Basic Fuel Systems and Carburetors 6

This chapter primarily explains basic aircraft fuels and fuel systems and their relation to both the engine and the fuel supply to the engine through the carburetor. The theory, operation, construction, and maintenance of float-type carburetors used on small and medium-size reciprocating engines are covered in detail. Also, pressure carburetors which were used on many older engines are included for your familiarization. Other types of fuel metering and fuel control devices are described in later chapters. Additional information on aircraft and engine fuel systems is provided in a related text of this series, *Aircraft Maintenance and Repair.*

CHARACTERISTICS OF GASOLINE

Gasoline possesses desirable characteristics that make it suitable for use as an aviation fuel. These characteristics, compared with those of other fuels, are high heat value and the ability to evaporate when exposed to air at ordinary temperatures. A fuel such as gasoline evaporates readily at low temperatures and is said to have high volatility. For engine-starting purposes, high volatility is a desirable characteristic. However, a gasoline that evaporates too readily is apt to "boil" and form air bubbles in the fuel lines, resulting in vapor locks. A good aircraft fuel must have **volatility** that is high enough to start an engine easily but not so high as to readily form excessive vapors in the fuel system.

Testing Fuels

To determine the volatility of an aircraft fuel, a fractional-distillation test is made. Figure 6–1 illustrates this test and shows the type of apparatus used. A measured quantity of gasoline to be tested is placed in a glass flask, and then glass tubing is connected from the flask through a condenser unit to a calibrated receiver. Heat is applied under the flask and the amount of fuel condensed in the receiver at various temperatures is recorded. The data can be plotted on a graph as shown in Fig. 6–2, and a temperature range found where 10, 50, and 90 percent of the fuel condenses.

The temperature at which 10 percent of a test fuel is boiled off is indicative of the lowest atmospheric temperature at which an engine will start when primed with this fuel. The temperature at which 50 percent of the fuel condenses determines the engine's acceleration ability; 90 percent condensation determines overall engine performance.

The volatility of a gasoline is also important because of its effect on carburetor icing. Fuel engineers speak of the **latent heat of vaporization,** which is simply the amount of heat necessary to vaporize a given amount of fuel. Vaporization cannot take place without heat. In a carburetor, this heat for vaporizing the fuel is taken from the air and from the metal. If too much heat is used in vaporization, ice may form. A highly volatile fuel extracts heat from its surroundings more rapidly than a less volatile fuel does. Carburetor icing has been practically eliminated from all aircraft except the small types equipped with float-type car-

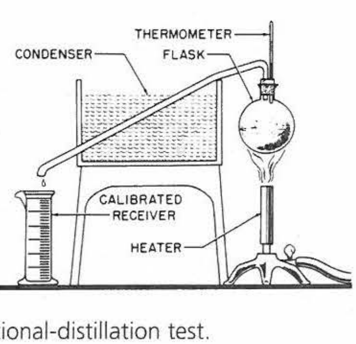


FIG. 6–1 Fractional-distillation test.

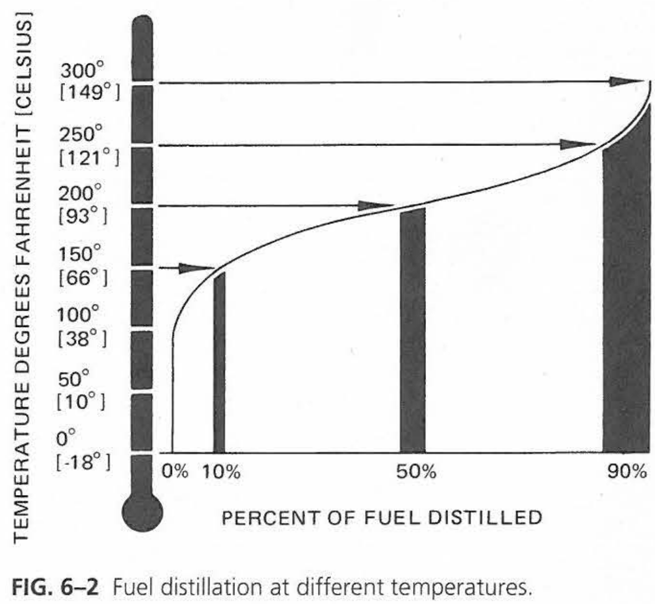


FIG. 6–2 Fuel distillation at different temperatures.

buretors. This has been done through the use of pressure injection and fuel injection systems, with the fuel injection occurring in locations not conducive to ice formation.

For this reason, aviation fuels that, in general, are blends of a number of different gasolines are checked carefully for vaporizing properties. An instrument known as the **Reid vapor pressure bomb** is used. In this apparatus, shown in Fig. 6–3, a pressure gage attached to one end of a sealed container registers the amount of vapor pressure that a given fuel creates at various temperatures.

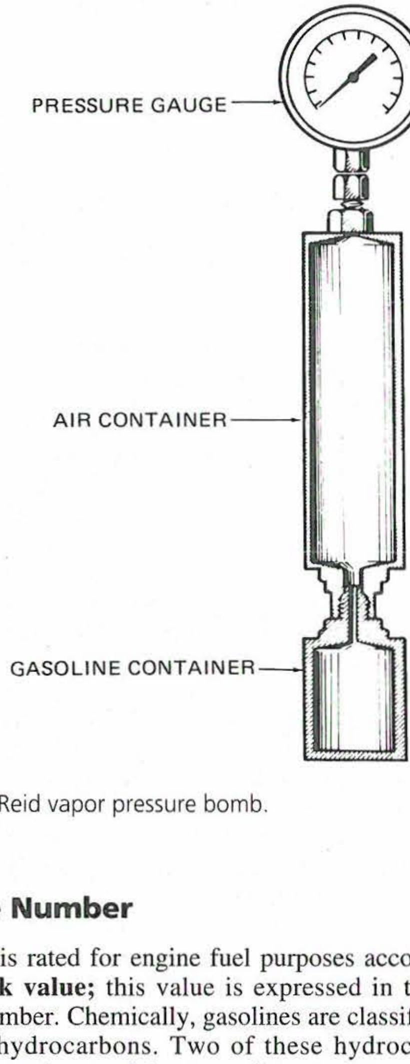


FIG. 6–3 Reid vapor pressure bomb.

Octane Number

Gasoline is rated for engine fuel purposes according to its **antiknock value;** this value is expressed in terms of an octane number. Chemically, gasolines are classified as mixtures of hydrocarbons. Two of these hydrocarbons are isooctane and normal heptane. Isooctane possesses high antiknock qualities, while normal heptane has low antiknock qualities. This quality, or value, is expressed as the percentage of isooctane in the mixture. *For example, a reference fuel of 70 octane means a mixture of 70% isooctane in normal heptane.*

The octane rating of a fuel is tested in a special engine that compares the performances of the fuel being tested and of reference fuel, usually a mixture of isooctane and normal heptane. The test engine is coupled to a generator that provides a constant load factor. Two valves, two fuel chambers, and two carburetors are used. First, the engine is run on the fuel being tested, and its knocking qualities are noted. Then the engine is switched over to the reference-fuel mixture. The reference-fuel mixture is varied until it has the same knock qualities as the fuel being tested. The tested fuel is given a number that is determined by the percentage of isooctane in the reference-fuel mixture.

Performance Number

Aviation fuels have been developed that possess greater antiknock qualities than 100 octane, or pure isooctane. To classify these fuels, a special **performance number** is used. This scale, or rating, is based on isooctane to which measured quantities of **tetraethyl-lead** (TEL) are added. For example, isooctane has an octane number of 100; likewise, it has a performance number of 100. If TEL is added to it, a performance number above 100 is obtained. The performance numbers obtained by mixing various amounts of TEL with octane are shown in the chart in Fig. 6–4.

When ordinary gasoline is rated, the octane number is generally used, but since, with the addition of lead, the rating may run over the fixed 100 rating of isooctane, it is preferable to rate aviation gasoline by giving it a performance number. Since the antiknock qualities of a fuel will vary according to the fuel-air (F/A) ratio, the performance numbers are expressed with two numbers—one rating for a lean mixture and the other for a rich mixture. The performance numbers are expressed as follows: 100/130, 115/145. The first number is the lean-performance number; the second number is the rich-performance number.

Use of Lead in Aviation Fuels

Lead, in the form of TEL, is used in relatively small quantities in aviation gasoline to improve antiknock qualities. The standard method in this country for expressing the quantity of lead is in terms of milliliters per gallon. The maximum lead concentration used is 630 volumes of gasoline to 1 volume of TEL. This corresponds to 6 milliliters (mL) of TEL to 1 gal [3.79 L] of gasoline.

Lead, if added alone to gasoline, will burn to form lead oxide, which is a solid with a very high boiling point. For this reason the lead remains as a residue in the cylinders to a large extent. To prevent this, a gasoline-soluble bromine compound is added to the lead. The mixture forms lead bromide, which has a much lower boiling point than lead oxide, and therefore a large portion is expelled from the cylinders with the exhaust gases. Another chemical compound, **tricresyl phosphate** (TCP), is now being added to

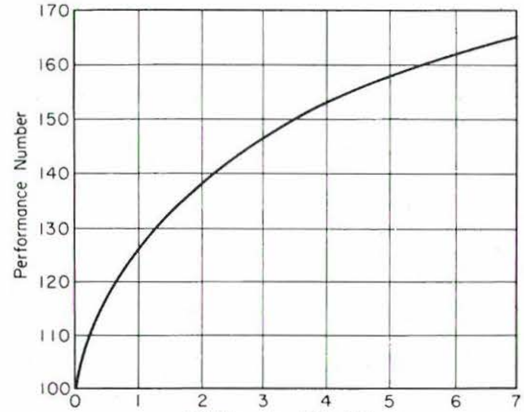


FIG. 6–4 Chart of performance numbers.

leaded fuel to further reduce the effects of the lead bromide deposits in the cylinder and on spark plug electrodes. The TCP converts the lead residue to lead phosphate rather than lead bromide. Lead phosphate is nonconductive and is easier to dispose of than lead bromide.

Aviation Gasoline: Grades and Color Codes

Technicians and refueling personnel should be familiar with grades of aviation gasoline (avgas) and their color codes, to ensure proper servicing of engines. Three grades of avgas are now produced for civil use: 80, 100LL (low lead), and 100. These grades replaced 80/87, 91/96, 100/130, and 115/145 avgas.

The lead quantity, or concentration of lead, in avgas is expressed in milliliters ($\frac{1}{1000}$ L) per 1 gal [3.79 L] of avgas. The Standard Specification for Aviation Gasolines, Specification D910-75, developed by ASTM (American Society for Testing and Materials), established that grade 80 should be red and contain a maximum of 0.5 mL of TEL per 1 gal [3.79 L] of avgas. Grade 100LL is blue and contains a maximum of 2.0 mL/gal. Grade 100 is green and contains a maximum of 3.0 mL/gal.

Grades 100LL and 100 represent two avgases which are identical in antiknock quality but differ in maximum lead content and color. The color identifies the difference for engines with a low tolerance to lead.

Limited availability of grade 80 in some U.S. geographic areas has forced owners and operators to use the next higher grade of avgas. Specific use of higher grades is dependent on the applicable manufacturer's recommendations. Continuous use of higher-lead fuels in low-compression engines designed for low-lead fuels can cause erosion or necking of the exhaust valve stems and spark plug lead fouling.

Engine Design and Fuel Performance

Aircraft engines are specifically designed to operate with fuels having certain octane ratings, or performance numbers. The minimum octane rating, or performance number, is usually more critical than the maximum, although the use of a fuel with either too high or too low a rating may cause engine failure. FAA Type Certificate Data Sheets for Aircraft specify the minimum octane rating of fuel for each engine installation. Using a fuel with too low a rating usually leads to detonation, with accompanying damage to the pistons and cylinders, and eventual engine failure.

The principal factors governing the grade of fuel required for an engine are the compression ratio and the manifold air pressure (MAP). Supercharged engines require a higher grade of fuel than unsupercharged engines having the same compression ratio. As the compression ratio and MAP increase, the pressure of the F/A mixture in the cylinder also increases. Higher pressures lead to higher temperatures, which in turn increase the possibility of detonation.

Note that a fuel with a high performance number contains the same energy as a fuel with a low performance number. However, since the higher-rated fuel makes it possible for the engine to be operated at a higher compression ratio, a higher MAP, and higher temperatures, an engine designed to operate on higher-rated fuels can develop more power for the amount of fuel consumed.

High compression ratios enable economical long-range operation and aid in cylinder cooling. The cooling effect is a result of the fact that more of the heat in the fuel is converted to useful work at the crankshaft and that less goes into the cylinder walls. High compression is also advantageous in that a reduced weight of air is required for a given horsepower; this is a particular advantage at high altitudes.

An increase in the compression ratio improves fuel economy at the expense of reducing the power for takeoff and emergencies. Attempts to increase the range by employing a higher compression ratio are limited because this may so reduce takeoff power that the airplane cannot develop the power required for takeoff, since high compression ratios increase the possibility of detonation. In the ideal situation, a maximum compression ratio compatible with the fuel used is designed into the engine. Any increase in compression ratio above that at which the fuel will burn satisfactorily under full-power conditions will cause detonation and loss of power.

Corrosive Effects of Leaded Fuels

As previously stated, TEL is used with aviation fuels to improve the antiknock quality. Also, the use of TEL requires the addition of a bromide compound to help reduce the accumulation of lead deposits inside the combustion chamber. The bromide compound used commonly is ethylene dibromide.

The burning of TEL and ethylene dibromide produces the compound of lead bromide, most of which is carried out of the cylinder with the exhaust gases. However, a certain amount will remain, even under the best conditions. Lead bromide in the presence of water and metals, particularly aluminum, produces corrosive liquids, particularly hydrobromic acid, which cause rusting of steel and cast iron.

Great damage has been caused to engines by the corrosive action of hydrobromic acid and other chemical residues. The damage is especially great when an engine is allowed to stand unattended for several weeks. If an engine will not be operated for an extended period, it should be given a preservation treatment. This is done by operating the engine on unleaded fuel for at least 15 min and then spraying the interior of the cylinders with a rust-preventing oil while the engine is being rotated.

Aromatic and Alcohol Aviation Fuels

Gasoline, the aromatics, and alcohol are the ideal fuels for internal-combustion engines. In the following paragraphs we point out the relative merits of aromatics and alcohol as aviation fuels.

