through the power and accelerating valve to the power and accelerating jet and out into the venturi. This jet then allows only enough additional fuel to enter the discharge nozzle to continue full power engine operation.

(4) When the throttle is partly closed, the vacuum in the suction passage increases and lifts the accelerating piston toward the top of

the well. When the moving piston clears the accelerating valve, the latter is closed by its spring and no fuel flows through it until the next accelerating charge is needed. At the same time, the upward movement of the piston draws fuel from the float chamber through the check valve into the accelerating well. The compensating valve (fig. 30) functions only when the suction above the throttle valve is low, which is from about three-quarter to wide open throttle. From starting, through idling, and up to about the three-quarter throttle opening, the fuel passes in sequence or in combination through the idling, compensating, and main jets. In the compound nozzle type carburetor, the idling system, the compensating and main jet, and the accelerating device are all coordinated to measure the correct fuel-air mixture at any engine speed or under any load condition.

e. (1) When starting a cold engine, it is necessary to provide an air-fuel mixture richer in fuel than that required by an engine at normal operating temperatures. The choke valve is used to cut off the air supply and increase the suction on the fuel nozzle. The choke valve plate is off-center with relation to the shaft, and the wider half has a spring controlled poppet valve, as shown in figure 35. When the choke valve is closed, as when starting a cold engine, very little air passes through the horn to mix with the fuel. As the engine increases in speed, more air is needed to mix with the fuel to keep the engine running smoothly. The attempts of the air in the carburetor horn to push past the choke valve and the partial vacuum on the other side cause the poppet valve to open despite the pull of the spring that tends to keep it closed. The open valve allows more air to pass through the carburetor, giving a leaner mixture and keeping the engine running smoothly. As the engine warms up, the choke valve should be opened by pushing in the control on the instrument panel. A (fig. 35 ①) shows a choke valve in the open position with the poppet valve closed, allowing air to flow through the main choke valve into the carburetor after the engine has started. B (fig. 35 ①) shows the choke valve in the closed position and the poppet valve in an open position. This device is usually known as a spring loaded choke valve.

(2) In another type of spring loaded choke valve, the valve plate is divided into two parts. One part is permanently fastened to the choke valve shaft and the other is hinged to the same shaft as shown in A (fig. 35 ②). These two parts are connected by a spring.

When the choke valve is in the closed position, the unequal pressure due to the vacuum on one side pushes the hinged half inward against the spring pressure allowing more air to pass.

(3) Spring loaded chokes operate only when the carburetor choke valve is closed. Although a greater proportion of fuel is added to the air-fuel mixture during the period the choke valve is closed, the spring loaded device aids in minimizing crankcase dilution and avoiding excessively rich mixtures during warm-up periods by increasing the quantity of air passing through the carburetor.

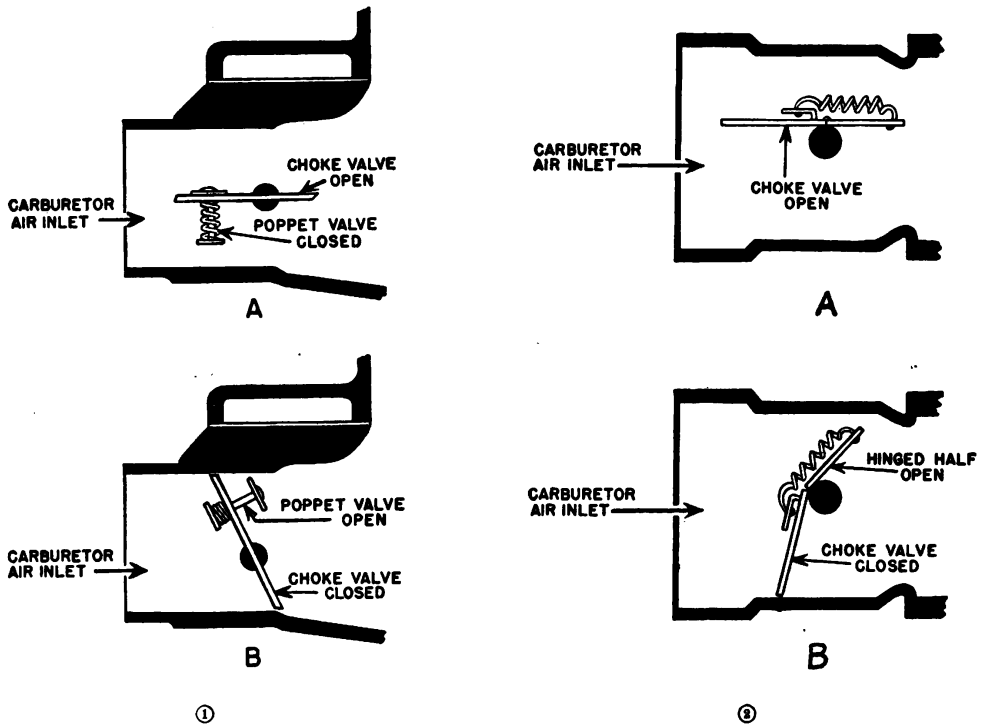


FIGURE 35.—Two common types of spring loaded choke valves.

45. **Combination plain tube and air bleed type.**—*a.* The plain tube and air bleed system is used in all Stromberg carburetors. Before describing its operation, the principles of the air bleed must be understood.

b. (1) In a plain tube elementary carburetor (fig. 36), the correct fuel supply is maintained by the jet. A venturi is placed over the nozzle of the plain tube (jet) that receives fuel from a simple carbu-

retor float chamber. When the engine is in operation, the action of its pistons produces suction on the nozzle. Particles of fuel are drawn from this nozzle into the venturi tube (fig. 36). Such an arrangement gives fairly satisfactory operation at a vehicle speed of about 16 miles per hour. However, the mixture becomes so lean at a lower speed that the engine slows down and stops due to lack of suction in the venturi.

(2) If it is desired to have the engine operate at a speed of 10 miles per hour, the size of the fuel jet must be materially increased. However, this enlarged jet would increase the fuel delivered at speeds over 16 miles per hour, giving too rich a mixture for satisfactory

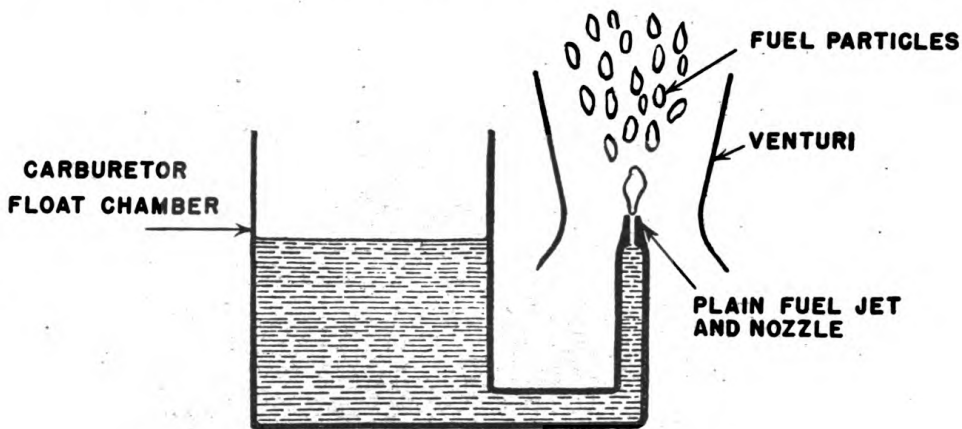


FIGURE 36.—Plain tube elementary carburetor.

operation. In addition, the engine would not idle properly no matter what size opening was used, because the suction on the nozzle at extremely low speed would be so weak that fuel would not be lifted into the mixing chamber.

c. To prevent the fuel in any carburetor float chamber from overflowing at the nozzle, it is necessary to design the float and needle valve so that the fuel level will always be slightly below the nozzle tip. Consequently, considerable vacuum (suction) is required to lift the fuel from the nozzle into the mixing chamber. At low engine speeds, the fuel is likely to come out of the nozzle in large drops and not atomize properly (fig. 36).

d. (1) To help break the fuel into smaller particles as they leave the nozzle, the air bleed principle is used in plain tube air bleed carburetors. This principle is illustrated in figure 39. As the

liquid is sucked into the tube, shown at A (fig. 37), it is drawn up in a solid column free of air. If a small opening is placed in the tube above the level of the liquid, as shown at B (fig. 37), air bubbles will enter the tube and the liquid will be drawn upward in a continuous series of large drops with air spaces between them. At C (fig. 37) which illustrates the air bleed principle, an air bleed tube with one end open to the air has been set into the main tube at a point below the surface of the liquid. Suction on the main tube now introduces a considerable quantity of air along with the liquid. The constriction in the lower end of the main tube makes the air

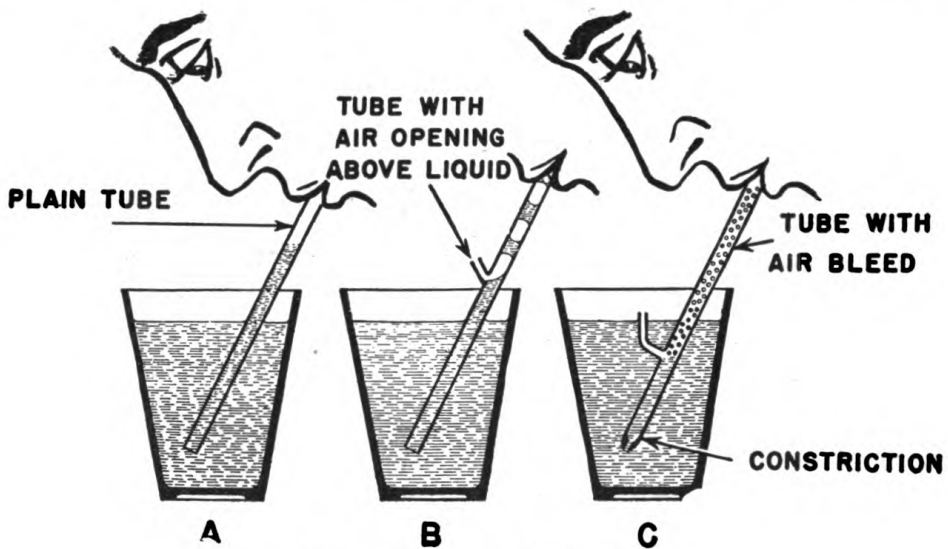


FIGURE 37.—Air bleed principle.

bleed opening larger, so that the liquid will be more completely broken up and mixed with the air as it is drawn upward. A very fine balance of the two openings must be maintained when the air bleed principle is applied to a carburetor.