The **aromatics** are hydrocarbon compounds acquired either from coal (as a by-product during the manufacture of coke) or from oil. They are also present in straight-run gasoline as a natural product of the fractional-distillation process to an extent of about 7 percent or less. Aromatic fuel is so named because the atomic arrangement of its molecular structure is identical with that in perfumes.

When two fuels have equal performance numbers, both lean and rich, the fuel not containing aromatics is somewhat preferable to the fuel containing 15 percent aromatics.

Also, aromatic fuel blends cause trouble with rubber parts and require the use of synthetic rubber for fuel hoses, pump packings, carburetor diaphragms, etc.

Benzol is the best known of the aromatic group. It has a high compression point at rich mixtures, and tests show that it will withstand a compression pressure of 175 psi [1 206.63 kPa] within the combustion chamber of an engine before knocking occurs. But benzol has certain undesirable characteristics, among them a slow burning rate. It is also a powerful solvent of rubber. This objection to benzol was overcome to some extent by the development of synthetic-rubber fuel lines. However, for various reasons, the amount of benzol in aviation fuel at present is limited to 5 percent by volume.

Three other important aromatics are **toluene, xylene,** and **cumene.** Some of the characteristics of toluene, such as low freezing point, good volatility, and rubber-solvent properties less powerful than those of benzol, make it suitable for blending in aviation fuel up to 15 percent by volume. Xylene also has desirable qualities for blending in aviation fuels. However, it can be used only in limited quantities owing to its relatively high boiling point. Cumene is made from benzol. This limits the amount that can be used for blending purposes. Cumene has an extremely high boiling point, which tends to cause uneven distribution of the fuel-air charge to the various cylinders of the aircraft engine.

Since all aromatics are rubber solvents to some extent, the use of aviation fuels containing large amounts of aromatics requires aromatic-resistant materials in the fuel system. Parts such as flexible hoses, pump packings, and carburetor diaphragms must be made of special synthetic rubber.

Purity of Aviation Fuel

Aviation fuel must be free of any such impurities as water, dirt, microorganisms, acid, or alkali. It must also have low sulfur and gum contents. Sulfur has a corrosive effect on the various metal parts of the fuel system and engine. Gum may cause valves to stick, and it will clog fuel metering jets and restrictions.

Excessive water in an engine fuel system constitutes a serious problem. A small amount of water will pass through the system and carburetor jets without radically affecting engine performance, but any significant amount of water in the system will stop the flow of fuel through the metering jets and result in engine failure.

Water in the fuel poses a serious threat to high-altitude aircraft such as jet transport types. Fuel becomes cooled well below the freezing point of water, and since fuel cannot contain as much dissolved water at low temperatures as it can when it is comparatively warm, the water is precipitated out and forms minute ice crystals. These crystals adhere to fuel system screens and filters and effectively shut off the flow of fuel.

Effective water removers are used in airplane servicing equipment to eliminate the danger of water being pumped into the tanks during refueling. However, condensation will form within fuel tanks during periods of variable atmospheric temperatures, the amount of this condensation being proportional to the extent of airspace in the tank above the fuel line. To eliminate any possibility of this trouble, the tanks should be kept filled, especially at night or when extreme changes in temperature are likely.

When it is suspected that gasoline contains more water than is allowable [approximately 30 parts per million (ppm)], various tests can be made. A water-soluble coloring agent can be added to a sample of the fuel; if the fuel becomes tinted, water is present. Another testing method involves passing the fuel through a special filter paper; if the amount of water in the fuel is excessive, the yellow filter paper turns blue. Fuel cannot be tested for water content if the fuel is below the freezing temperature of water, for the water would be in the form of ice crystals and would not react with the testing agents. Aircraft that have been flying at high altitudes, especially in winter, are likely to contain fuel that has been "cold-soaked" to the extent that water tests cannot be made. When the fuel temperature is below the freezing temperature of water, the fuel must be allowed to warm up before tests for water are made.

As explained later in this section, fuel tanks are provided with sumps at the lowest points to collect water. Regular drainage of these sumps is an important step in preflight preparations.

Avgas vs. Automotive Gasoline

Because several of the major oil companies reduced or stopped the production of 80/87-octane avgas, many aircraft engines designed to operate on 80/87-octane avgas have been forced to use 100LL-octane (low-lead) avgas. This caused many problems since 100LL contains four times the lead of 80/87 avgas. These problems became apparent in the valves and spark plugs where excess lead deposits accumulated and other lead-related problems arose. Another problem was the increasing cost of 100LL avgas. To remedy some of these problems, several supplemental-type certificates (STCs) have been granted by the FAA to use automotive gasoline (autogas) in specific aircraft. Although the use of unleaded autogas has decreased or eliminated the problem with valves and spark plug deterioration, the use of autogas in aircraft still remains very controversial.

The aircraft manufacturers, engine manufacturers, major oil companies, and some aviation professional organizations remain staunchly opposed to the use of autogas. The four main areas of concern involve its volatility, combustion characteristics (antiknock), additives and blending components, and quality control. In the area of autogas volatility, a Reid vapor pressure of 9.0 to 15 is very common, compared to the vapor pressure of avgas, which is 5.5 to 7. At high temperatures and/or altitudes, because of the difference in volatility, autogas may vaporize in the fuel lines and pumps, preventing flow and possibly resulting in vapor lock. Due to the lack of stringent ASTM specifications for the combustion characteristics of autogases, there is much concern that not all unleaded autogas may meet the avgas rich rating of 87. Thus, autogas may not possess sufficient antiknock capability to prevent preignition and detonation in all applicable aircraft engines. Some blending agents used in autogas such as detergents and corrosion inhibitors could adversely affect the aircraft fuel system's components.

Quality control remains a concern in both the manufacture of autogas and its distribution to the aircraft. Although fuel contamination can occur in either avgas or autogas, the method of distribution of autogas remains somewhat questionable. Many times aircraft are fueled with autogas from 5-gal [18.9-L] cans that were filled at and transported from an automotive service station. Because the handling of autogas is not governed by quality control anywhere near that of avgas, there is a greater chance of fuel contamination. Another concern is the use of an autogas containing any type of alcohol. Alcohol is not compatible with the seals in most aircraft fuel systems. If the seals were to deteriorate and break loose, fuel starvation could occur, resulting in engine stoppage. Many people have used autogas very successfully in their aircraft by taking special handling precautions and closely adhering to the autogas STCs.

The avgas-vs.-autogas controversy in engines designed to use 80/87-octane avgas is far from resolved. Before using autogas in an aircraft, one should become very familiar with the special characteristics of autogas which could affect engine performance. It is also a good idea to check the engine manufacturer's warranty, since it may be void if autogas is used.

The future development of special engines and fuel systems designed to operate on autogas could increase its acceptance. Many view the widespread use of autogas as necessary to revive the general-aviation small-aircraft industry. Autogas is currently used widely in Europe, where valuable experience and data on its use are being gathered.

FUEL SYSTEMS

The complete fuel system of an airplane can be divided into two principal sections: the aircraft fuel system and the engine fuel system. The **aircraft fuel system** consists of the fuel tank or tanks, fuel boost pump, tank strainer (also called a *finger strainer*), fuel tank vents, fuel lines (tubing and hoses), fuel control or selector valves, main (or master) strainer, fuel flow and pressure gages, and fuel drain valves. Fuel systems for different aircraft vary in complexity and may or may not include all these components. The **engine fuel system** begins where the fuel is delivered to the engine-driven pump and includes all the fuel controlling units from this pump through the carburetor or other fuel metering devices.

Requirements

The complete fuel system of an aircraft must be capable of delivering a continuous flow of clean fuel under positive pressure from the fuel tank or tanks to the engine under all conditions of engine power, altitude, and aircraft attitude and throughout all types of flight maneuvers for which the aircraft is certificated or approved. To do this and provide for maximum operational safety, certain conditions must be met:

1. Gravity systems must be designed with the fuel tank placed far enough above the carburetor to provide such fuel pressure that the fuel flow can be 150 percent of the fuel flow required for takeoff.

2. A pressure, or pump, system must be designed to provide 0.9 lb/h [0.41 kg/h] of fuel flow for each takeoff horsepower delivered by the engine, or 125 percent of the actual takeoff fuel flow of the engine, at the maximum power approved for takeoff.

3. In a pressure system, a **boost pump,** usually located at the lowest point in the fuel tank, must be available for engine starting, for takeoff, for landing, and for use at high altitudes. It must have sufficient capacity to substitute for the engine-driven fuel pump in case the engine-driven pump fails.

4. Fuel systems must be provided with valves so that fuel can be shut off and prevented from flowing to any engine. Such valves must be accessible to the pilot.

5. In systems in which outlets are interconnected, it should not be possible for fuel to flow between tanks in quantities sufficient to cause an overflow from the tank vent when the airplane is operated in the condition most apt to cause such overflow on full tanks.

6. Multiengine airplane fuel systems should be designed so that each engine is supplied from its own tank, lines, and fuel pumps. However, means may be provided to transfer fuel from one tank to another or to run two engines from one tank in an emergency. This is accomplished by a **cross-flow system** and valves.

7. A gravity-feed system should not supply fuel to any one engine from more than one tank unless the tank airspaces are interconnected to ensure equal fuel feed.

8. Fuel lines should be of a size sufficient to carry the maximum required fuel flow under all conditions of operation and should have no sharp bends or rapid rises, which would tend to cause vapor accumulation and subsequent vapor lock. Fuel lines must be kept away from hot parts of the engine insofar as possible.

9. Fuel tanks should be provided with drains and sumps to permit the removal of the water and dirt which usually accumulate in the bottom of the tank. Tanks must also be vented with a positive-pressure venting system to prevent the development of low pressure, which will restrict the flow of fuel and cause the engine to stop. Fuel tanks must be able to withstand, without failure, all loads to which they may be subjected during operation.

10. Fuel tanks must be provided with baffles if the tank design is such that a shift in fuel position will cause an appreciable change in balance of the aircraft. This applies chiefly to wing tanks, where a sudden shift of fuel weight can cause loss of aircraft control. Baffles also aid in preventing fuel sloshing, which can contribute to vapor lock.

Gravity-Feed Fuel Systems

A gravity-feed fuel system is one in which the fuel is delivered to the engine solely by gravity. (See items 1 and 7 in the previous list.) The gravity system does not require a boost pump because the fuel is always under positive pressure to the carburetor. A fuel quantity gage must be provided to show the pilot the quantity of fuel in the tanks at all times. The system includes fuel tanks, fuel lines, a strainer and sump, a fuel cock or shutoff valve, a priming system (optional), and a fuel quantity gage. The carburetor may also be considered part of the system. A gravity-feed fuel system is shown in Fig. 6–5.

Pressure Systems

For aircraft in which the fuel tanks cannot be placed the required distance above the carburetors or other fuel meter-

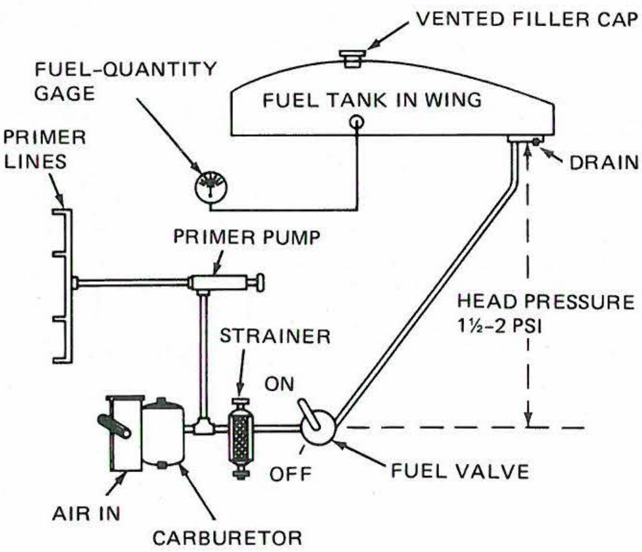


FIG. 6–5 Gravity-feed fuel system.

ing devices and in which a greater pressure is required than can be provided by gravity, fuel boost pumps and engine-driven fuel pumps are needed.

For a fuel system which relies entirely on pump pressure, the **fuel boost pump** is located at the bottom of the fuel tank and may be either inside or outside the tank. In many systems the boost pump is submerged in the fuel at the bottom of the tank. In some systems (Fig. 6–6), gravity feeds the fuel to reservoir tanks and then through the fuel selector valve to the auxiliary (boost) fuel pump. This system utilizes a fuel injection metering unit and requires more pressure than can be supplied by gravity alone.

In a pressure system, the **engine-driven fuel pump** is in series with the boost pump, and the fuel must flow through the engine-driven pump to reach the fuel metering unit. The pump must be designed so that fuel can bypass it when the engine is not running. This is normally accomplished by a bypass valve. The pump must also include a **relief valve** or similar unit to permit excess fuel to return to the inlet side of the pump. The engine-driven pump must be capable of delivering more fuel to the engine than is required for any mode of operation.

The fuel boost pump supplies fuel for starting the engine, and the engine pump supplies the fuel pressure necessary for normal operation. During high-altitude operation, takeoff, and landing, the boost pump is operated to ensure adequate fuel pressure. This is particularly important during landing and takeoff in case of engine pump failure.

Fuel Strainers and Filters

All aircraft fuel systems must be equipped with strainers and/or filters to remove dirt particles from the fuel. Strainers are often installed in fuel tank (cell) outlets, or they may be integral with the fuel boost pump assembly. Fuel tank strainers have a comparatively coarse mesh, some being as coarse as eight mesh to 1 in [2.54 cm]. **Fuel sump strainers,** also called **main strainers** or **master strainers,** are located at the lowest point in the fuel system between the fuel tank and engine and are much finer in mesh size, usually being 40 or more mesh per inch. The fuel filters installed in carburetors and other fuel metering units may be screens or sintered (heat-bonded) metal filters. Many of these are designed to remove all particles larger than 40 micrometers. A **micrometer** is one one-thousandth of a millimeter (1 μm = 0.001 m).

Fuel strainers and filters should be checked and cleaned as specified in the aircraft service manual.

Fuel System Precautions

In servicing fuel systems, remember that fuel is flammable and that the danger of fire or explosion always exists. The following precautions should be taken:

1. Aircraft being serviced or having the fuel system repaired should be properly grounded.
2. Spilled fuel should be neutralized or removed as quickly as possible.
3. Open fuel lines should be capped.
4. Fire-extinguishing equipment should always be available.
5. Metal fuel tanks must not be welded or soldered unless they have been adequately purged of fuel fumes. Keeping a tank or cell filled with carbon dioxide will prevent explosion of fuel fumes. Additional information on aircraft fueling procedures is provided in a related text in this series, *Aircraft Basic Science.*

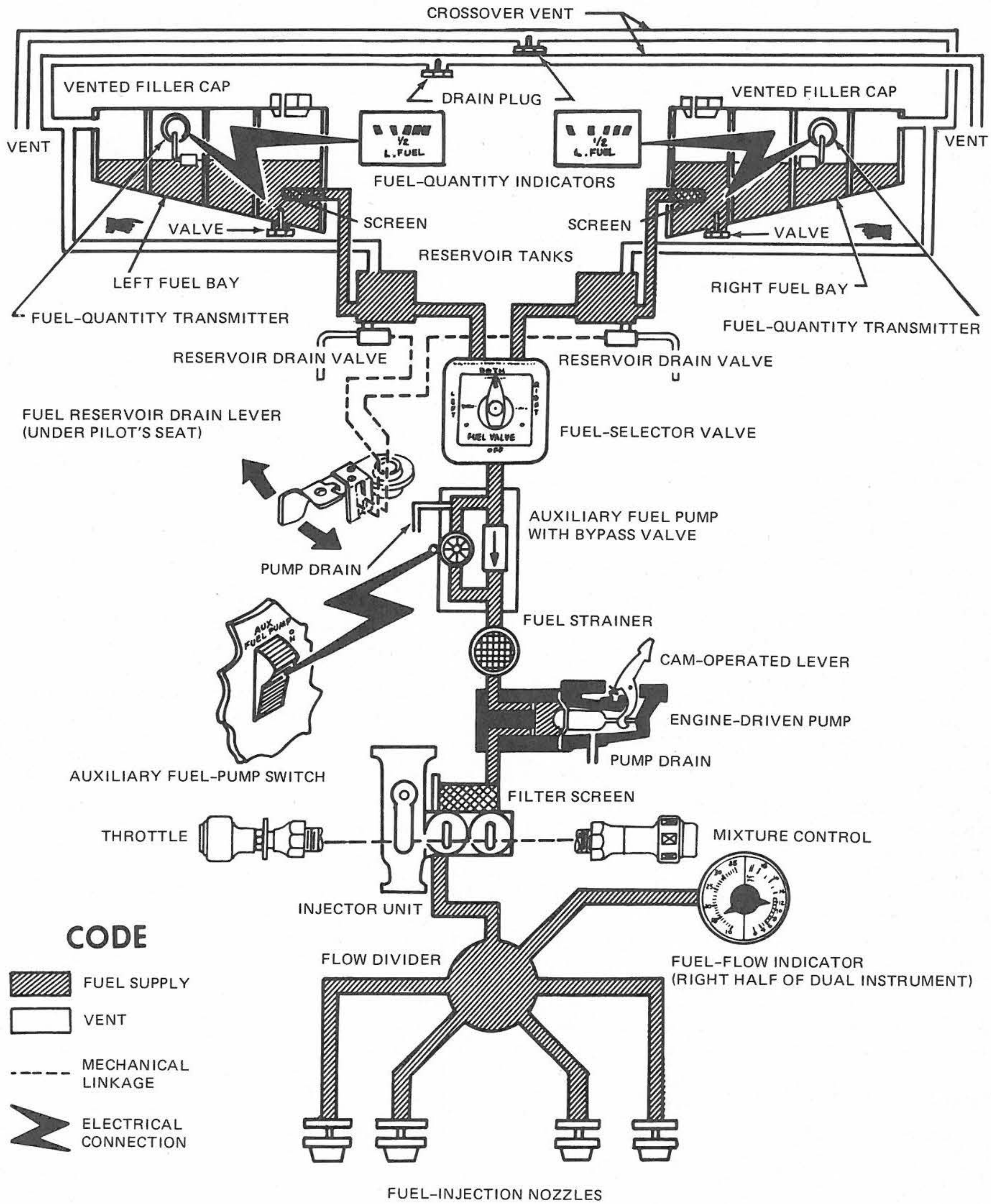
Vapor Lock

The condition known as **vapor lock** is caused by fuel vapor and air collecting in various sections of the fuel system. The fuel system is designed to handle liquid fuel rather than a gaseous mixture. When a substantial amount of vapor collects, it interferes with the operation of pumps, valves, and the fuel metering section of the carburetor. Vapor lock is caused to form by the low atmospheric pressure of high altitude, by excessive fuel temperature, and by turbulence (or sloshing) of the fuel.

The best solution for vapor lock is to use a boost pump, which is why the boost pump is operated at high altitudes. The boost pump applies positive pressure to the fuel in the lines, reducing the tendency of the fuel to vaporize and forcing vapor bubbles through the system and out through the venting devices. Since the boost pump is located at the bottom of the fuel tank or below the tank, the boost pump will always have a good supply of fuel and will continue to force fuel through the supply lines, even though vapor bubbles may be entrained in the fuel.

Fuel pumps and carburetors are often equipped with vapor-separating devices (which are discussed later, in relation to various types of fuel metering units). **Vapor separators** are chambers provided with float valves or other types of valves which open when a certain amount of vapor accumulates. When the valve opens, the vapor is vented through a line to the fuel tank. The vapor is thereby prevented from entering the fuel metering system and interfering with normal operation.

The design of a fuel system must be such that an accumulation of vapor is not likely. Fuel lines must not be bent into sharp curves; neither should there be sharp rises or falls in the line. If a fuel line rises and then falls, vapor can collect in the high point of the resulting curve. It is desirable that the fuel line have a continuous slope upward or



TO ENSURE DESIRED FUEL CAPACITY WHEN REFUELING, PLACE THE FUEL-SELECTOR VALVE IN EITHER LEFT OR RIGHT POSITION TO PREVENT CROSS-FEEDING.

FIG. 6–6 Pressure fuel system. *(Cessna Aircraft Company)* downward from the tank to the boost pump and a continuous slope upward or downward from the boost pump to the engine-driven pump, to prevent vapor from collecting anywhere in the line.

Fuel System Icing

Ice formation in the aircraft fuel system results from the presence of water in the fuel system. This water may be undissolved or dissolved. One form of undissolved water is **entrained water,** which consists of minute water particles suspended in the fuel. This may occur as a result of mechanical agitation of free water or conversion of dissolved water through temperature reduction. Entrained water will settle out in time under static conditions and may or may not be drained during normal servicing, depending on the rate at which it is converted to free water. In general, it is not likely that all entrained water can be separated from fuel under field conditions. The settling rate depends on a series of factors, including temperature and droplet size.

The droplet size will vary depending on the mechanics of formation. Usually, the particles are so small as to be invisible to the naked eye, but in extreme cases they can cause slight haziness in the fuel.

Another form of undissolved water is **free water**, which may be introduced as a result of refueling or the settling of entrained water at the bottom of a fuel tank. Free water is usually present in easily detectable quantities at the bottom of the tank. It can be drained from a fuel tank through the sump drains provided for that purpose. Free water frozen on the bottoms of reservoirs, such as the fuel tanks and fuel filter, may render drains useless and can later melt, releasing water into the system and thereby causing engine malfunction or stoppage. If such a condition is detected, the aircraft may be placed in a warm hangar to reestablish proper draining of these reservoirs, and all sumps and drains should be activated and checked prior to flight. Entrained water (that is, water in solution with petroleum fuels) constitutes a relatively small part of the total potential water in a particular system, with the quantity dissolved depending on fuel temperature, existing pressure, and water solubility characteristics of the fuel. Entrained water will freeze in cold fuel and tend to stay in suspension longer, since the specific gravity of ice is approximately the same as that of avgas.

Water in suspension may freeze and form ice crystals big enough to block fuel screens, strainers, and filters. Some of this water may be cooled further when the fuel enters carburetor air passages and causes carburetor metering-component icing, when conditions are not otherwise conducive to this form of icing.

The use of **anti-icing additives** for some piston-engine aircraft has been approved as a means of preventing problems with water and ice in avgas. Some laboratory and flight testing have indicated that the use of hexylene glycol, certain methanol derivatives, and ethylene glycol monomethyl ether (EGME) in small concentrations inhibits fuel system icing. These tests indicate that the use of EGME at a maximum concentration of 0.15 percent by volume substantially inhibits fuel system icing under most operating conditions. The concentration of additives in the fuel is critical. Marked deterioration in additive effectiveness may result from too little or too much additive.

CAUTION The anti-icing additive is in no way a substitute or replacement for carburetor heat. Operating instructions involving the use of carburetor heat should be strictly adhered to at all times during operation under atmospheric conditions conducive to icing.

PRINCIPLES OF CARBURETION

In the discussion of heat engine principles, we explained that a heat engine converts a portion of the heat of a burning fuel to mechanical work. To obtain heat from fuel, the fuel must be burned, and the burning of fuel requires a combustible mixture. The purpose of **carburetion,** or **fuel metering,** is to provide the combustible mixture of fuel and air necessary for the operation of an engine.

Since gasoline and other petroleum fuels consist of carbon (C) and hydrogen (H) chemically combined to form hydrocarbon molecules (CH), it is possible to burn these fuels by adding oxygen (O) to form a gaseous mixture. The carburetor mixes the fuel with the oxygen of the air to provide a combustible mixture which is supplied to the engine through the induction system. The mixture is ignited in the cylinder; then the heat energy of the fuel is released, and the fuel-air mixture is converted to carbon dioxide (CO_2), water (H_2O), and possibly some carbon monoxide (CO).

The carburetors used in aircraft engines are comparatively complicated because they play an extremely important part in engine performance, mechanical life, and the general efficiency of the airplane, due to the widely diverse conditions under which airplane engines are operated. The carburetor must deliver an accurately metered fuel-air mixture for engine loads and speeds between wide limits and must provide for automatic or manual mixture correction under changing conditions of temperature and altitude, all the while being subjected to a continuous vibration that tends to upset the calibration and adjustment. Sturdy construction is essential for all parts of an aircraft carburetor, to provide durability and resistance to the effects of vibration. A knowledge of the functions of these parts is essential to an understanding of carburetor operation.

Fluid Pressure

In the carburetor system of an internal-combustion engine, liquids and gases, collectively called **fluids,** flow through various passages and orifices (holes). The volume and density of liquids remain fairly constant, but gases expand and contract as a result of surrounding conditions.

The atmosphere surrounding the earth is like a great pile of blankets pressing down on the earth's surface. **Pressure** may be defined as force acting on an area. It is commonly measured in pounds per square inch (psi), inches of mercury (inHg), centimeters of mercury (cmHg), or kilopascals (kPa). The **atmospheric pressure** at any place is equal to the weight of a column of water or mercury a certain number of inches, centimeters, or millimeters in height. For example, if the cube-shaped box shown in Fig. 6–7, each side of which is 1 in^2 [6.45 cm^2] in area, is filled with mercury, that quantity of mercury will weigh 0.491 lb [2.18 N]; therefore, a force of 0.491 lb [2.18 N] is acting on the bottom 1 in^2 [6.45 cm^2] of the box. If the same box were 4 in

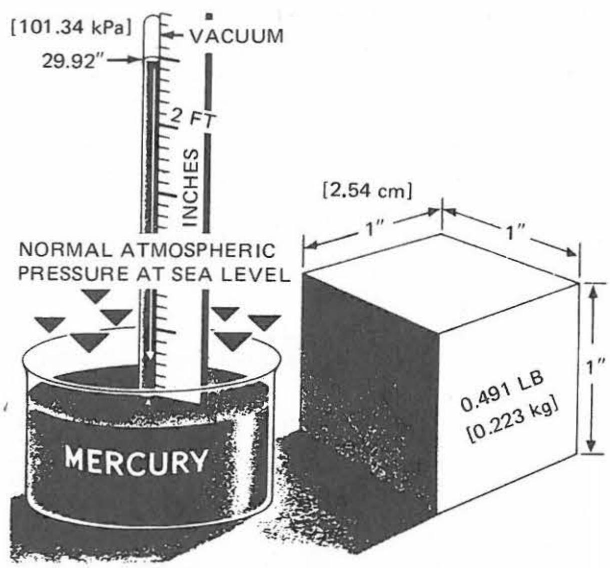


FIG. 6–7 Measuring atmospheric pressure.

[10.16 cm] high, the weight of the mercury would be 4 × 0.491, or 1.964 lb [8.74 N]; therefore, the downward force on the bottom of the box would be 1.964 lb [8.74 N]. Therefore, each 1 in [2.54 cm] of height of a column of mercury represents a 0.491-psi [3.385-kPa] pressure. To change inches of mercury to pounds per square inch, simply multiply by 0.491. For example, if the height of a column of mercury is 29.92 inHg [101.34 kPa], multiply 29.92 by 0.491, and the product is 14.69 psi, which is standard atmospheric pressure at sea level.

Refer again to Fig. 6–7. A glass tube about 36 in [91.44 cm] long, with one end sealed and the other end open, is filled completely with mercury. The tube is then placed in a vertical position with the open end submerged in a small container partly filled with mercury. If this is done at sea level under standard conditions, the mercury will sink and come to rest 29.92 in [76 cm] above the mercury in the container. There is then a vacuum above the mercury in the tube; therefore, there is no atmospheric pressure above the mercury in the tube.

The atmospheric pressure acts on the surface of the mercury in the container in Fig. 6–7. The weight of the mercury column above the surface of the mercury in the container must therefore equal the weight of the air column above the same surface. The length of the mercury column in the tube indicates the atmospheric pressure and is measured by a scale placed beside the tube or marked on its surface. Atmospheric pressure is expressed in *pounds per square inch, inches of mercury, kilopascals,* or *millibars.*

Standard sea-level pressure is 14.7 psi, 29.92 inHg, 101.34 kPa, or 1013 millibars (mbar). NASA and the International Committee for Aeronautical Operations (ICAO) have established a standard atmosphere for comparison purposes. The standard atmosphere table will be found in the appendixes of this text. **Standard atmosphere** is defined as a pressure of 29.92 inHg [101.34 kPa] at sea level and at a temperature of 15°C [59°F] when the air is perfectly dry at latitude 40°N. This is a purely fictitious and arbitrary standard, but it has been accepted and should be known to pilots, technicians, and others engaged in aircraft work.

The pressure of the atmosphere varies with the altitude.