(2) The arrangement C (fig. 37), when incorporated in a carburetor jet, usually takes a form similar to that shown in figure 38, in which the air bleed is located in the plain tube. This type of fuel jet will give a relatively uniform mixture at ordinary engine speeds.

e. (1) Since the suction at the nozzle would not be sufficient to maintain full engine power, a venturi is placed around the nozzle to increase the suction.

(2) In all plain tube air bleed carburetors, the advantage gained by using a single venturi (fig. 38) can be increased by using a double venturi (fig. 39).

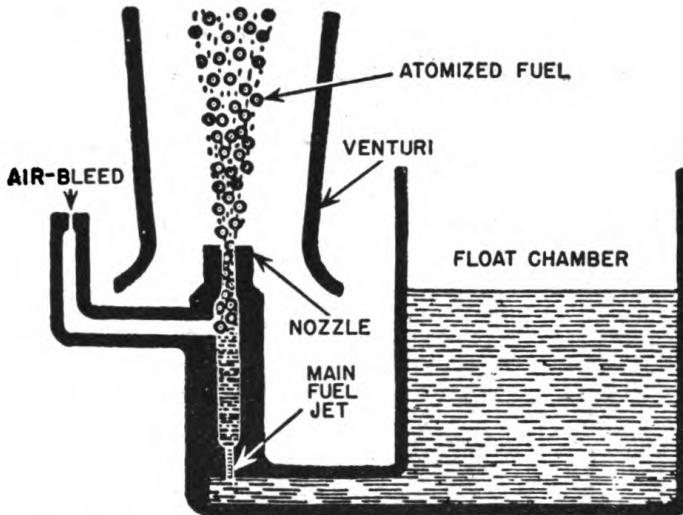


FIGURE 38.—Air bleed principle with single venturi.

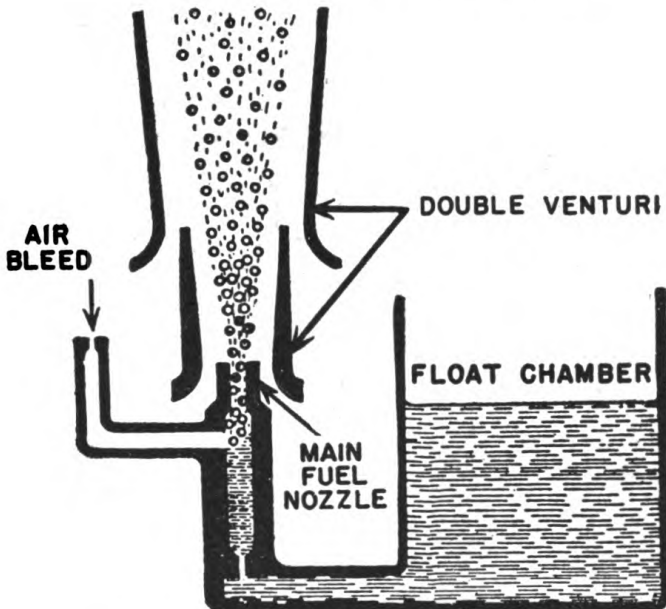


FIGURE 39.—Air bleed principle with double venturi.

f. (1) Some types of plain tube air bleed carburetors have a variable air bleed opening entering the discharge nozzle as shown in figure 40, while others have a fixed air bleed opening.

(2) A needle valve raised and lowered by the throttle lever regulates the quantity of air passing into the air bleed tube. When the throttle is in closed position, the needle valve is raised from the tube, as shown in figure 40 ①, allowing an increased quantity of air to pass into the tube. When the throttle is wide open, the needle valve is seated and air can pass only through the very small hole drilled from the side and through the point of the needle valve as shown in figure 40 ②. This enriches the mixture during wide open throttle for hard pulling or for high speed.

(3) The idling system of this carburetor and its principles of operation are essentially the same as that described in paragraph 35.

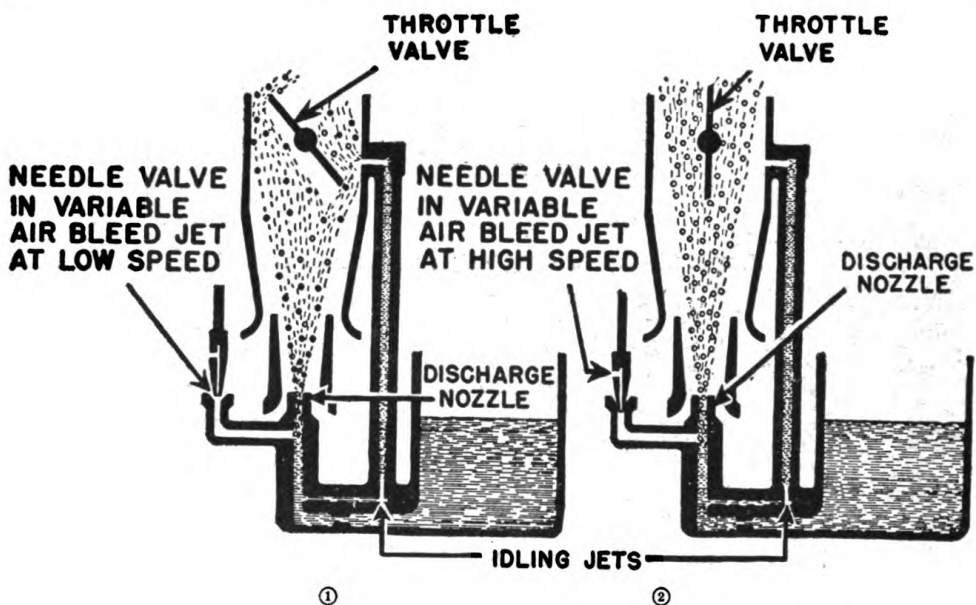


FIGURE 40.—Variable air bleed used with a plain tube double venturi carburetor.

g. (1) The Stromberg model "SF" carburetor (fig. 41) is a plain tube air bleed updraft type designed for heavy duty engines. It contains a double venturi; a fixed high speed air bleed entering the main discharge nozzle, an idling system; a vacuum controlled compensating valve for open throttle operation and an accelerating device.

(2) The idling and low speed system is controlled the same as the one described in paragraph 35.

(3) The intermediate speed and high speed fuel mixture is controlled by the fixed main discharge jet and the vacuum operated compensating valve. The main discharge jet may be replaced by another

having an adjustable screw type needle valve which gives finer adjustments; this needle valve may be regulated from the outside of the carburetor. The main fuel jet supplies fuel up to about three-quarter open throttle. As the throttle is opened wider, the accelerating device functions and adds the necessary additional fuel for immediate acceleration. After this accelerating charge has entered the mixing chamber, the low vacuum created by the throttle valve opening actuates a piston which opens a compensating valve allowing the additional fuel required for continued high speed (wide open throttle) to flow out of the main discharge nozzle.

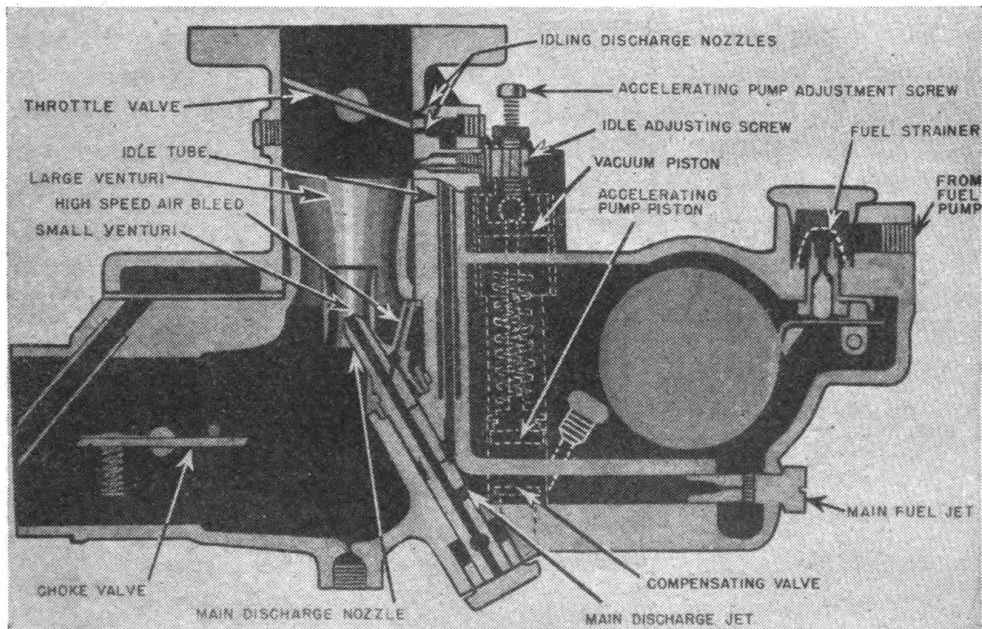


FIGURE 41.—Sectional view of an air bleed, updraft, heavy duty type carburetor.

(4) The accelerating pumps in these carburetors are of two types. The carburetor shown in figure 41 has a vacuum operated pump, and the type operated by a linkage connected to the throttle lever is shown in figure 42.

(a) The vacuum operated accelerating pump (fig. 41) is similar to that described in paragraph 44c.