- At 5000 ft [1 524 m] it is 24.89 inHg [84 kPa].
- At 10,000 ft [3 048 m] it is 20.58 inHg [69.7 kPa].
- At 20,000 ft [6 098 m] it is 13.75 inHg [46.57 kPa].
- At 30,000 ft [9 144 m] it is 8.88 inHg [30 kPa].
- At 50,000 ft [15 240 m] it is only 3.346 inHg [11.64 kPa].

Expressing the same principle in different terms, we say that the pressure of the atmosphere at sea level is 14.7 psi [101.34 kPa], but at an altitude of 20,000 ft [6 096 m] the pressure is only about 6.74 psi [46.47 kPa].

The pressure exerted on the surface of the earth by the weight of the atmosphere, **absolute pressure,** can be measured by a barometer. A **relative pressure** assumes that the atmospheric pressure is zero. Relative or differential pressures are usually measured by fuel pressure gages, steam gages, etc. This means that when a pressure is indicated by such a gage, the pressure actually shown is so many pounds per square inch above atmospheric pressure. This pressure is often designated as **psig,** meaning psi gage. When absolute pressure is indicated, it is designated as **psia,** meaning psi absolute.

The effect of atmospheric pressure is important to the understanding of aircraft fluids, including fuel, oil, water, hydraulic fluid, etc. The effect of atmospheric pressure on liquids can be shown by a simple experiment. Place a tube in a glass of water, place your finger over the open end of the tube, and take the tube out of the water, keeping your finger over the end. The water will not run out of the tube until you remove your finger. This shows the importance of providing and maintaining open vents to the outside atmosphere for tanks, carburetor chambers, and other parts or units which depend on atmospheric venting for their operation.

Venturi Tube

Figure 6–8 shows the operation of a **venturi tube,** which was originally used for the measurement of the flow of water in pipes. This device consists of a conical, nozzlelike reducer through which the air enters, a narrow section called the **throat,** and a conical enlargement for the outlet, which attains the same size as the inlet but more gradually.

The quantity of air drawn through the inlet is discharged through the same-size opening at the outlet. The velocity of the fluid must therefore increase as the fluid passes through

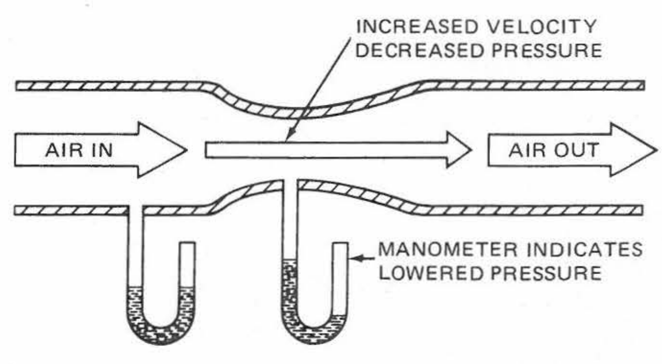


FIG. 6–8 Operation of a venturi tube.

the inlet cone, attain a maximum value in the throat, and thereafter gradually slow down to its initial value at the outlet. The pressure in the throat is consequently less than that at either the entrance or the exit.

Figure 6–8 shows manometers connected to the venturi. These are gages for measuring pressure and are similar in principle to barometers.

The operation of the venturi is based on **Bernoulli's principle,** which states that the total energy of a particle in motion is constant at all points on its path in a steady flow; therefore, at a higher velocity the pressure must decrease. The pressure in the throat of the venturi tube is less than the pressure at either end of the tube because of the increased velocity in the constricted portion. This is explained by the fact that the same amount of air passes all points in the tube in a given time.

The venturi illustrates the relation between pressure (force per unit area) and velocity in a moving column of air. In equal periods, equal amounts of air flow through the inlet, which has a large area; through the throat, which has a small cross-sectional area; and then out through the outlet, which also has a large area.

If any body, fluid or solid, is at rest, force must be applied to set that body in motion. If the body is already in motion, force must be applied to increase its velocity. If a body in motion is to have its velocity decreased, or if the body is to be brought to a state of rest, an opposing force must be applied.

In Fig. 6–8, if the cross-sectional area of the inlet is twice that of the throat, the air will move twice as fast in the throat as it does in the inlet and outlet. Since the velocity of any moving object cannot be decreased without applying an opposing force, the pressure of the air in the outlet portion of the tube must be greater than it is in the throat. From this we see that the pressure in the throat must be less than it is at either end of the tube.

Venturi in a Carburetor

Figure 6–9 shows the venturi principle applied to a simplified carburetor. The amount of fluid which flows through a given passage in any unit of time is directly proportional to the velocity at which the fluid is moving. The velocity is directly proportional to the difference in applied forces. If a fuel discharge nozzle is placed in the venturi throat of a carburetor, the effective force applied to the fuel will depend on the velocity of air going through the venturi. The rate of flow of fuel through the discharge nozzle will be

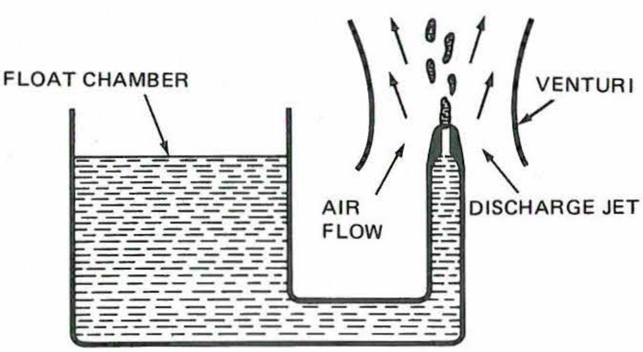


FIG. 6–9 Venturi principle applied to a carburetor.

proportional to the amount of air passing through the venturi, and this will determine the supply of the required fuel-air mixture delivered to the engine. The ratio of fuel to air should be varied within certain limits; therefore, a mixture control system is provided for the venturi-type carburetor.

Review of the Engine Cycle. The conventional aircraft internal-combustion engine is a form of heat engine in which the burning of the fuel-air mixture occurs inside a closed cylinder and in which the heat energy of the fuel is converted to mechanical work to drive the propeller.

The **engine cycle** (Otto cycle) must be understood and remembered in order to understand the process of carburetion. The fuel and air must be mixed and inducted into the cylinder during the **intake stroke;** the fuel-air charge must be compressed during the **compression stroke;** the charge must be ignited and must burn and expand in order to drive the piston downward and cause the crankshaft to revolve during the **power stroke;** finally, the burned gases must be exhausted (or scavenged) during the **exhaust stroke.**

The quantity and the nature of the charge of fuel and air inducted into the engine cylinder must be given considerable attention because the power, speed, and operating efficiency of the engine are governed largely by this charge.

Fuel-Air Mixtures

Gasoline and other liquid fuels will not burn in the liquid state, but must be vaporized and combined with correct amounts of oxygen to form a combustible mixture. The mixture of fuel and air is described as **chemically correct** when there is just enough oxygen present in the mixture to burn the fuel completely. If there is not quite enough air, combustion may occur but will not be complete. If there is either too much or too little air, the mixture will not burn.

As mentioned previously, burning is a chemical process. Gasoline is composed of carbon and hydrogen, and a gasoline called isooctane has the formula C_8H_{18}. During the burning process, this molecule must be combined with oxygen to form carbon dioxide (CO_2) and water (H_2O). The equation for the process may be written

$$2C_8H_{18} \times 25O_2 = 16CO_2 + 18H_2O$$

Thus, we see that two molecules of this particular gasoline require 50 atoms of oxygen for complete combustion. The burning of fuel is seldom as complete as this, and the resulting gases would likely contain carbon monoxide (CO). In such a case the equation could be

$$C_8H_{18} + 12O_2 = 7CO_2 + 9H_2O + CO$$

Air is a mechanical mixture containing by weight about 75.3 percent nitrogen, 23.15 percent oxygen, and a small percentage of other gases. Nitrogen is a relatively inert gas which has no chemical effect on combustion. Oxygen is the only gas in the mixture which serves any useful purpose as far as the combustion of fuel is concerned.

Gasoline will burn in a cylinder if mixed with air in a ratio ranging between 8 parts of air to 1 part of fuel and 18 parts of air to 1 part of fuel (by weight). That is, the air-fuel (A/F) ratio would be from 8:1 to 18:1 for combustion. This means that the A/F mixture can be ignited in a cylinder when the ratio is anywhere from as *rich* as 8 parts of air by weight to 1 part of fuel by weight to as *lean* as 18 parts of air by weight to 1 part of fuel by weight. In fuel-air (F/A) mixtures, the proportions are expressed on the basis of weight, because a ratio based on volumes would be subject to inaccuracies resulting from variations of temperature and pressure.

The proportions of fuel and air in a mixture may be expressed as a ratio (such as 1:12) or as a decimal fraction. The ratio 1:12 becomes 0.083 (which is derived by dividing 1 by 12). The decimal proportion is generally employed in charts and graphs to indicate F/A mixtures.

Fuel-air mixtures employed in the operation of aircraft engines are described as **best-power mixture, lean best-power mixture, rich best-power mixture,** and **best-economy mixture.** The graph in Fig. 6–10 illustrates the effects of changes in the F/A ratio for a given engine operating at a given rpm. The mixture at A is the lean best-power mixture and is the point below which any further leaning of the mixture will rapidly reduce engine power; in other words, the lean best-power mixture is the leanest mixture that can be used and still obtain maximum power from the engine. The mixture indicated by B in Fig. 6–10 is the rich best-power mixture and is the richest mixture that can be used and still maintain maximum power from the engine. The mixtures from A to B in the graph therefore represent the best-power range for the engine. Points C and D in Fig. 6–10 are the limits of flammability for the F/A mixture; that is, the F/A mixture will not burn at any point richer than that represented by C or at any point leaner than that represented by D.

The chart in Fig. 6–11 illustrates how the best-power mixture will vary for different power settings. Note that there is a very narrow range of F/A ratios for the best-power mixture. For example, the setting for 2900 rpm is 0.077, for 3000 rpm is 0.082, and for 3150 rpm is 0.091. Any F/A ratios other than those given will result in a rapid falling off of power. Internal-combustion engines are so sensitive to the proportioning of fuel and air that the mixture ratios must be maintained within a definite range for any given engine. A perfectly balanced F/A mixture is approximately 15:1, or 0.067. This is called a **stoichiometric mixture;** it is one in which all the fuel and oxygen in the mixture can be combined in the burning process. For a variety of reasons, the stoichiometric mixture is not usually the best to employ.

Specific fuel consumption (sfc) is the term used to indicate the economical operation of an engine. The **brake specific fuel consumption** (bsfc) is a ratio which shows the amount of fuel consumed by an engine in pounds per hour for each bhp developed. For example, if an engine is producing 147 hp [109.62 kW] and burns 10.78 gal/h [40.807 L/h] of fuel, the fuel weight being 6 lb/gal [0.719 kg/L], then the sfc is 0.44 lb/(hp•h) [0.15 kg/(kW•h)].

The chart in Fig. 6–12 was derived from a test run to determine the effects of F/A ratios. Note that the lowest sfc in this case occurred with an F/A ratio of approximately

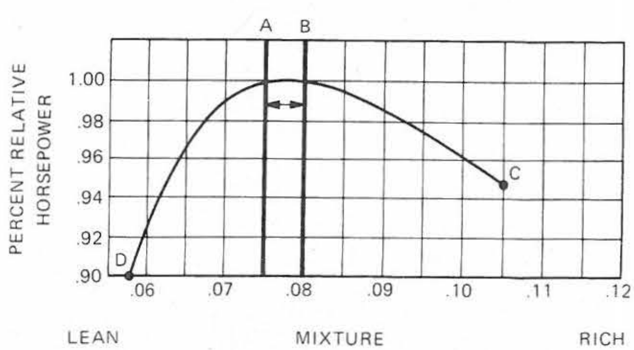


FIG. 6–10 Effects of F/A ratios on power at constant rpm.

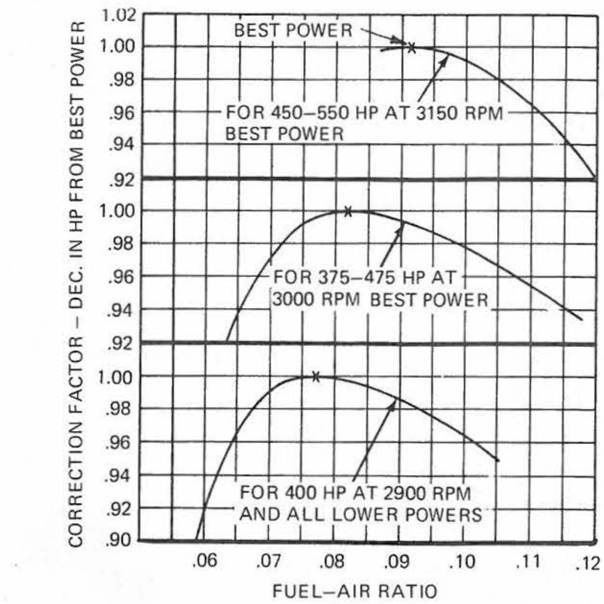


FIG. 6–11 Chart of best-power mixtures for different power settings.

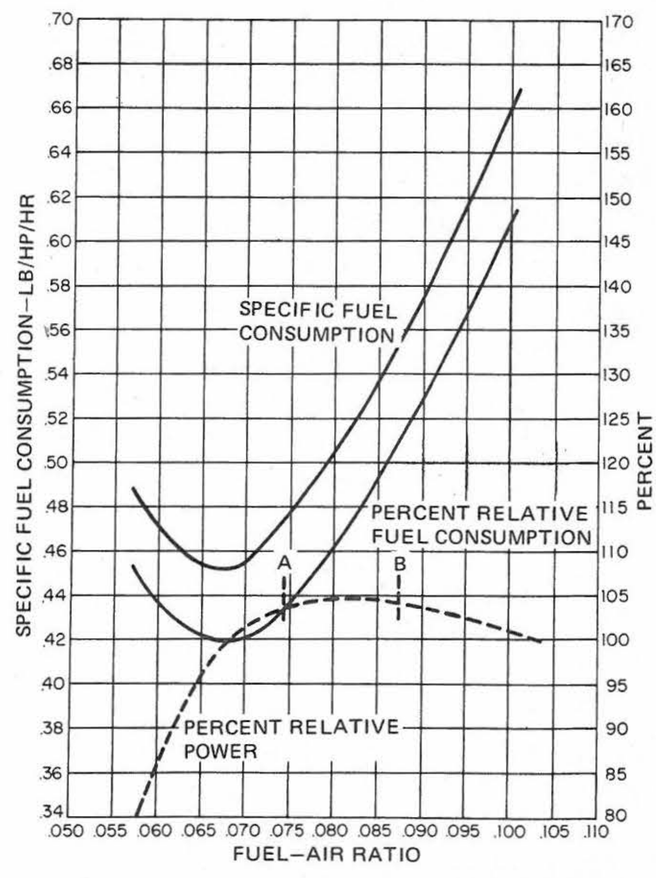


FIG. 6–12 Effects of F/A ratios and power settings on fuel consumption.

0.067 and that maximum power was developed at F/A ratios between 0.074 and 0.087. For this particular engine, we may say that lean best power is at point A on the chart (F/A ratio of 0.074) and that rich best power is at point B (F/A ratio of 0.087).

Note further that the sfc increases substantially as the mixture is leaned or enriched from the point of lowest sfc. From this observation it is clear that excessive leaning of the mixture in flight will not produce maximum economy. Furthermore, excessive leaning of the mixture is likely to cause detonation, as mentioned previously.

If detonation is allowed to continue, the result will be mechanical damage or failure of the tops of the pistons and rings. In severe cases, cylinder heads may be fractured. It is therefore important to follow the engine operating instructions regarding mixture control settings, thereby avoiding detonation and its unfavorable consequences. A careful observance of cylinder-head temperature and/or exhaust gas temperature (EGT) in most cases will enable the pilot to take corrective action before damage occurs. A reduction of power and an enrichment of the mixture usually suffice to eliminate detonation.

We have already stated that if there is too much air or too much fuel, the mixture will not burn. In other words, when the mixture is excessively rich or excessively lean, it approaches the limit of flammability; as it approaches this limit, the rate of burning decreases until it finally reaches zero. This is much more pronounced on the lean side than it is on the rich side of the correct proportion of fuel and air.

We noted that the best-power mixtures of fuel and air for the operation of an engine are those which enable the engine to develop maximum power. There is, however, a mixture of fuel and air which will produce the greatest amount of power for a given consumption of fuel. This is called the **best-economy mixture,** attained by leaning the mixture below the lean best-power mixture. As the mixture is leaned, both power and fuel consumption drop, but fuel consumption decreases more rapidly than engine power until the best-economy mixture is reached. The point is reached with a mixture somewhere between 0.055 and 0.065, depending on the particular engine and operating conditions. Remember that leaning of the mixture below the best-power mixture is not practiced with the engine developing its maximum power. Usually the engine is operating at less than 75 percent power. The operator's manual should be consulted for specific information on the operation of a particular powerplant and aircraft combination.

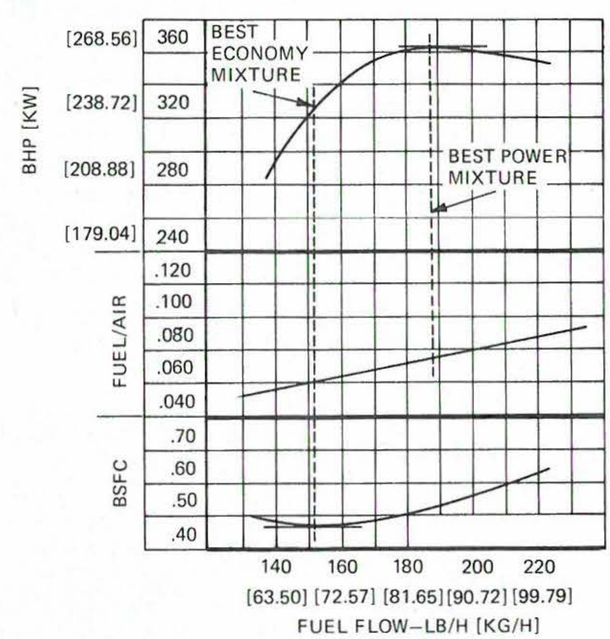


FIG. 6–13 Best-economy mixture and best-power mixture at constant throttle and constant rpm.

The chart in Fig. 6–13 provides a graphic illustration of the difference between best-economy mixture and best-power mixture. This chart is based on a constant-throttle position with a constant rpm. The only variable is the F/A ratio. With a very lean F/A ratio of about 0.055, the engine delivers 292 bhp [217.7 kW] with a fuel flow of 140 lb/h [63.50 kg/h], and the bsfc is about 0.48 lb/(hp•h) [0.218 kg/(kW•h)]. The best-economy mixture occurs when the F/A ratio is approximately 0.062. At this point the bhp is 324, and the fuel flow is 152 lb/h [68.95 kg/h]. The bsfc is then 0.469 lb/(hp•h) [0.213 kg/(kW•h)]. As the strength of the F/A mixture is increased, a point is reached where the engine power has reached a peak and will begin to fall off. This is the best-power mixture, and it is approximately 0.075, or 1:13.3. At this point the bhp is 364, and the bsfc is 0.514 with a fuel flow of 187 lb/h [84.82 kg/h].

We have now established the effects of F/A ratio when other factors are constant, and we can see that the mixture burned during the operation of the engine will have a profound effect on the performance. We must, however, explore the matter further because the engine operating temperature must be considered. If an engine is operated at full power and at the best-power mixture, as shown in the upper curve in Fig. 6–11, it is likely that the cylinder-head temperature will become excessive and detonation will result. For this reason, at full-power settings the mixture will be enriched beyond the best-power mixture. This is the function of the **economizer,** or **enrichment valve,** in the carburetor or fuel control, as explained later. The extra fuel will not burn but will vaporize and absorb some of the heat developed in the combustion chamber. At this time the manual mixture control is placed in the FULL RICH or AUTO RICH position, and the F/A ratio will be at or above the rich best-power mixture.

When operating under cruising conditions of rpm and manifold pressure (MAP), it is possible to set the mixture at the lean best-power value to save fuel and still obtain a maximum value of cruising power from the engine. If it is desired to obtain maximum fuel economy at a particular cruise setting, the manual mixture control can be used to lean the mixture to the best-economy F/A ratio. This will save fuel but will result in a power reduction of as much as 15 percent.

The chart in Fig. 6–14 illustrates graphically the requirements of an aircraft engine with respect to F/A ratio and power output. As shown, a rich mixture is required for very low-power settings and for high-power settings. When the power is in the 60 to 75 percent range, the F/A ratio can be set for lean best power or for best economy. The curve shown in Fig. 6–14 will vary from engine to engine.

The effect of the F/A mixture on cylinder-head and exhaust gas temperatures is illustrated in Fig. 6–15. The temperatures rise as the mixture is leaned to a certain point; however, continued leaning leads to a drop in the tempera-

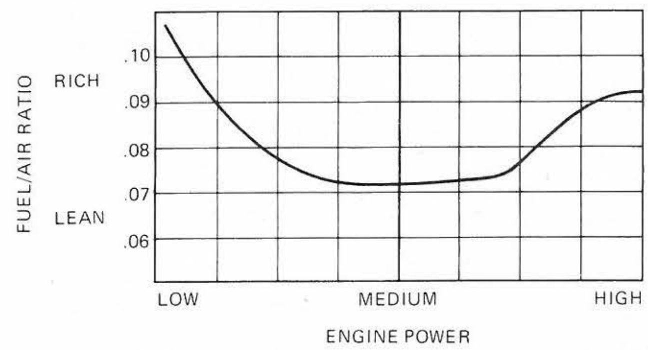


FIG. 6–14 Fuel-air ratios required for different power settings.

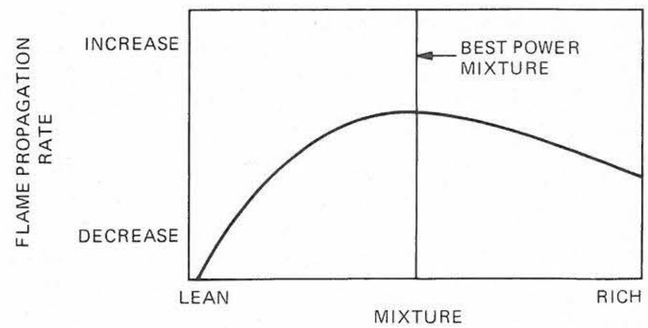


FIG. 6–16 Effect of F/A ratio on flame propagation.

tures. This is true if the engine is not operating at high power settings. An excessively lean mixture may cause an engine to **backfire** through the induction system or to stop completely. A backfire is caused by slow flame propagation. This happens because the F/A mixture is still burning when the engine cycle is completed. The burning mixture ignites the fresh charge when the intake valve opens, the flame travels back through the induction system, the combustible charge is burned, and often any gasoline that has accumulated near the carburetor is burned. This occurs because the flame propagation speed decreases as the mixture is leaned. Thus, a mixture which is lean enough will still be burning when the intake valve opens.

The **flame propagation** in an engine cylinder is the rate at which the flame front moves through the mixture of fuel and air. The flame propagation is most rapid at the best-power setting and falls off substantially on either side of this setting. If the mixture is too lean, the flame propagation will be so slow that the mixture will still be burning when the intake valve opens, thus igniting the mixture in the intake manifold and causing a backfire. The effect of the F/A ratio on flame propagation is illustrated in Fig. 6–16.

Backfiring is *not* the same as **kickback,** which occurs when the ignition is advanced too far at the time that the engine is to be started. If the mixture is ignited before the piston reaches top center, the combustion pressure may cause the piston to reverse its direction and turn the crankshaft against the normal direction of rotation.

Afterfiring is caused when raw fuel is permitted to flow through the intake valve into the cylinder head, then out the

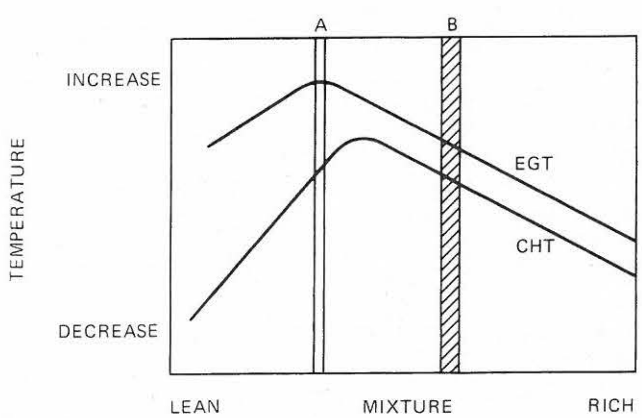


FIG. 6–15 Effects of F/A mixture on cylinder-head and exhaust gas temperatures.

exhaust valve into the exhaust stack, manifold and muffler, and heater muff. The fuel can cause a fire or explosion that can be very damaging to the exhaust and cabin-heating systems.

Effects of Air Density

Density may be defined simply as the *weight per unit volume of a substance.* The weight of 1 cubic foot (ft^3) [28.32 L] of dry air at standard sea-level conditions is 0.076475 lb [0.034 7 kg]. A pound [0.453 6 kg] of air under standard conditions occupies approximately 13 ft^3 [368.16 L].

The density of air is affected by pressure, temperature, and humidity. An increase in pressure will *increase* the density of air, and an increase in humidity will *decrease* the density. Therefore, the F/A ratio is affected by air density. For example, an aircraft engine will have less oxygen to burn with the fuel on a warm day than on a cold day at the same location; that is, the mixture will be richer when the temperature is high, and the engine cannot produce as much power as when the air is cool. The same is true at high altitudes, where air pressure decreases and density decreases. For this reason, pilots usually "lean out" the mixture at higher altitudes to avoid an overrich mixture and waste of fuel.

Water vapor in the air (humidity) decreases the density because a molecule of water weighs less than a molecule of oxygen or a molecule of nitrogen. Therefore, pilots must realize that an engine will not develop as much power on a warm, humid day as it will on a cold, dry day. This is because the less-dense air provides less oxygen for fuel combustion in the engine.

Effect of Pressure Differential in a U-Shaped Tube

Figure 6–17 shows two cross-sectional views of a U-shaped glass tube. In the left view, the liquid surfaces in the two arms of the tube are even because the pressures above them are equal. In the right view, the pressure in the right arm of the tube is reduced while the pressure in the left arm of the tube remains the same as before. This causes the liquid in the left arm to be pushed down while the liquid in the right arm is raised, until the difference in weights of liquid in the two arms are exactly proportional to the difference in forces applied on the two surfaces.

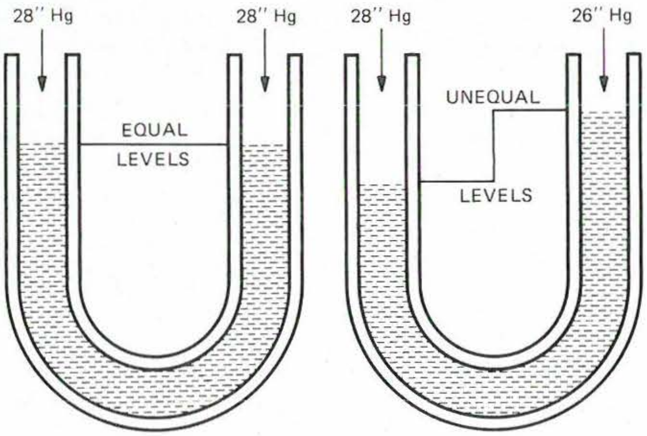


FIG. 6–17 Pressure effects on fluid in a U-shaped tube.

Pressure Differential in a Simple Carburetor

The principle explained in the preceding paragraph is applied in a simple carburetor, such as the one shown in Fig. 6–9. The rapid flow of air through the venturi reduces the pressure at the discharge nozzle so that the pressure in the fuel chamber can force the fuel out into the airstream. Since the airspeed in the tube is comparatively high and there is a relatively great reduction in pressure at the nozzle during medium and high engine speeds, there is a reasonably uniform fuel supply at such speeds.

When the engine speed is low and the pressure drop in the venturi tube is slight, the situation is different. This simple nozzle, otherwise known as a **fuel discharge nozzle,** in a carburetor of fixed size does not deliver a continuously richer mixture as the engine suction and airflow increase. Instead, a plain discharge nozzle will give a fairly uniform mixture at medium and high speeds; but at low speeds and low suction, the delivery falls off greatly in relation to the airflow.