(b) The accelerating pump, operated by a linkage connected to the throttle lever, delivers additional fuel to the main jet when the throttle is suddenly opened during accelerating periods. It consists of a cylinder with its upper end closed as shown in figure 42. This cylinder is forced downward as the throttle is opened. Within the cylinder is a piston riding on a spring which slides up and down on a stationary

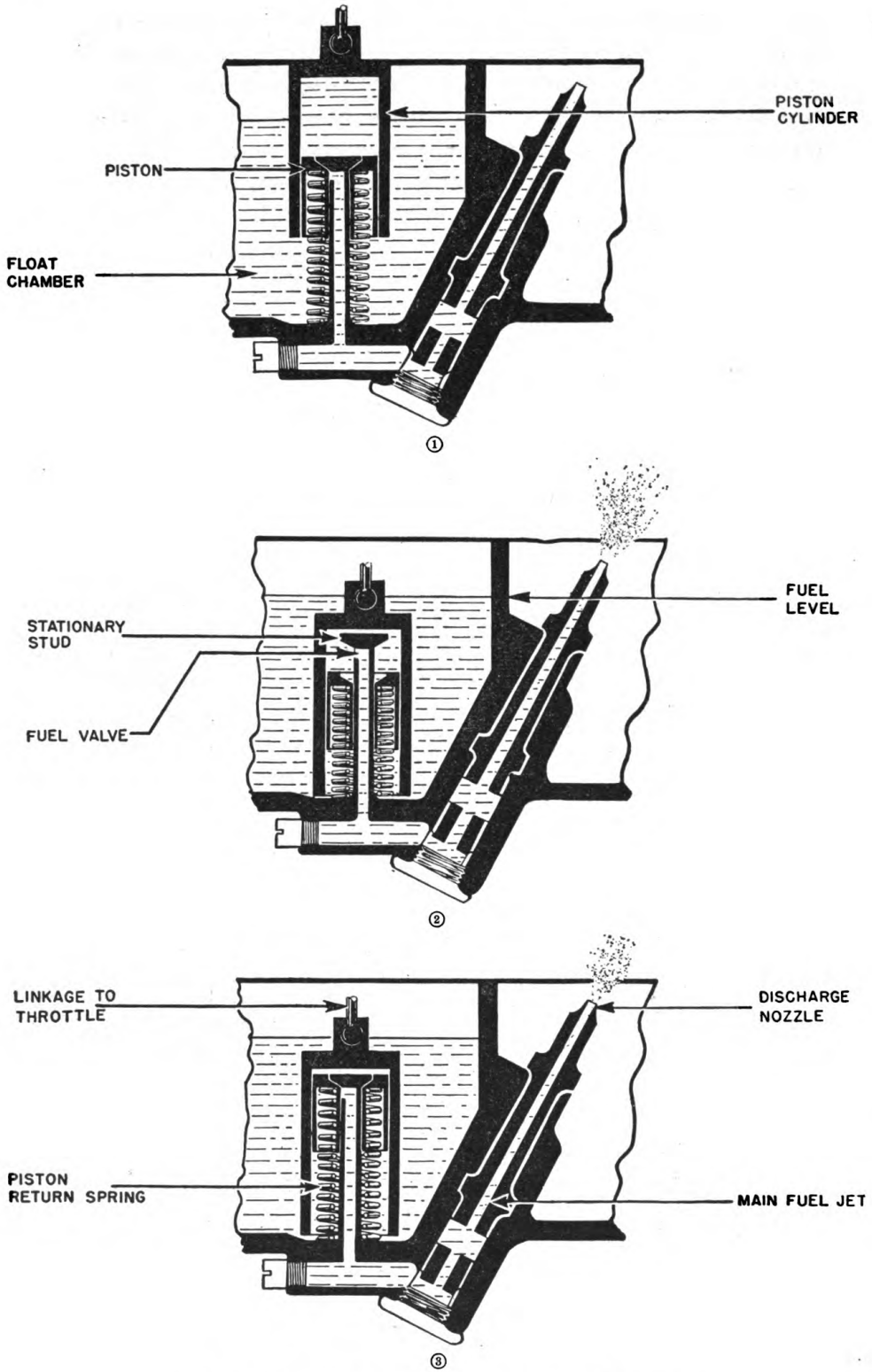


FIGURE 42.—Linkage controlled accelerating pump.

stud. When the throttle is almost closed, the piston is seated against the upper end of the stud as shown in figure 42 ①. This closes the fuel valve through the vertical stud to the main fuel jet. When the throttle is opened, the pump cylinder is immediately pushed down. At the same time, the fuel trapped above the piston forces it downward against the spring pressure and a quick spurt of fuel is delivered through the stud valve to the main jet as shown in figure 42 ②. As the throttle is held in this wide open position, the spring slowly lifts the piston and a gradual flow of fuel continues until the space above the piston is empty. When the throttle valve has been closed to about three-quarter opening, the piston in the cylinder has reached the top. From three-quarter to wide open throttle, the required extra fuel is drawn directly from the float chamber through a compensating valve such as shown in figure 30. As the throttle is closed, the accelerating pump cylinder is drawn upward, the valve in the vertical stud is closed by the rising piston as shown in figure 42 ③, and fuel from the float chamber enters the cylinder between its inside wall and the piston. This provides the fuel charge for the next accelerating period.

46. Mechanical metering rod system.—*a. General.*—This system, illustrated by the downdraft Carter carburetor (fig. 43), uses the metering rod principle of carburetion. In addition to a metering rod, it has some special features such as a triple venturi, automatic choke built into the carburetor, automatic fast idle, antipercolating device, and slow-closing throttle device.

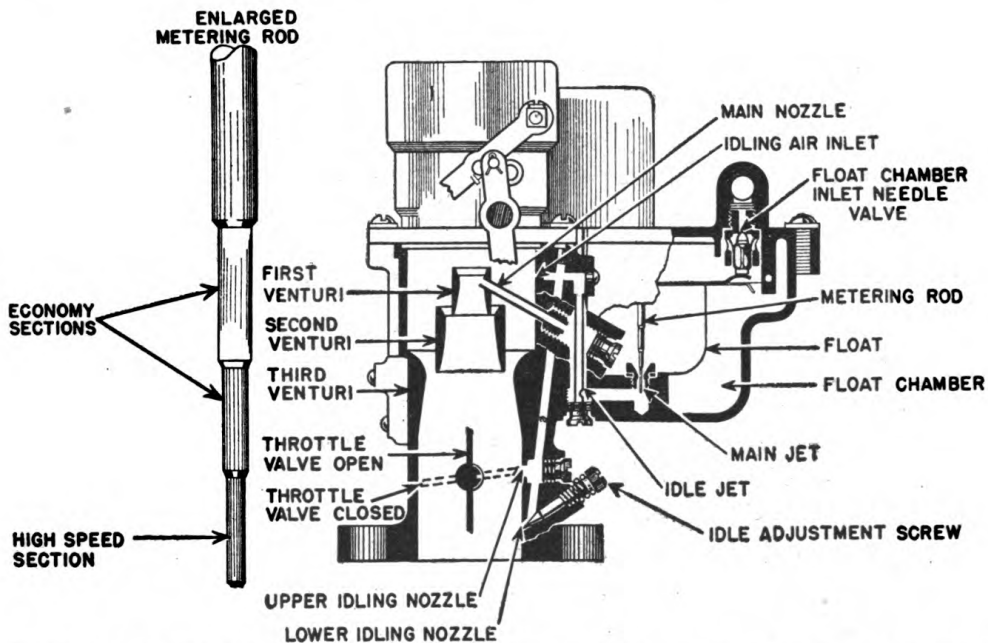


FIGURE 43.—Sectional view of mechanically controlled metering rod type carburetor.

b. Carburetor operation.—(1) Closing the throttle lowers the metering rod and the economy sections are lowered into the main jet, reducing the flow of fuel for the lower ranges of speed and power. The smallest or high speed sections offer less restriction to the flow of fuel from the main jet, giving a rich mixture for acceleration and hill climbing. Figure 43 shows an enlarged metering rod with these various sections. The position of the metering rod with respect to the throttle opening is important. If the metering rod does not change from one section to the other at the correct throttle opening, it will cause poor gasoline mileage, poor performance, and “flat spots” in acceleration.

(2) The mouth of the main nozzle and the top of the idle jet are slightly higher than the normal level of fuel in the float chamber so that fuel will stand near the end of the nozzle but will not run out.

c. Low speed operation.—(1) When the engine is cranked with the throttle in the closed (idle) position, shown by the dotted lines in figure 43, a vacuum is created below the throttle. This permits only a small amount of air under atmospheric pressure to move past the edge of the throttle. However, the air passes the main nozzle in the first venturi in such small quantities that it does not have enough velocity to pick up any fuel.

(2) The vacuum below the closed throttle valve, however, draws air through the idling air inlet and down through the idling air passage. This air picks up fuel from the idling jet and the air-fuel mixture is delivered to the mixing chamber by the upper idling nozzle near the throttle valve and by the lower idling nozzle just below the closed throttle valve. The richness of the mixture is determined by the setting of the idle adjustment screw located in the lower idling nozzle.

(3) Opening the throttle increases the quantity of air and exposes more of the upper idling nozzle, allowing more fuel mixture to enter the mixing chamber. This provides for increased engine speed.

(4) As the throttle valve is opened still farther, the quantity and velocity of air passing it increases. The air passing the main nozzle now draws fuel from it which is carried through the three venturis.

(5) Further opening of the throttle causes the vacuum to extend upward so that the difference in vacuum between the idling air inlet and the idling nozzles is equalized and the flow of air and fuel through the idling system ceases. At speeds above 20 miles per hour, no fuel mixture is supplied through the idling passage. The idling system, therefore, has no effect on performance or fuel consumption at speeds above 20 miles per hour.

d. High speed operation.—Fuel flows from the main nozzle at speeds greater than about one-quarter throttle opening. It is atomized in the first venturi (fig. 43) and kept in the center of the air stream by the surrounding blanket of air passing into the second and third venturis. This air blanket, in addition to increasing the vacuum in the first venturi, prevents liquid fuel from coming in contact with the walls of the carburetor where it is hard to atomize. This minimizes the possibility of liquid fuel being drawn into the intake manifold.

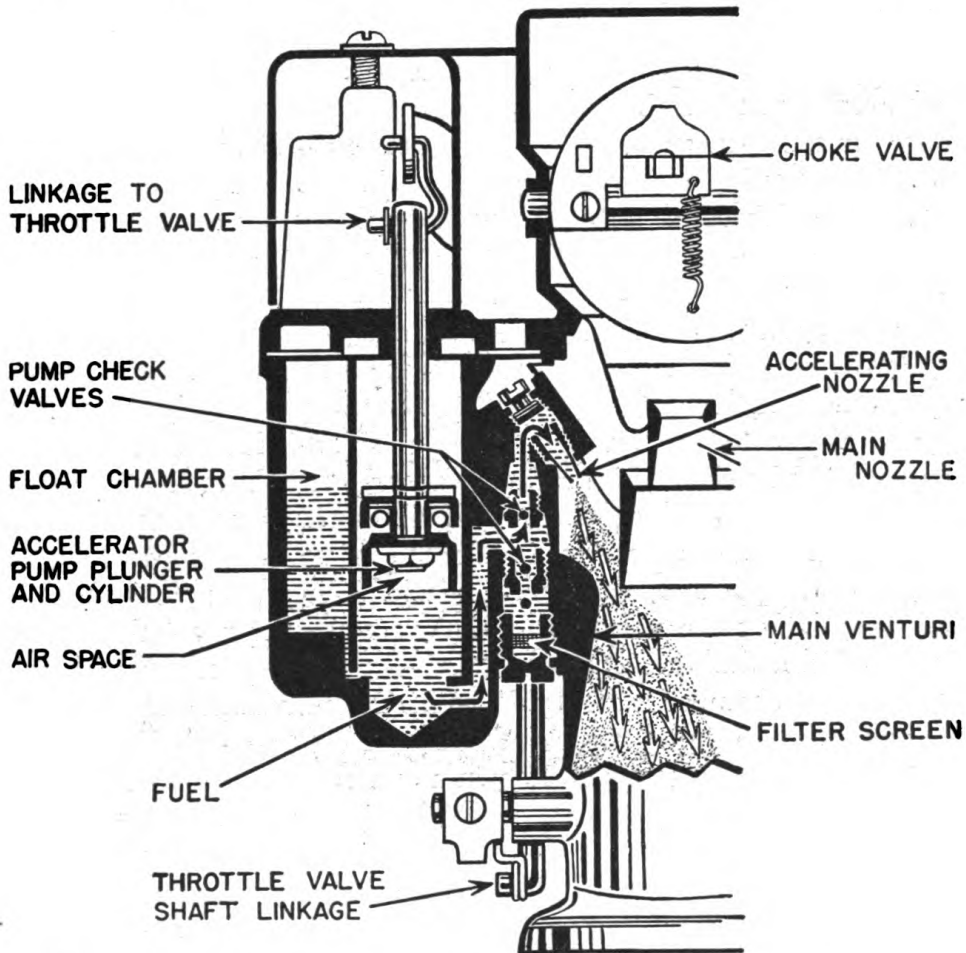


FIGURE 44.—Accelerating pump mechanism in a metering rod type carburetor.

e. Accelerating pump.—(1) The quantity of fuel available through the main jet is not sufficient for rapid acceleration, so an accelerating pump, controlled by a lever linked to the throttle valve, is used to force extra fuel out of the accelerating nozzle into the main venturi when the accelerator is depressed rapidly. Figure 44 shows a sectional view of an accelerating pump.

(2) As the throttle is closed, it pulls the plunger (piston) upward, drawing fuel out of the float chamber through a filter screen, through an inlet ball check valve, and into the pump cylinder.

(3) The opening of the throttle moves the plunger downward, compressing the air, and causing an immediate discharge of fuel past the upper pump ball check valve and through the accelerating nozzle which points downward into the large venturi. When the throttle is fully opened, the discharge is continued for a number of seconds by the compressed air in the space between the plunger and the fuel.

(4) An air space always remains between the fuel in the cylinder and the plunger. When the pump is not delivering fuel, a ball check valve arrangement in the upper passage above the accelerating nozzle allows air to be drawn from the top of the float chamber. This prevents a vacuum in the pump passages so that no fuel can be delivered from the accelerating pump jet except by the action of the accelerating pump.

f. Antipercolating device.—(1) While a vehicle is being driven, the carburetor is kept cool by the large volume of air passing through it and by the heat absorbed during atomization and vaporization of the fuel. When the engine is stopped, the cooling system is not able to carry off the heat stored in the engine parts and it is radiated into the air under the hood. The carburetor absorbs this heat so that in hot weather or after hard driving, the fuel in the float chamber often becomes hot. The vapor from the hot fuel rises in bubbles which are trapped in the passage to the main nozzle. They push fuel ahead of them and out of the nozzle into the venturi. As the bubbles continue to form, the fuel that is forced out collects in the manifold until the float chamber is empty. The flooded manifold makes restarting the engine difficult.

(2) To prevent this action, known as percolation, an antipercolating valve controlled by the throttle (fig. 45) is incorporated in the carburetor. With the throttle closed, the antipercolating valve opens a vent connected directly to the passage between the main jet and nozzle which carries off any vapor bubbles that may form in the float chamber.

g. Slow closing throttle.—(1) When driving at high speeds with wide open throttle, there is a rapid flow of fuel through the carburetor. If the throttle is suddenly closed, cutting off the flow of air to the engine, the inertia of the fuel will make it continue flowing. This will momentarily result in a rich mixture which may cause the engine to run unevenly or possibly stall. By preventing the throttle from closing rapidly when pressure is released from the accelerator pedal, this rich mixture may be avoided.

(2) Slow closing of the throttle is accomplished by a slow closing plunger (fig. 46) connected to the throttle lever. When the accelerator pedal is released, the throttle spring attempts to close the throttle valve. However, the ball check valve in the slow closing throttle plunger goes to its seat and the speed with which the throttle valve closes is retarded because the fuel below the plunger can escape only through the single small hole in the plunger stem below the check valve.

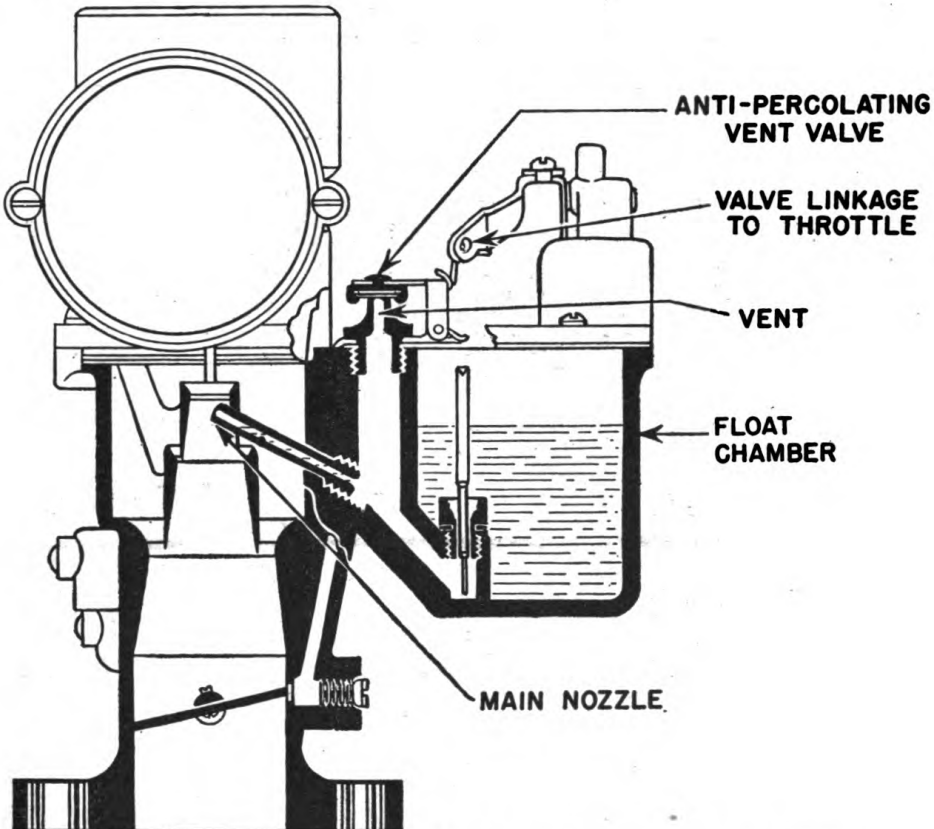


FIGURE 45.—Antipercolating device in a metering rod type carburetor.

h. Automatic choke.—(1) The automatic choke, sometimes called the climatic control, is an integral part of the carburetor and consists primarily of two major assemblies: a bimetal thermostatic coil spring and a piston plate housing, as shown in figure 47. The thermostatic coil assembly consists of cover, insulators, and a bimetal thermostatic coil spring. The housing assembly consists of the piston plate housing, choke shaft lever, screen, and piston.

(2) The operation of the automatic choke depends on intake manifold vacuum and exhaust manifold heat. On starting a cold engine, the thermostatic coil holds the choke valve closed. As the engine starts, the vacuum created in the intake manifold tends to pull the piston down, exerting tension on the thermostatic coil and opening the choke valve far enough for initial running. Hot air is drawn from the heater on the exhaust manifold and through the filter screen

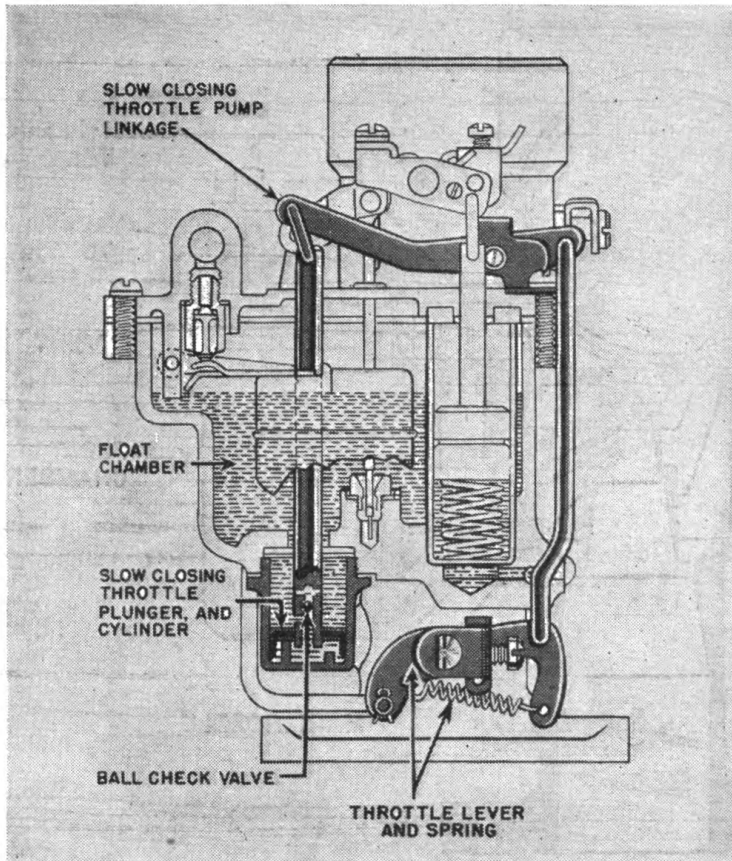


FIGURE 46.—Slow closing throttle device in a metering rod type carburetor.

into the housing and around the piston to the intake manifold. As the thermostatic coil is heated by engine operation, it loses its tension and allows the choke valve to open gradually.