This occurs partly because some of the suction force is consumed in raising the fuel from the float level to the nozzle outlet, which is slightly higher than the fuel level in the fuel chamber to prevent the fuel from overflowing when the engine is not operating. It is also caused by the tendency of the fuel to adhere to the metal of the discharge nozzle and to break off intermittently in large drops instead of forming a fine spray. The discharge from the plain fuel nozzle is therefore retarded by an almost constant force, which is not important at high speeds with high suction but which definitely reduces the flow when the suction is low because of reduced speed.

Figure 6–18 shows how the problem is overcome in the design and construction of the venturi-type carburetor. Air is bled from behind the venturi and passed into the **main discharge nozzle** at a point slightly below the level of the fluid, causing the formation of a finely divided F/A mixture which is fed into the airstream at the venturi. A metering jet between the fuel chamber and the main discharge nozzle controls the amount of fuel supplied to the nozzle. A **metering jet** is an orifice, or opening, which is carefully dimensioned to meter (measure) fuel flow accurately in accordance with the pressure differential between the float chamber and discharge nozzle. The metering jet is an essential part of the main metering system.

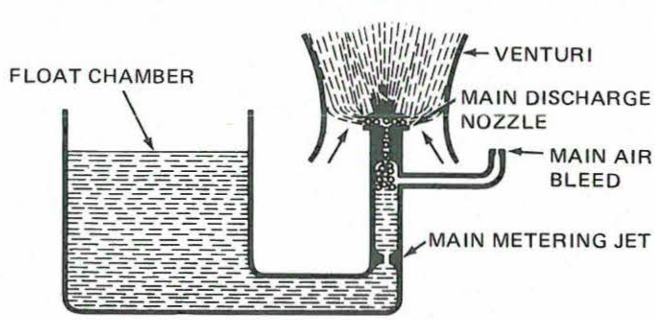


FIG. 6–18 Basic venturi-type carburetor.

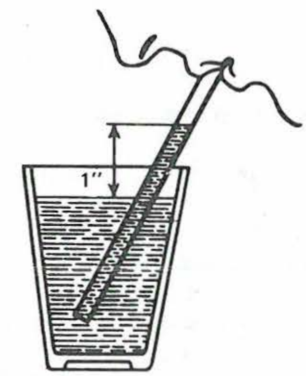


FIG. 6–19 Suction lifts a liquid.

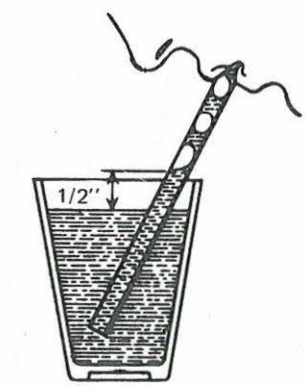


FIG. 6–20 Effects of air bleed.

Air Bleed

The **air bleed** in a carburetor lifts an emulsion of air and liquid to a higher level above the liquid level in the float chamber than would be possible with unmixed fuel. Figure 6–19 shows a person sucking on a straw placed in a glass of water. The suction is great enough to lift the water above the level in the glass without that person drawing any into the mouth. In Fig. 6–20 a tiny hole has been pricked in the side of the straw above the surface of the water in the glass, and the same suction is applied as before. The hole causes bubbles of air to enter the straw, and liquid is drawn up in a series of small drops or slugs.

In Fig. 6–21 the air is taken into a tube through a smaller tube which enters the main tube below the level of the water. There is a restricting orifice at the bottom of the main tube; that is, the size of the main tube is reduced at the bottom. Instead of a continuous series of small drops or slugs being drawn up through the tube when the person

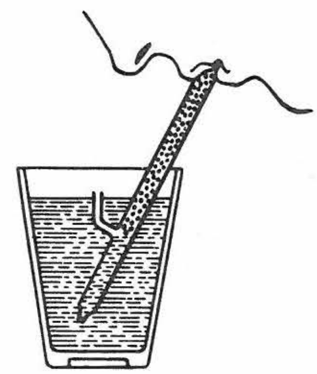


FIG. 6–21 Air bleed breaking up a liquid.

sucks on it, a finely divided mixture of air and water is formed in the tube.

Since there is a distance through which the water must be lifted from its level in the glass before the air begins to pick it up, the free opening of the main tube at the bottom prevents a very great suction from being exerted on the air-bleed hole or vent. If the air openings were too large in proportion to the size of the main tube, the suction available to lift the water would be reduced.

In Fig. 6–21 the ratio of water to air could be modified for high and low airspeeds (produced by sucking on the main tube) by changing the dimensions of the air bleed, the main tube, and the opening at the bottom of the main tube.

The carburetor nozzle in Fig. 6–18 has an air bleed, as explained previously. We can summarize our discussion by stating that the purpose of this air bleed in the discharge nozzle is to assist in the production of a more uniform mixture of fuel and air throughout all operating speeds of the engine.

Vaporization of Fuel

The fuel leaves the discharge nozzle of the carburetor in a stream which breaks up into drops of various sizes suspended in the airstream, where they become even more finely divided. Vaporization occurs on the surface of each drop, causing the very fine particles to disappear and the large particles to decrease in size. The problem of properly distributing the particles would be simple if all the particles in each drop vaporized completely before the mixture left the intake pipe. But some particles of the fuel enter the engine cylinders while they are still in a liquid state and thus must be vaporized and mixed in the cylinder during the compression stroke.

The completeness of vaporization depends on the volatility of the fuel, the temperature of the air, and the degree of atomization. Volatile means readily vaporized; therefore, the more volatile fuels evaporate more readily. Higher temperatures increase the rate of vaporization; therefore, carburetor air intake heaters are sometimes provided. Some engines are equipped with "hot-spot" heaters which utilize the heat of exhaust gases to heat the intake manifold between the carburetor and the cylinders. This is usually accomplished by routing a portion of the engine exhaust through a jacket surrounding the intake manifold. In another type of hot-spot heater, the intake manifold is passed through the oil reservoir of the engine. The hot oil supplies heat to the intake manifold walls, and the heat is transferred to the F/A mixture.

The degree of atomization is the extent to which fine spray is produced; the more fully the mixture is reduced to fine spray and vaporized, the greater is the efficiency of the combustion process. The air bleed in the main discharge nozzle passage aids in the atomization and vaporization of the fuel. If the fuel is not fully vaporized, the mixture may run lean even though an abundance of fuel is present.

Throttle Valve

A **throttle valve,** usually a **butterfly-type valve,** is incorporated in the fuel-air duct to regulate the fuel-air output. The throttle valve is usually an oval-shaped metal disk mounted on the throttle shaft in such a manner that it can completely close the throttle bore. In the closed position, the plane of the disk makes an angle of about 70° with the axis of the throttle bore. The edges of the throttle disk are shaped to fit closely against the sides of the fuel-air passage. The arrangement of such a valve is shown in Fig. 6–22. The amount of air flowing through the venturi tube is reduced when the valve is turned toward its closed position. This reduces the suction in the venturi tube, so that less fuel is delivered to the engine. When the throttle valve is opened, the flow of the F/A mixture to the engine is increased. Opening or closing the throttle valve thus regulates the power output of the engine. In Fig. 6–23, the throttle valve is shown in the OPEN position.

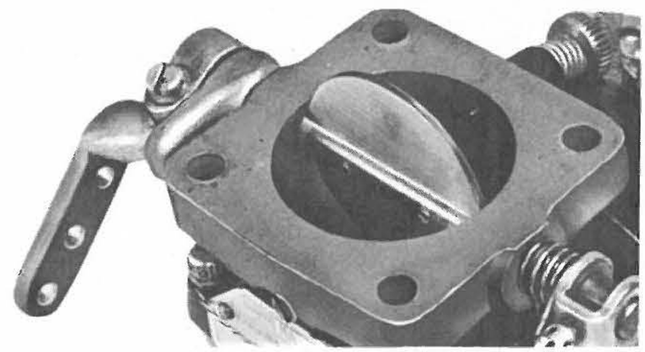


FIG. 6–22 Throttle valve.

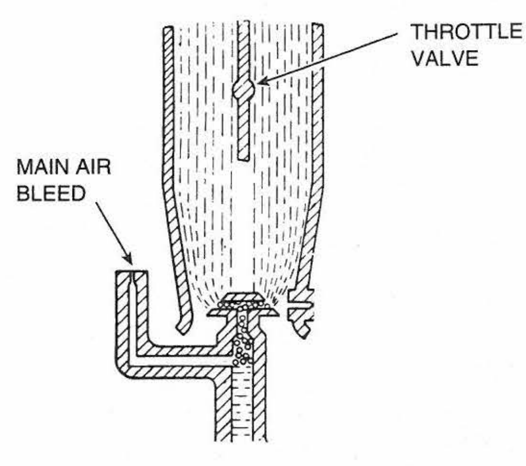


FIG. 6–23 Throttle valve in open position.

FLOAT-TYPE CARBURETORS

Essential Parts of a Carburetor

The carburetor consists essentially of a main air passage through which the engine draws its supply of air, mechanisms to control the quantity of fuel discharged in relation to the flow of air, and a means for regulating the quantity of F/A mixture delivered to the engine cylinders.

The essential parts of a float-type carburetor are (1) the float mechanism and its chamber, (2) the strainer, (3) the main metering system, (4) the idling system, (5) the economizer (or power enrichment) system, (6) the accelerating system, and (7) the mixture control system.

In the float-type carburetor, atmospheric pressure in the fuel chamber forces fuel from the discharge nozzle when the pressure is reduced at the venturi tube. The intake stroke of the piston reduces the pressure in the engine cylinder, thus causing air to flow through the intake manifold to the cylinder. This flow of air passes through the venturi of the carburetor and causes the reduction of pressure in the venturi which, in turn, causes the fuel to be sprayed from the discharge nozzle.

Float Mechanism. As previously explained, the float in a carburetor is designed to control the level of fuel in the float chamber. This fuel level must be maintained slightly below the discharge-nozzle outlet holes to provide the correct amount of fuel flow and to prevent leakage of fuel from the nozzle when the engine is not running. The arrangement of a float mechanism in relation to the discharge nozzle is shown in Fig. 6–24. Note that the float is attached to a lever which is pivoted and that one end of the lever is engaged with the float needle valve. When the float rises, the needle valve closes and stops the flow of fuel into the chamber. At this point, the fuel level is correct for proper operation of the carburetor, provided that the needle valve seat is at the correct level.

As shown in Fig. 6–24, the float valve mechanism includes a needle and a seat. The needle valve is constructed of hardened steel, or it may have a synthetic-rubber section which fits the seat. The needle seat is usually made of bronze. There must be a good fit between the needle and seat to prevent fuel leakage and overflow from the discharge nozzle.

During operation of the carburetor, the float assumes a position slightly below its highest level, to allow a valve opening sufficient for replacement of the fuel as it is drawn out through the discharge nozzle. If the fuel level in the float chamber is too high, the mixture will be rich; if the fuel is too low, the mixture will be lean. To adjust the fuel level for the carburetor shown in Fig. 6–24, washers are placed under the float needle seat. If the fuel level (float level) needs to be raised, washers are removed from under the seat. If the level needs to be lowered, washers are added. The specifications for the float level are given in the manufacturer's overhaul manual.

For some carburetors, the float level is adjusted by bending the float arm.

Figure 6–25 shows two additional types of float mechanisms. The upper drawing illustrates the **concentric** (having a common center) float and valve, while the lower drawing illustrates an **eccentric** (off-center) float and valve.

Fuel Strainer. In most carburetors, the fuel supply must first enter a strainer chamber, where it passes through a strainer screen. The **strainer** consists of a fine wire mesh

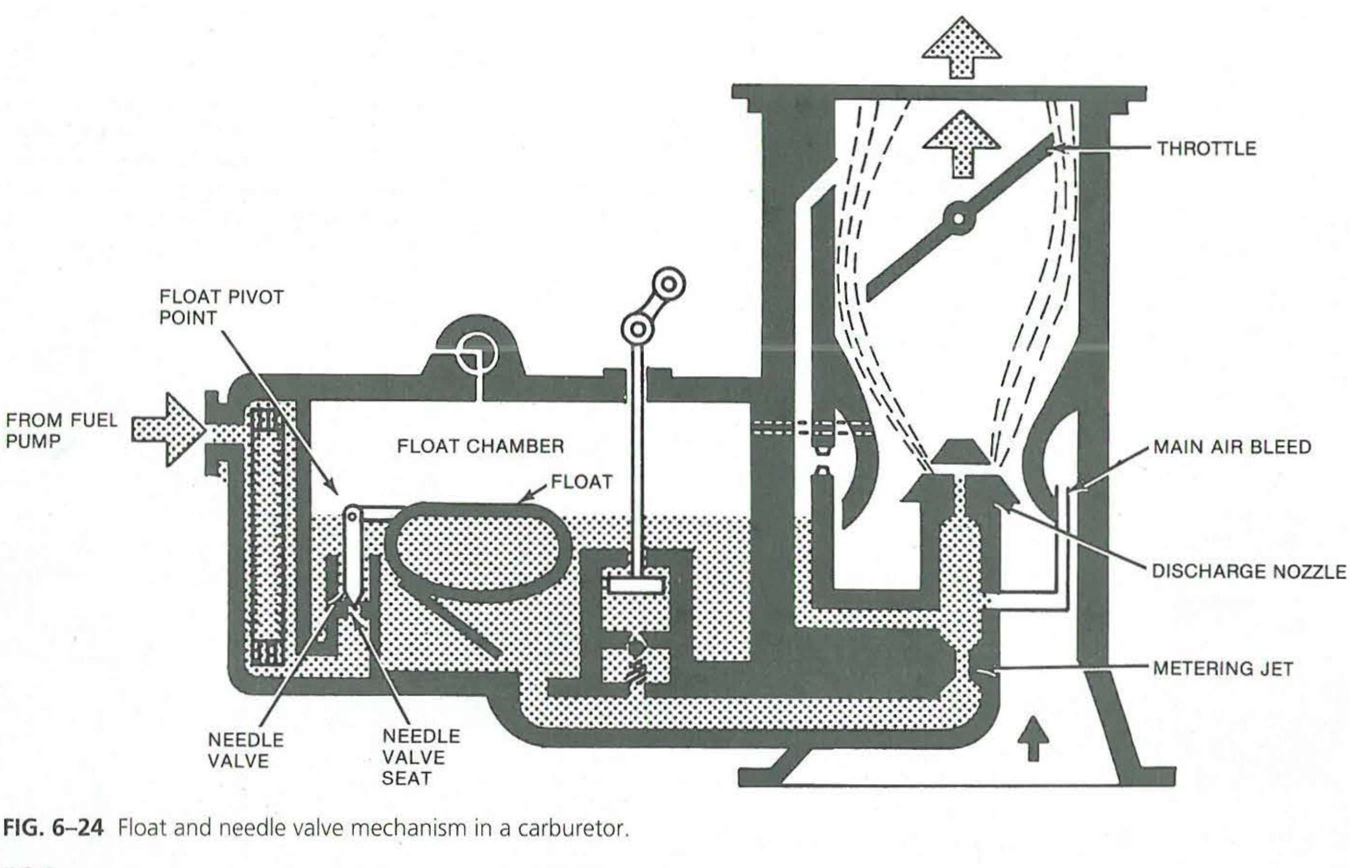


FIG. 6–24 Float and needle valve mechanism in a carburetor.