(3) After the choke reaches full open position it is held open by the action of the intake manifold vacuum on the piston. When the engine is stopped the thermostatic coil cools and closes the choke valve. The choke valve is fully closed at a temperature of about 70° F.

i. Slow and fast idle.—When the choke valve is closed by the automatic choke, a fast idle bar (fig. 47) falls behind the throttle adjusting screw and holds the throttle valve open to give an idle speed of approximately 15 miles per hour. This gives the correct throttle valve opening for starting and prevents the engine stalling during the warm-up period. As the engine becomes warm and the choke valve opens, the fast idle bar is raised so that the throttle can close to its normal idle position.

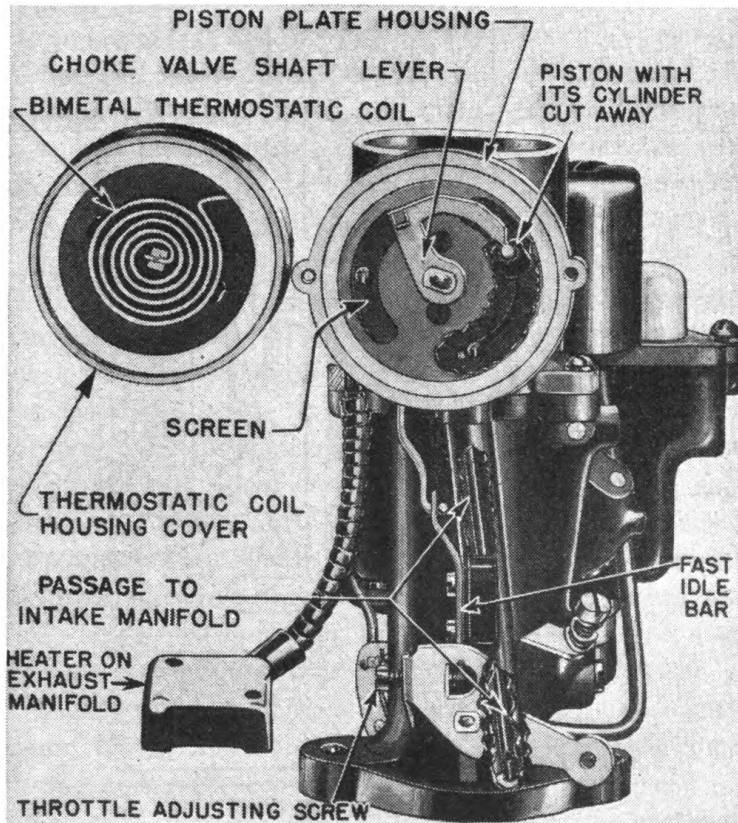


FIGURE 47.—An automatic choke mechanism built into a metering rod type carburetor.

47. Mechanical air valve, high vacuum system.—*a.* This system, illustrated by the downdraft Mallory carburetor (fig. 48), has but one fuel jet which functions as the idling jet, the part throttle jet, and the full power jet. There are no air bleeds, compensating jets, idle jets, or bypasses. The combined air valve and choke is both vacuum and mechanically operated. The metering rod, the air valve, and the throttle valve are synchronized with the foot accelerator pedal.

b. Carburetor operation.—When idling, the throttle valve, air valve, and metering rod are nearly closed (fig. 48). The vacuum between the throttle valve and the air valve and around the nozzle produces a high suction of about 1/2 pound per square inch, giving better atomization of the fuel and increased vaporization. As the throttle valve is progressively opened, the air valve and metering rod are also opened. The air flow, fuel flow, and vacuum (suction) all increase at the same time and at each speed automatically operate

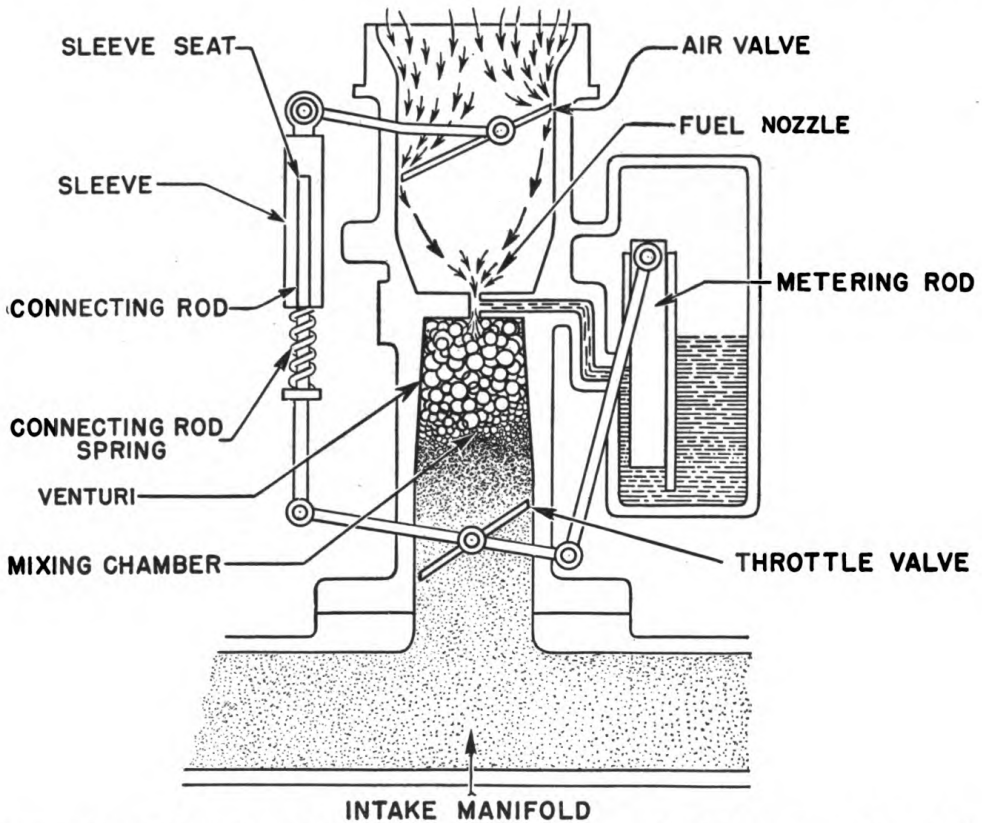


FIGURE 48.—Section through body of a mechanical air valve, high vacuum, downdraft carburetor.

together to maintain the proper ratio of air to fuel. The air valve is attached by an arm to the sleeve that encloses the connecting rod. The rod is linked to the throttle valve. Suction in the mixing chamber pulls the air valve open and keeps the spring on the connecting rod compressed. The spring has no effect on the air valve, except on part throttle openings and warm-up periods. Under these conditions, there is a slight drop in vacuum in the mixing chamber which reduces the pull on the air valve. The spring then tends to close the air valve, which increases the vacuum and slightly enriches the

mixture. After the engine is warm, the vacuum will completely compress the spring and the operation will be the same as if the spring were eliminated or as if the air valve and throttle valve were rigidly connected.

c. Suction.—(1) In all carburetors, the suction or vacuum is maintained as high as possible. In some carburetors, this suction is controlled by spring loaded air valves, but not in the mechanical air valve high vacuum system. With spring loaded air valves, the suction is practically zero at engine speeds up to 15 miles per hour. Idling sections are used and are relied upon to run the engine up to about 20 miles per hour before the suction is high enough to cause fuel to flow from the main or power nozzle. When there is an idling section, there is a lapse of time or “cross-over” from the idle section to the main jet which tends to cause a “flat spot” when accelerating. That is, when the fuel supply is shut off in the idling jet, a short period of time elapses before fuel starts to flow from the main jet.

(2) Due to the high suction of about $\frac{1}{2}$ pound per square inch in the mixing chamber of a mechanical air valve, high vacuum carburetor at low and idling speeds, the correct fuel mixture is supplied to the engine without using an idling or slow speed device. As the throttle valve and the air valve are opened progressively, the “still” suction in the mixing chamber blends into a “moving” suction due to the increase of air flow through the venturi. This gives increased suction or vacuum for all throttle positions. If the throttle valve is suddenly opened wide for full power, the air valve opens wide and the full sucking action of the engine is thrown on the venturi, developing a higher vacuum or suction for acceleration.

48. Adjustments.—*a.* All carburetor adjustments, cleaning, and repairs should be made whenever possible by an experienced carburetor mechanic using the correct tools.

b. It sometimes happens that faults not in the carburetor have an effect on engine performance and indicate that the carburetor needs adjustment or repair. These faults may be due to low intake manifold vacuum, low compression, leaky carburetor and manifold flange gaskets, loose intake manifold bolts, incorrect gap on the spark plugs, incorrect gap or pitted breaker points, incorrect ignition timing, or poor action of engine valves. Before removing or adjusting any part of the carburetor, the above should be checked and corrected if necessary.

c. Carburetor tools, gages, and test equipment should be used in making carburetor adjustments and repairs. Special jet wrenches for removing and installing jets are preferable to the ordinary

screw driver bit, which is likely to chip or distort jet slots and openings. Proper gages should be used in adjusting float levels and metering rods to insure correct settings. Exhaust gas analyzers and manifold vacuum gages are often helpful in adjusting carburetors. These analyzers indicate the completeness of combustion by registering the amount of carbon monoxide gas present in the exhaust gases. The dial of the instrument may be calibrated in air-fuel ratio or in percentage of combustion. The manifold vacuum gage indicates when the vacuum is constant and the amount of vacuum.

d. (1) Modern carburetors usually have six principal adjustments. The first adjustment is the idle needle valve screw, referred to as the idle or slow speed adjusting screw. This controls the ratio of the fuel-air mixture for idling and slow speeds up to about 20 miles per hour. The second is the throttle valve stop screw which usually controls the idling speed of the engine. The third adjustment is the high speed main jet which controls the ratio of the fuel-air mixture during cruising or high speed operation. In some carburetors, this adjustment is made by an adjustable screw or needle valve, in others it is made by changing to a larger or smaller main jet or a richer or leaner metering rod. The fourth adjustment, usually made to some part of the automatic choke mechanism, provides for a greater or lesser amount of choking effect when starting the engine. The fifth adjustment usually requires correction of the distance of accelerating pump travel to produce the proper amount of fuel required for acceleration and to time its movement to meet the sudden demand incident to such acceleration. The sixth adjustment is that of float level which regulates and controls the movement of fuel from the fuel pump into the carburetor float chamber.