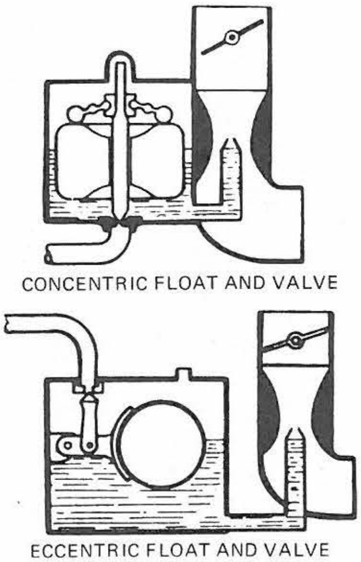


FIG. 6–25 Concentric and eccentric float mechanisms.

or other type of filtering device, cone-shaped or cylindrically shaped, located so that it will intercept any dirt particles which might clog the needle valve opening or, later, the metering jets. The strainer is usually removable so that it can be taken out and thoroughly drained and flushed. A typical strainer is shown in Fig. 6–26.

Main Metering System. The **main metering system** controls the fuel feed in the upper half of the engine speed range as used for cruising and full-throttle operations. It consists of three principal divisions, or units: (1) the **main metering jet,** through which fuel is drawn from the float chamber; (2) the **main discharge nozzle,** which may be any one of several types; and (3) the **passage leading to the idling system.**

Although the previous statement is correct, some authorities state that the purpose of the main metering system is to maintain a constant F/A mixture at all throttle openings throughout the power range of engine operation. The same authorities divide the main metering system into four parts: (1) the venturi, (2) a metering jet which measures the fuel drawn from the float chamber, (3) a main discharge nozzle, including the main air bleed, and (4) a passage leading to the idling system. These are merely two different approaches to the same thing.

The three functions of the main metering system are (1) to proportion the F/A mixture, (2) to decrease the pressure at the discharge nozzle, and (3) to control the airflow at full throttle.

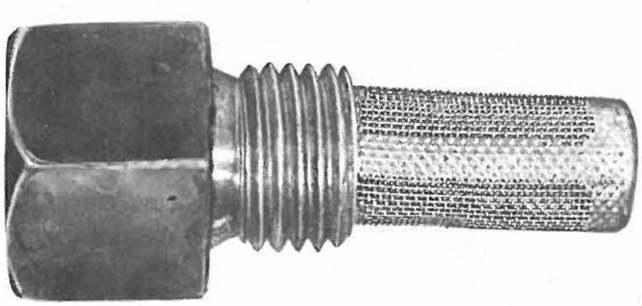


FIG. 6–26 Carburetor fuel strainer.

The airflow through an opening of fixed size and the fuel flow through an air-bleed jet system respond to variations of pressure in approximately equal proportions. If the discharge nozzle of the air-bleed system is located in the center of the venturi, so that both the air-bleed nozzle and the venturi are exposed to the suction of the engine in the same degree, it is possible to maintain an approximately uniform mixture of fuel and air throughout the power range of engine operations. This is illustrated in Fig. 6–27, which shows the air-bleed principle and the fuel level of the float chamber in a typical carburetor. If the main air bleed of a carburetor should become restricted or clogged, the F/A mixture would be excessively rich because more of the available suction would be acting on the fuel in the discharge nozzle and less air would be introduced with the fuel.

The full-power output from the engine makes it necessary to have, above the throttle valve, a manifold suction (reduced pressure, or partial vacuum) which is between 0.4 and 0.8 psi [2.8 and 5.5 kPa] at full engine speed. However, more suction is desired for metering and spraying the fuel and is obtained from the venturi. When a discharge nozzle is located in the central portion of the venturi, the suction obtained is several times as great as the suction found in the intake manifold. Thus, it is possible to maintain a relatively low manifold vacuum (high MAP). This results in high volumetric efficiencies. In contrast, high manifold vacuums result in low volumetric efficiencies.

We have stated previously that the venturi tube affects the air capacity of the carburetor. Therefore, the tube should be obtainable in various sizes, so that it can be selected according to the requirements of the particular engine for which the carburetor is designed. The main metering system for a typical carburetor is shown in Fig. 6–28.

Idling System. At idling speeds, the airflow through the venturi of the carburetor is too low to draw sufficient fuel from the discharge nozzle, so the carburetor cannot deliver enough fuel to keep the engine running. At the same time, with the throttle nearly closed, the air velocity is high and the pressure is low between the edges of the throttle

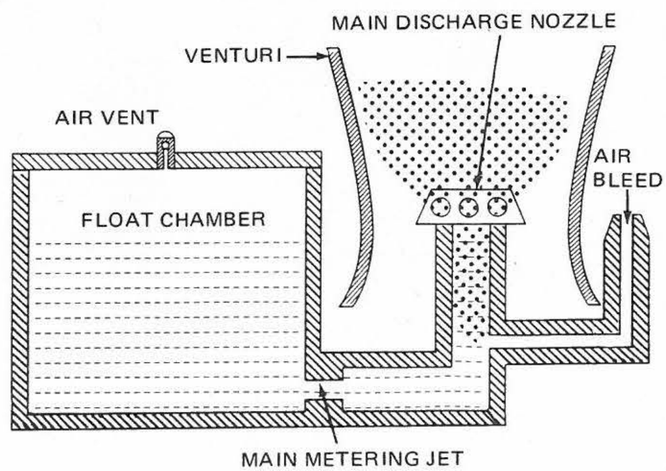


FIG. 6–27 Location of air-bleed system and main discharge nozzle.

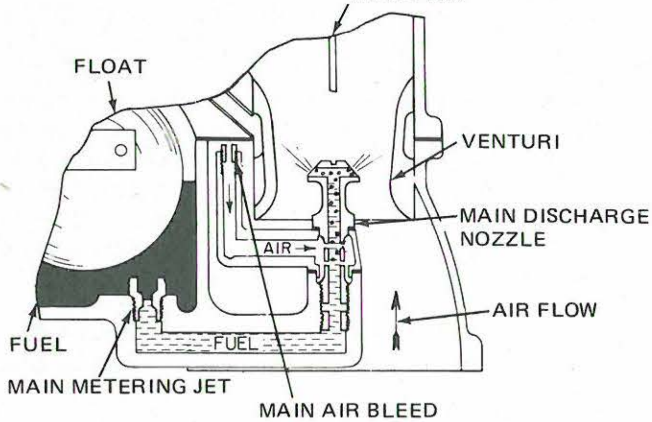


FIG. 6–28 Main metering system in a carburetor. *(Energy Controls Div., Bendix Corp.)*

valve and the walls of the air passages. Furthermore, there is very high suction on the intake side of the throttle valve. Because of this situation, an idling system with an outlet at the throttle valve is added. This idling system delivers fuel only when the throttle valve is nearly closed and the engine is running slowly. An **idle cutoff** valve stops the flow of fuel through this idling system on some carburetors, and this is used for stopping the engine. An increased amount of fuel (richer mixture) is used in the idle range because at idling speeds there may not be enough air flowing around its cylinders to provide proper cooling.

Figure 6–29 shows a three-piece main discharge assembly, with a main discharge nozzle, main air bleed, main-discharge-nozzle stud, idle feed passage, main metering jet, and accelerating well screw. This is one of the two types of main discharge nozzle assemblies used in updraft, float-type carburetors. An **updraft carburetor** is one in which the air flows upward through the carburetor to the engine. In the other type, the main discharge nozzle and the main-discharge-nozzle stud are combined in one piece that is screwed directly into the discharge-nozzle boss, which is

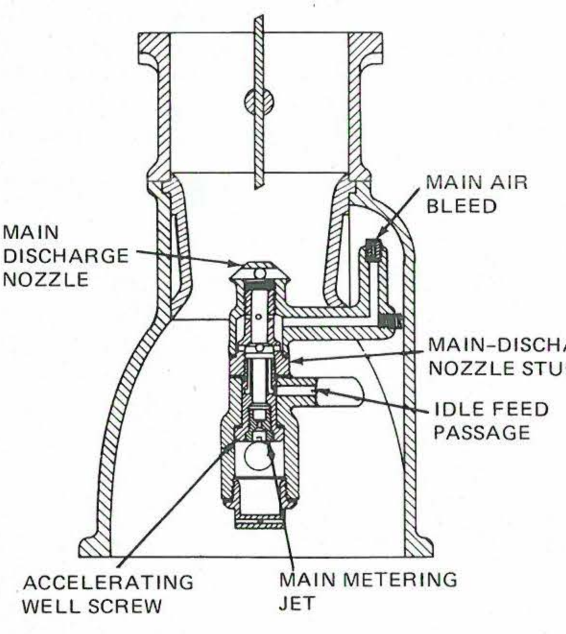


FIG. 6–29 Three-piece main discharge assembly.

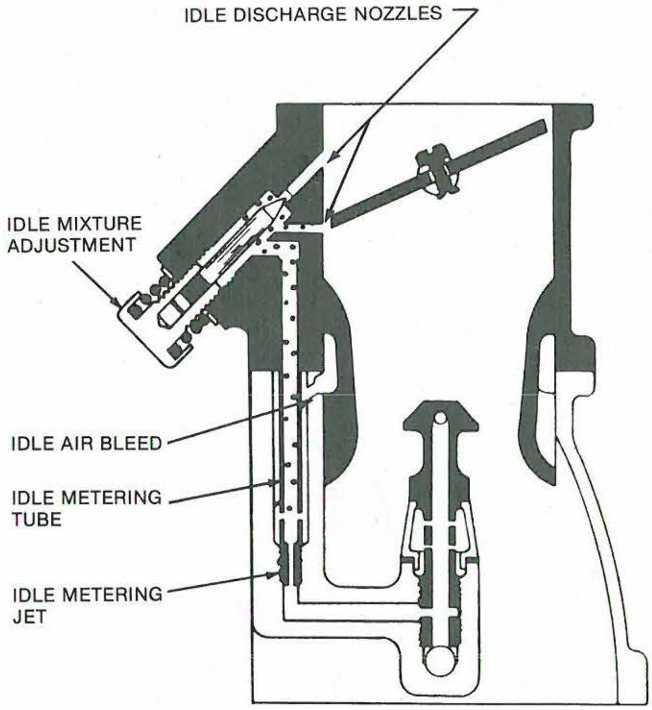


FIG. 6–30 Conventional idle system.

part of the main body casting, thereby eliminating the necessity of having a discharge-nozzle screw.

Figure 6–30 is a drawing of a conventional idle system, showing the idling discharge nozzles, the mixture adjustment, the idle air bleed, the idle metering jet, and the idle metering tube. Note that the fuel for the idling system is taken from the fuel passage for the main discharge nozzle and that the idle air-bleed air is taken from a chamber outside the venturi section. Thus the idle air is at air inlet pressure. The idle discharge is divided between two discharge nozzles, and the relative quantities of fuel flowing through these nozzles are dependent on the position of the throttle valve. At very low idle, all the fuel passes through the upper orifice, since the throttle valve covers the lower orifice. In this case, the lower orifice acts as an additional air bleed for the upper orifice. As the throttle is opened further, exposing the lower orifice, additional fuel passes through this opening.

Since the idle-mixture requirements vary with climatic conditions and altitude, a needle valve type of mixture adjustment is provided to vary the orifice in the upper idle discharge hole. Moving this needle in or out of the orifice varies the idle fuel flow accordingly, to supply the correct F/A ratio to the engine.

The idling system described above is used in the Bendix-Stromberg NA-S3A1 carburetor and is not necessarily employed in other carburetors. The principles involved are similar in all carburetors, however.

Figure 6–31A, B, and C show a typical float-type carburetor at idling speed, medium speed, and full speed, respectively. The greatest suction (pressure reduction) in the intake manifold above the throttle is at the lowest speeds, when the smallest amount of air is received, which is also the condition requiring the smallest amount of fuel. When the engine speed increases, more fuel is needed, but the suction in the manifold decreases. For this reason, the

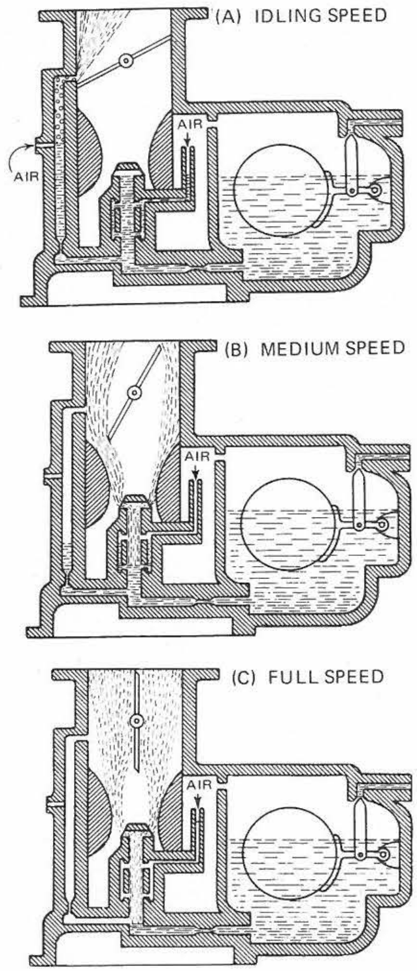


FIG. 6–31 Float-type carburetor at different engine speeds.

metering of the idling system is not accomplished by the suction existing in the intake manifold. Instead, the metering is controlled by the suction existing in a tiny intermediate chamber, or slot, formed by the idling discharge nozzle and the wall of the carburetor at the edge of the throttle valve. This chamber has openings into the barrel of the carburetor, both above and below the throttle.