(2) Other minor but no less important adjustments include bending levers or lengthening and shortening control rods to regulate the action of float valves, metering rods, accelerator pumps, and similar parts.

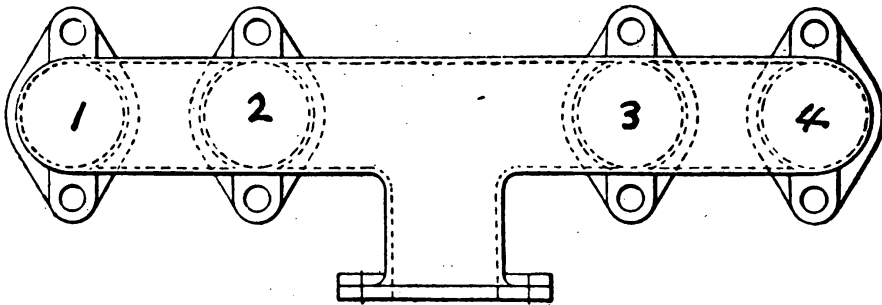
SECTION VII

INTAKE AND EXHAUST SYSTEMS

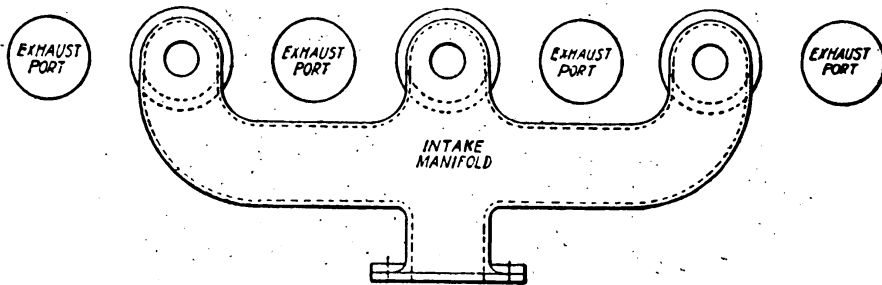
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49. General.—Intake manifolds are usually separate from the exhaust manifolds. Figure 49 shows intake manifolds for a four- and six-cylinder engine.

50. Intake manifolds.—*a.* This is the passage or system of passages which conducts the fuel mixture from the carburetor to the intake valves of the engine. Manifold design has a great deal to do with the efficient operation of the internal combustion engine. For smooth and even operation, the fuel charge taken into each cylinder should be of the same strength and quality. The distribution of fuel to a cylinder should, therefore, be as even as possible. This depends greatly on the design of the intake manifold. Dry fuel vapor is the ideal form of fuel charge but present day fuel prevents this unless the mixture is subjected to high temperature. If the fuel charge is



① Four-cylinder intake manifold with one branch for each cylinder.



② Six-cylinder intake manifold with one branch for each two cylinders.

FIGURE 49.—Four- and six-cylinder engine intake manifolds.

heated too highly, the power of the engine is reduced because the heat expands the fuel charge. Therefore it is better to have some of the fuel deposited on the walls of the cylinders and manifold passages. Manifolds in modern engines are designed so that the amount of fuel condensing on the intake manifold walls is reduced to a minimum.

b. The inside of the intake manifold should be smooth and the passages should be large enough not to obstruct the flow of the fuel mixture. The bends or curves in the manifold should be designed so that a minimum amount of fuel will be condensed on the walls of the

manifold. A manifold with a flat bottom can be more easily heated than one with a round bottom, and it permits quicker vaporization of fuel that has condensed on its walls. This applies to all manifolds whether for four, six, or more cylinders.

c. Intake and exhaust manifolds are usually fitted closely together so that considerable heat is transmitted from the exhaust to the intake manifold to help vaporize the fuel. In some types, the two are bolted together with a gasket between them so exhaust gases will pass through a chamber around the intake manifold and heat it.

d. *Four-cylinder intake manifold.*—Firing order and valve timing influence the design of the intake manifold. When two cylinders next to each other in the same cylinder block or bank fire imme-

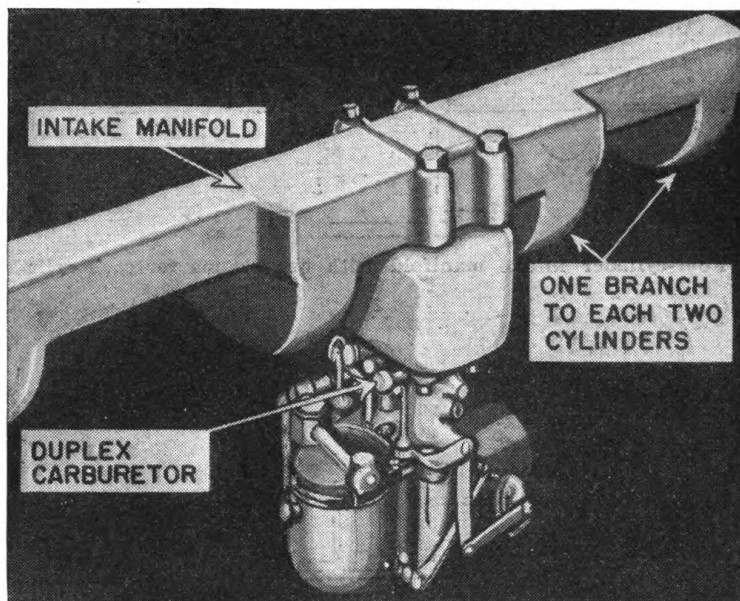


FIGURE 50.—Intake manifold and duplex carburetor for an eight-cylinder "in line" engine.

diately after each other, the second intake valve opens a little before the first intake valve closes. The fuel supply to the first cylinder may be diverted by the suction of the second cylinder. (See fig. 49 ①.)

e. *Six-cylinder intake manifold.*—The design of a six-cylinder intake manifold (fig 49 ②) is also governed by the firing order of the engine. In most six-cylinder engines, the intake valve and ports are designed so that two intake valves draw their charge from the same manifold branch. Usually the most desirable six-cylinder manifold arrangement is one in which there is alternate suction coming from opposite ends of the engine.

f. Figure 50 shows an intake manifold design used in an eight-cylinder "in line" engine fitted with a duplex carburetor. It will be noted that there are four connections running to the engine. Each is designed to supply two cylinders.

g. In most manifolds, round bends (fig. 51) have been used because it was thought that abrupt turns prevented the easy flow of the fuel vapor. However, a manifold with square bends (fig. 52) has been successfully used on some engines. This manifold has a flat floor and all fuel passages are shaped exactly alike. It is claimed that the abrupt turns tend to direct the fuel mixture in a

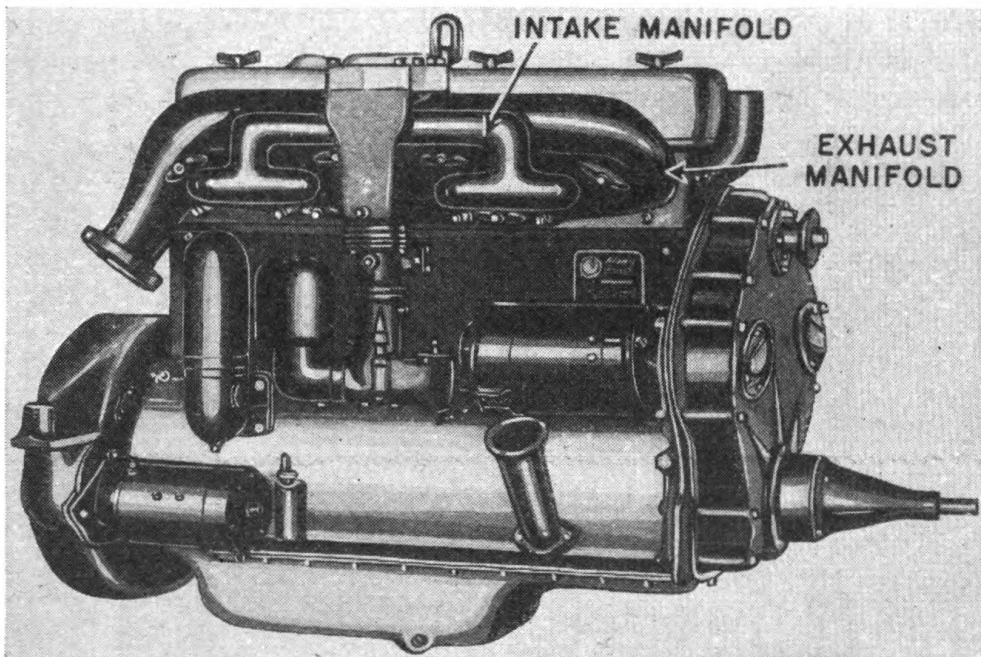


FIGURE 51.—Separately cast intake and exhaust manifolds for six-cylinder engine. (Note round section and smooth curves at corners.)

straight line. The turbulence set up by the abrupt turns helps to keep the particles of fuel in suspension at all times. Any particles of fuel that accumulate on the roof of the manifold tend to drop straight down and fall into the fuel stream rather than run down the sides. The square section gives a greater surface area for the evaporation of condensed fuel that might accumulate there.

h. *Hot spots.*—(1) It is very desirable to place the carburetor close to the cylinders so that there will not be a great deal of condensation in the lower part of the intake manifold. With an up-draft carburetor, a long connection between it and the manifold is necessary and a great deal of the condensed fuel drains back into

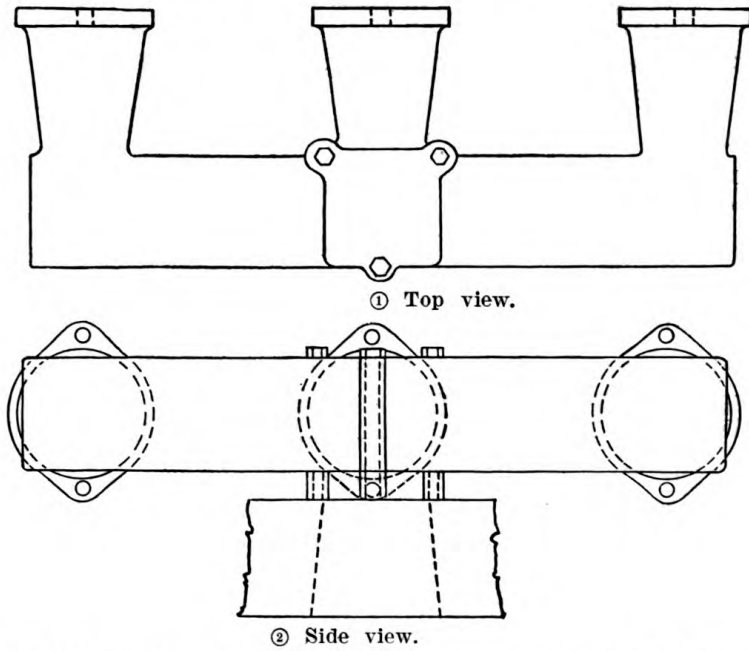


FIGURE 52.—Six-cylinder intake manifold having a square section and square corners.

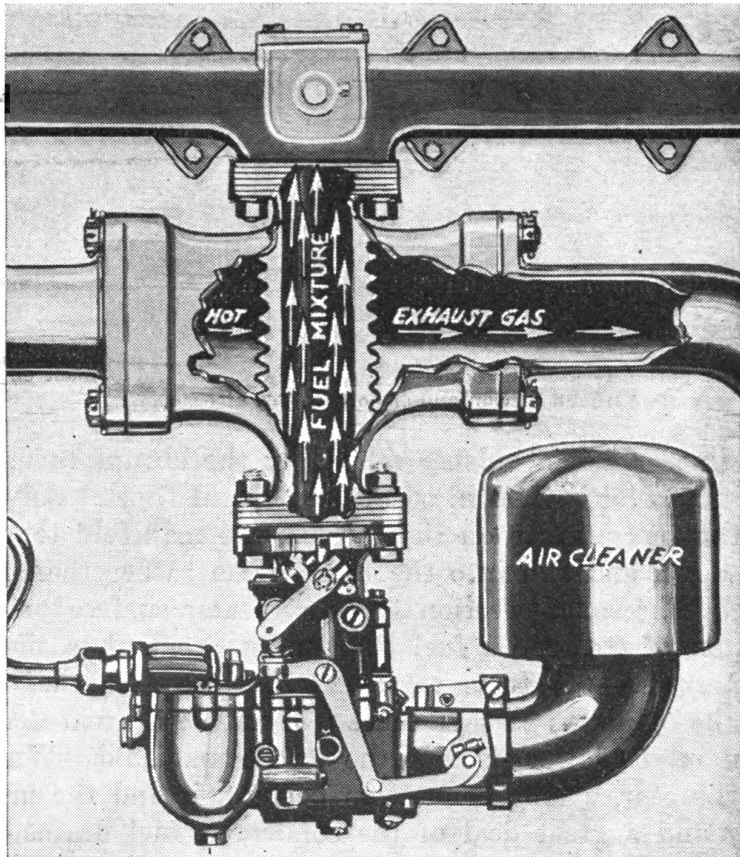


FIGURE 53.—Carburetor with "hot spot" or heated intake manifold.

the carburetor. The "hot spot" manifold was designed to overcome this. (See fig. 53.)

(2) The intake manifold is constructed so that a portion of it, which is in constant contact with the exhaust manifold, becomes heated. This "hot spot" is so located that all fuel must pass it before entering the cylinders. Any unvaporized particles remaining in the fuel mixture are thrown against the highly heated surfaces and vaporized instead of being carried into the engine cylinders as liquid fuel in small drops.

(3) Some engines having "hot spots" or exhaust heaters around the intake manifold are fitted with a thermostatically controlled valve in the exhaust manifold. This valve is open while the engine is cold, allowing the exhaust gases to pass around the intake manifold. As the engine becomes warm, the thermostatically operated valve par-

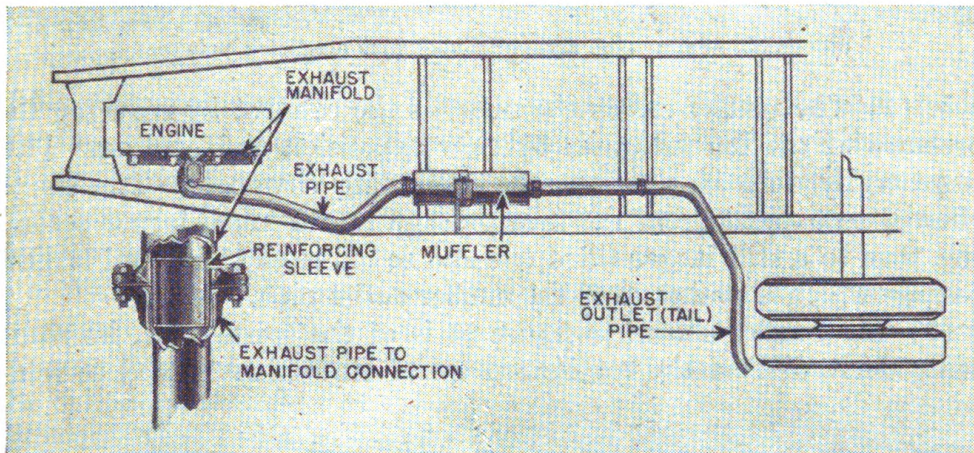


FIGURE 54.—Diagram of an exhaust system.

tially closes the exhaust gas passage to the intake manifold "hot spot" and most of the exhaust gases pass out through the exhaust manifold. This prevents excessive temperatures at the "hot spot" point.

51. Exhaust system.—*a.* (1) This system consists of an exhaust manifold, exhaust pipe, muffler, and muffler outlet (tail) pipe (fig. 54). The burned gases from the engine are conducted to the muffler and from there they are led by the muffler outlet pipe to the atmosphere.

(2) Sharp bends in the exhaust manifold and exhaust pipe should be eliminated because they cause back pressure. The exhaust manifold should offer the least possible resistance to the burned gases passing from the exhaust ports, otherwise part of the burned gases

remains in the cylinder and mixes with the fresh fuel mixture drawn into the cylinder.

(3) In multiple cylinder engines, the piston strokes overlap. At certain events of the cycle, two cylinders exhaust at the same time and the manifold and the exhaust pipe are designed large enough to care for the exhaust from both cylinders without too much resistance.

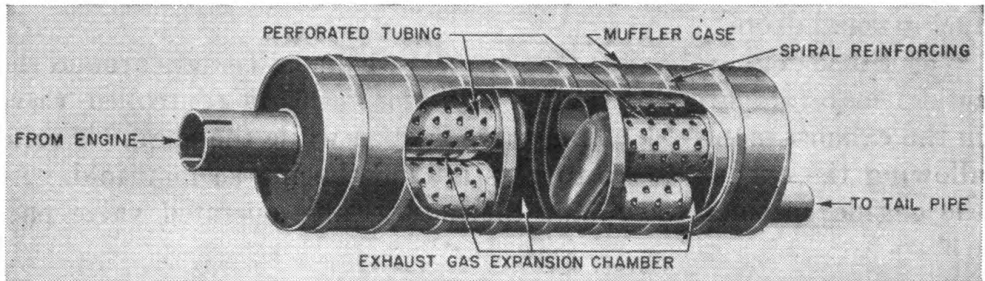


FIGURE 55.—Spiral type exhaust muffler with expansion chambers.

b. (1) The muffler quiets the noise of the exhaust by reducing the pressure of the burned gases by slow expansion and cooling. This is generally done in a number of expanding chambers. The gas is allowed to expand from the first passage into a much larger second one, then to a still larger third one and so on, to the final and largest passage which is connected to the muffler outlet pipe.

(2) The muffler shown in figure 55 is of the spiral type, its name being derived from the continuous spiral rib which is used to rein-

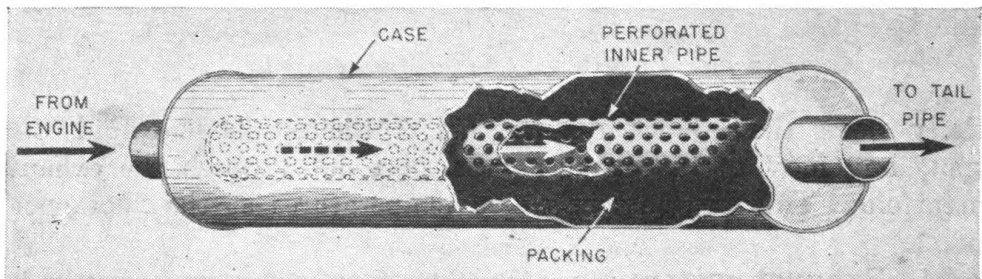


FIGURE 56.—Straight through type exhaust muffler.

force the outside case. The expansion chamber is designed so that the small perforations will give a "scooping" action to the incoming exhaust stream, deflecting it into a series of chambers where it is allowed to expand gradually.

(3) Figure 56 shows a straight through type muffler. This muffler is provided with a central tube, perforated with many openings which lead into an outside chamber packed with a sound absorbing (insulating) material. As the exhaust gases expand through the perforated

inner pipe into the outer chamber, they come in contact with the insulator and escape to the atmosphere under a constant pressure. In this manner, the expanding chamber tends to equalize or spread out the pressure peaks of the exhaust from each individual cylinder.

c. Engines of the V-type require two exhaust manifolds and either one or two mufflers. If one muffler is used, the exhaust pipe from one manifold meets the other one in the form of a Y. The muffler outlet pipe, made of seamless tubing, is connected to the outer end of the muffler. It is rigidly supported to the frame. As a rule, this outlet pipe does not extend beyond the rear of the vehicle, thus eliminating the possibility of its being damaged.

SECTION VIII

SUPERCHARGERS AND GOVERNORS

	Paragraph
Superchargers -----	52
Governors -----	53

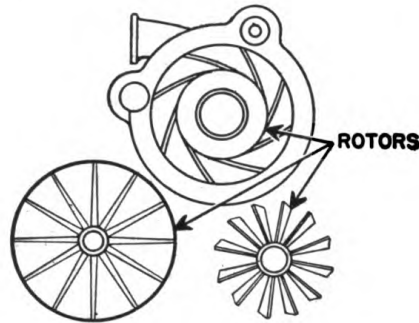
52. Superchargers.—*a.* The supercharger is a device that feeds the fuel mixture into the engine cylinders under pressure instead of making them dependent upon their own suction. A supercharger tends to “pack” the fuel charge into the cylinders and enables an engine to develop more power.

b. When a supercharger is used, the manifold pressures are positive at all engine speeds. Since with an unsupercharged engine a vacuum ranging from one to several pounds is required to draw the mixture into the cylinders, the effect of the supercharger is actually much greater than any gage pressure reading would indicate. Several pounds of vacuum are replaced by several pounds of pressure.

c. The demands for greater power placed upon racing engines led to the development of superchargers. The supercharger is considered a necessity for airplane engines because air grows rarer or thinner (less atmospheric pressure) as the altitude increases. Unless a supercharger is used, the airplane engine only receives a partial charge of air at high altitudes. Because of the decreased atmospheric pressure when the automobile engine is operated at high speeds, it is faced with much the same condition as an airplane engine at great altitudes.

d. Several types of supercharger blowers designed to give a positive flow of fuel mixture to internal combustion engine cylinders are shown in figures 57 and 58. The centrifugal type (figs. 57① and 58), operates on much the same principle as the water pump on an automobile engine. Tremendous speeds are attained by superchargers of this type. The rim or edge of the rotor travels at about 720 miles per hour, creating a

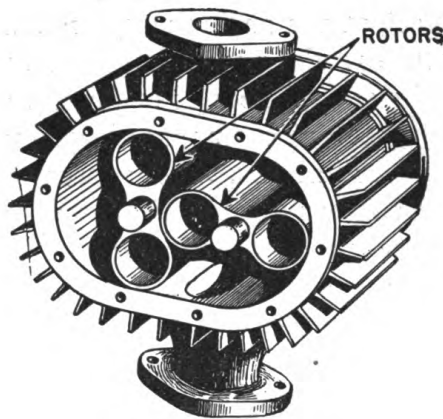
pressure of about 16 pounds per square inch which forces air and fuel into the cylinders. This pressure added to the vacuum of the engine gives an appropriate pressure of about 20 to 28 pounds per square inch, insuring even distribution of the mixture to all cylinders.



① Centrifugal type.



② Vane type.



③ Root blower type.

FIGURE 57.—Three types of supercharger rotors.

e. The vane type blower (fig. 57 ②) works much the same as a vane type oil pump. The supercharger blower (fig. 57 ③) works on the same principle as the Root air blower by confining the air

and forcing it ahead of the rotating units in much the same manner as oil is forced through a gear type oil pump.

f. (1) The Graham supercharger (fig. 58) is a true centrifugal type. It is mounted between the carburetor and the intake manifold of an engine. It consists of a casing containing a rotor, similar in form to that of a vacuum sweeper, that operates at speeds up to 35,000 or 40,000 revolutions per minute. The suction developed by the rotor draws the mixture of fuel and air from the carburetor into

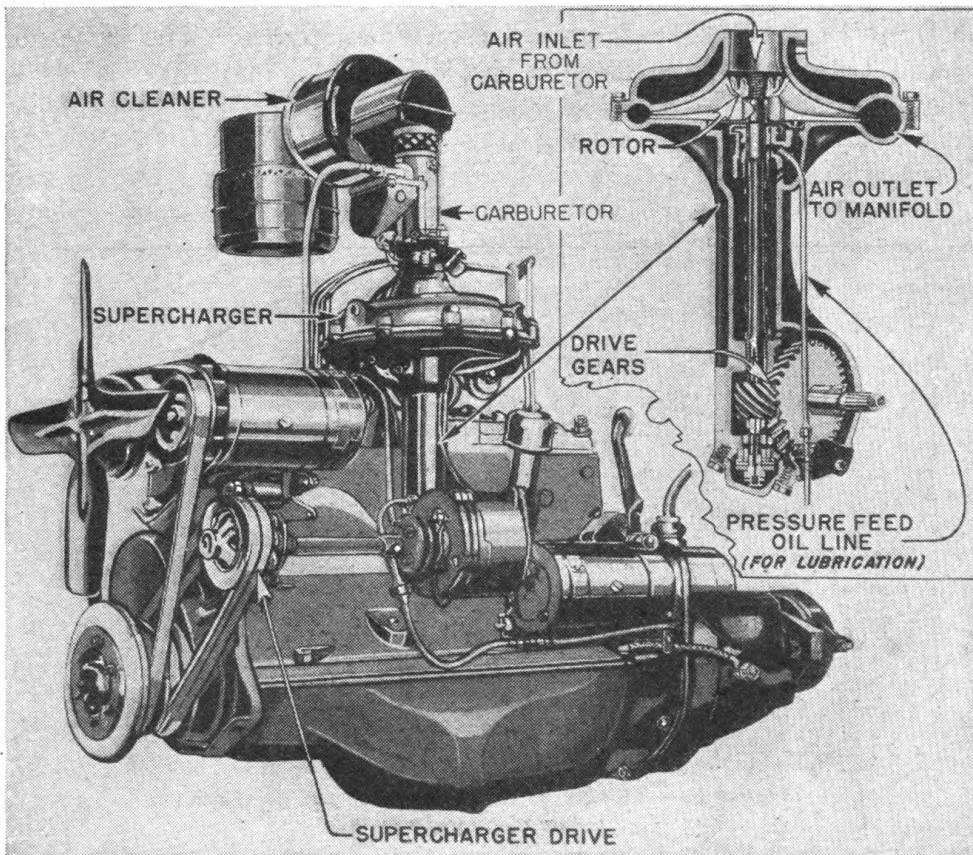


FIGURE 58.—Supercharger showing drive mechanism and method of lubrication.

the center of the casing and expels it under pressure at the edge of the rotor, forcing it through the intake manifold to the combustion chambers.

(2) The supercharger is mounted on the side of the engine, approximately at its center, with the rotor revolving horizontally.

(3) The downdraft carburetor is mounted directly upon the cover of the supercharger rotor. After passing through the supercharger, the fuel-air mixture (more completely mixed by contact with the

rotor) is carried over the top of the engine through a tube connected to the intake manifold and forced under pressure into the combustion chamber.

(4) The lower part of the unit consists of a gear case inclosing a worm gearing (insert, fig. 58) especially developed for driving centrifugal superchargers. The worm wheel is driven by the supercharger drive shaft connected by a double V belt to a pulley on the main crankshaft.

53. Governors.—*a.* Governors are used on motor vehicle engines to limit their speed to some predetermined figure. The governor, placed between the carburetor and the intake manifold, is set at whatever maximum speed is desired and then sealed. The driver

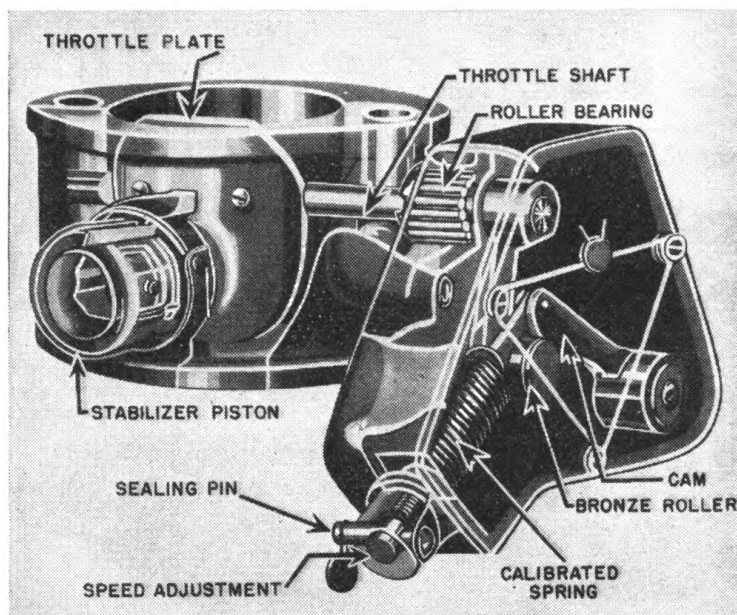


FIGURE 59.—Velocity or vacuum type engine governor.

can never exceed the speed for which the governor is set. The governor is used to prevent undue racing of the engine when changing gears or releasing the clutch. The average driver will work his engine at high speeds a great deal more than is necessary, straining the entire vehicle mechanism and wasting both fuel and oil.

b. Engine governors commonly used are of two types; the velocity or vacuum operated type and the mechanically driven centrifugal type.

(1) The velocity or vacuum type (fig. 59) is the more commonly used. It has no connection with any moving part of the engine. It

needs no lubrication, allows full acceleration, and requires minimum maintenance. Vacuum governors are operated by the force of the fuel mixture as it is sucked by the manifold vacuum through the governor housing. The throttle shaft in the governor throat, slightly offset from the center line of the throat, operates the throttle plate. Both of these are similar to the carburetor shaft and throttle, except that the governor throttle is set at an angle so that it will be moved by the flowing fuel mixture. The force of the fuel tends to close the governor throttle, but the spring attached to the throttle shaft is adjusted so that its force will just equal the force of the fuel mixture on the throttle at the maximum engine speed desired.

(2) The centrifugal type governor, sometimes used on heavy duty trucks and tractors, has fly weights attached to pivoted arms which are revolved by a gear drive from the camshaft and work against a spring tension. In one model, the centrifugal force of the weights actuates a needle valve in the main carburetor jet to limit the quantity of fuel delivered to the main nozzle thereby limiting the engine speed.

APPENDIX

BIBLIOGRAPHY

The following sources have been consulted in the preparation of this manual for illustrations and text material. They contain more detailed information on motor vehicles than is contained herein, and it is suggested that it would be advantageous for the student to consult them as collateral reading.

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BY ORDER OF THE SECRETARY OF WAR:

G. C. MARSHALL,
Chief of Staff.

OFFICIAL:

E. S. ADAMS,
Major General,
The Adjutant General.