In Fig. 6–30 and 6-31, note that there is a small chamber surrounding the main discharge-nozzle passage just below the main air-bleed inlet. This chamber serves as an **accelerating well** to store extra fuel that is drawn out when the throttle is suddenly opened. If this extra supply of fuel were not immediately available, the fuel flow from the discharge nozzle would be momentarily decreased and the mixture entering the combustion chamber would be too lean, thereby causing the engine to hesitate or misfire.

In the carburetor shown in Fig. 6–31, when the engine is operating at intermediate speed, the accelerating well still holds some fuel. However, when the throttle is wide open, all the fuel from the well is drawn out. At full power, all fuel is supplied through the main discharge and economizer system, and the idling system then acts as an auxiliary air bleed to the main metering system. The main metering jet provides an approximately constant mixture ratio for all speeds above idling, but it has no effect during idling. Remember that the purpose of the accelerating well is to prevent a power lag when the throttle is opened suddenly.

In many carburetors, an **accelerating pump** is used to force an extra supply of fuel from the discharge nozzle when the throttle is opened quickly.

Accelerating System. When the throttle controlling an engine is suddenly opened, there is a corresponding increase in the airflow; but because of the inertia of the fuel, the fuel flow does not accelerate in proportion to the airflow increase. Instead, the fuel lags behind, which results in a temporarily lean mixture. This, in turn, may cause the engine to miss or backfire, and it is certain to cause a temporary reduction in power. To prevent this condition, all carburetors are equipped with an **accelerating system.** This is either an accelerating pump or an accelerating well, mentioned previously. The function of the accelerating system is to discharge an additional quantity of fuel into the carburetor airstream when the throttle is opened suddenly, thus causing a temporary enrichment of the mixture and producing a smooth and positive acceleration of the engine.

The accelerating well is a space around the discharge nozzle and is connected by holes to the fuel passage leading to the discharge nozzle. The upper holes are located near the fuel level and are uncovered at the lowest pressure that will draw fuel from the main discharge nozzle; therefore, they receive air during the entire time that the main discharge nozzle operates.

Very little throttle opening is required at idling speeds. When the throttle is opened suddenly, air is drawn in to fill the intake manifold and whichever cylinder is on the intake stroke. This sudden rush of air temporarily creates a high suction at the main discharge nozzle, brings into operation the main metering system, and draws additional fuel from the accelerating well. Because of the throttle opening, the engine speed increases and the main metering system continues to function.

The accelerating pump illustrated in Fig. 6–32 is a sleeve-type piston pump operated by the throttle. The piston is mounted on a stationary hollow stem screwed into the body of the carburetor. The hollow stem opens into the main fuel passage leading to the discharge nozzle. Mounted over the stem and piston is a movable cylinder, or sleeve, which is connected by the pump shaft to the throttle linkage. When the throttle is closed, the cylinder is raised and the space within the cylinder fills with fuel through the clearance between the piston and the cylinder. If the throttle is quickly moved to the open position, the cylinder is

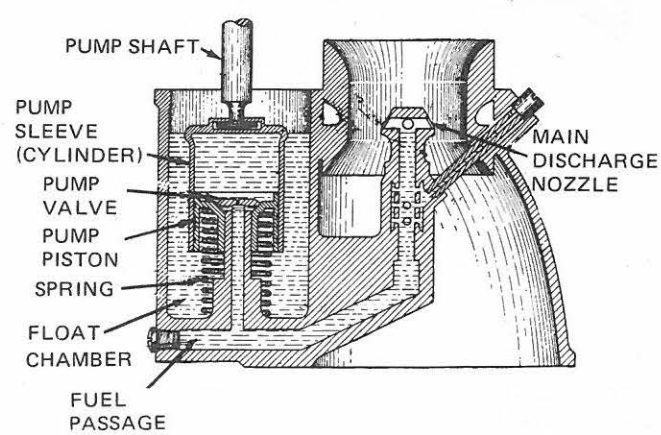


FIG. 6–32 Movable-piston-type accelerating pump.

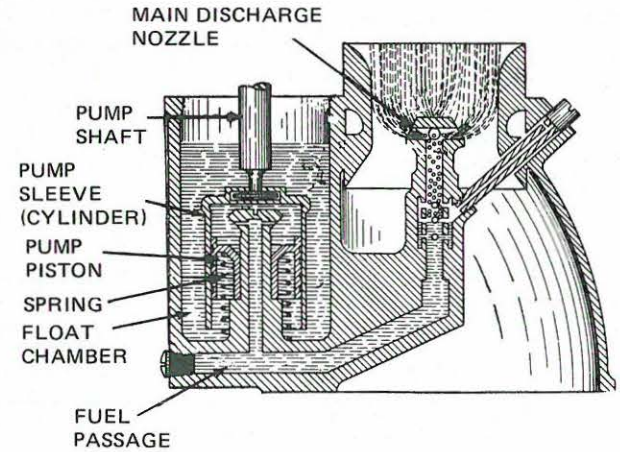


FIG. 6–33 Accelerating pump in operation.

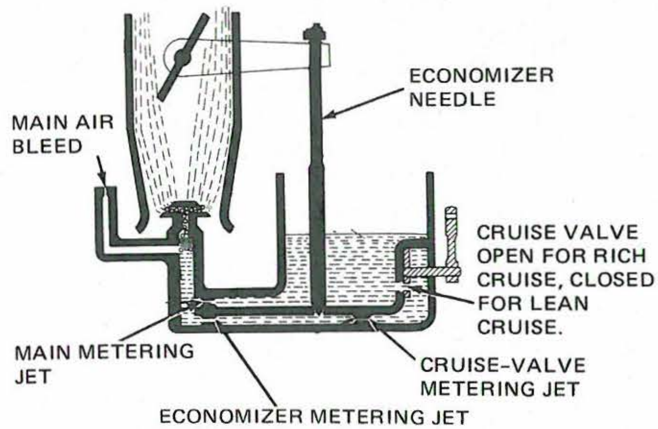


FIG. 6–34 Needle valve economizer.

forced down, as shown in Fig. 6–33, and the increased fuel pressure also forces the piston partway down along the stem. As the piston moves down, it opens the pump valve and permits the fuel to flow through the hollow stem into the main fuel passage. With the throttle fully open and the accelerating pump cylinder all the way down, the spring pushes the piston up and forces most of the fuel out of the cylinder. When the piston reaches its highest position, it closes the valve and no more fuel flows toward the main passage.

There are several types of accelerating pumps, but each serves the purpose of providing extra fuel during rapid throttle opening and acceleration of the engine.

When a throttle is moved slowly toward the OPEN position, the accelerating pump does not force extra fuel into the discharge system, because the spring in the pump holds the valve closed unless the fuel pressure is great enough to overcome the spring pressure. When the throttle is moved slowly, the trapped fuel seeps out through the clearance between the piston and the cylinder, and the pressure does not build up enough to open the valve.

Economizer System. An **economizer,** or **power enrichment system,** is essentially a valve which is closed at low engine and cruising speeds but is opened at high speeds to provide an enriched mixture to reduce burning temperatures and prevent detonation. In other words, this system supplies and regulates the additional fuel required for all speeds above the cruising range. An economizer is also a device for enriching the mixture at increased throttle settings. It is important, however, that the economizer close properly at cruising speed; otherwise, the engine may operate satisfactorily at full throttle but will "load up" at and below cruising speed because of the extra fuel being fed into the system. The extra-rich condition is indicated by rough running and by black smoke emanating from the exhaust.

The economizer gets its name from the fact that it enables the pilot to obtain maximum economy in fuel consumption by providing for a lean mixture during cruising operation and a rich mixture for full-power settings. Most economizers in their modern form are merely enriching devices. The carburetors equipped with economizers are normally set for their leanest practical mixture delivery at cruising speeds, and enrichment takes place as required for higher power settings.

Three types of economizers for float-type carburetors are (1) the needle valve type, (2) the piston type, and (3) the MAP operated type. Figure 6–34 illustrates the **needle valve economizer.** This mechanism utilizes a needle valve which is opened by the throttle linkage at a predetermined throttle position. This permits a quantity of fuel, in addition to the fuel from the main metering jet, to enter the discharge-nozzle passage. As shown in Fig. 6–34, the economizer needle valve permits fuel to bypass the cruise-valve metering jet.

The **piston-type economizer,** illustrated in Fig. 6–35, is also operated by the throttle. The lower piston serves as a fuel valve, preventing any flow of fuel through the system at cruising speeds. (See view A.) The upper piston functions as an air valve, allowing air to flow through the separate economizer discharge nozzle at part throttle. As the throttle is opened to higher power positions, the lower piston uncovers the fuel port leading from the economizer metering valve and the upper piston closes the air ports (view B). Fuel fills the economizer well and is discharged into the carburetor venturi where it adds to the fuel from the main discharge nozzle. The upper piston of the economizer permits a small amount of air to bleed into the fuel, thus assisting in the atomization of the fuel from the economizer system. The space below the lower piston of the economizer acts as an accelerating well when the throttle is opened.

The **MAP-operated economizer,** illustrated in Fig. 6–36, has a bellows which is compressed when the pressure from the engine blower rim produces a force greater than the resistance of the compression spring in the bellows chamber. As the engine speed increases, the blower pressure also increases. This pressure collapses the bellows and causes the economizer valve to open. Fuel then flows through the economizer metering jet to the main discharge system. The operation of the bellows and spring is stabilized by means of a dashpot, as shown in the drawing.

Mixture Control System. At higher altitudes, the air is under less pressure, has less density, and is at a lower temperature. The weight of the air taken into an unsupercharged (naturally aspirated) engine decreases with the decrease in air density, and the power is reduced in approximately the same proportion. Since the quantity of oxygen taken into the engine decreases, the F/A mixture becomes too rich for normal operations. The mixture proportion

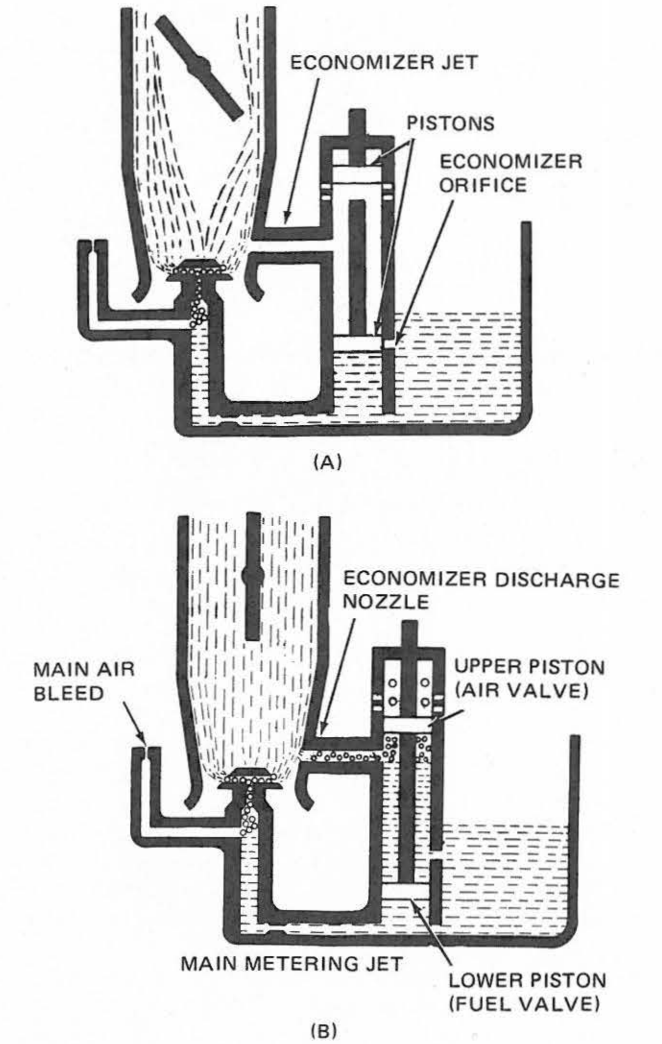


FIG. 6–35 Piston-type economizer.

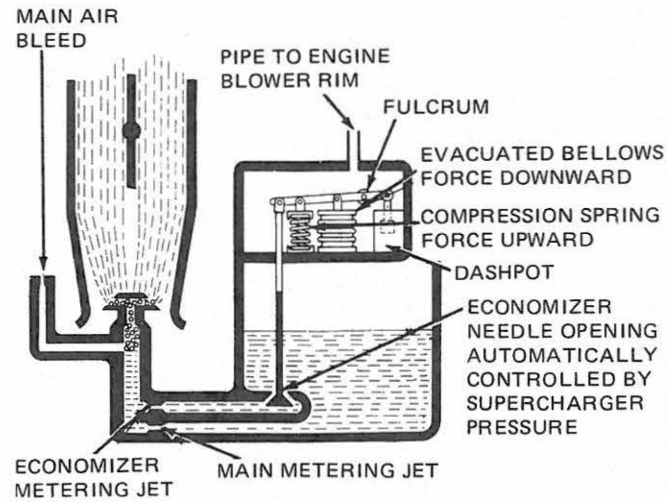


FIG. 6–36 MAP-operated economizer.

delivered by the carburetor becomes richer at a rate inversely proportional to the square root of the increase in air density.

Remember that the density of the air changes with temperature and pressure. If the pressure remains constant, the density of air will vary according to temperature, increasing as the temperature drops. This will cause leaning of the F/A mixture in the carburetor because the denser air contains more oxygen. The change in air pressure due to altitude is considerably more of a problem than the change in density due to temperature changes. At an altitude of 18,000 ft [5 486.4 m], the air pressure is approximately one-half the pressure at sea level. Therefore, to provide a correct mixture, the fuel flow must be reduced to almost one-half what it would be at sea level. Adjustment of fuel flow to compensate for changes in air pressure and temperature is a principal function of the mixture control.

Briefly, a **mixture control system** can be described as a mechanism or device through which the richness of the mixture entering the engine during flight can be controlled to a reasonable extent. This control should be maintainable at all normal altitudes of operation.

The functions of the mixture control system are (1) to prevent the mixture from becoming too rich at high altitudes and (2) to economize on fuel during engine operation in the low-power range where cylinder temperature will not become excessive with the use of the leaner mixture.

Mixture control systems may be classified according to their principles of operation as (1) the **back-suction** type, which reduces the effective suction on the metering system; (2) the **needle** type, which restricts the flow of fuel through the metering system; and (3) the **air-port** type, which allows additional air to enter the carburetor between the main discharge nozzle and the throttle valve. Figure 6–37 shows two views of a back-suction-type mixture control

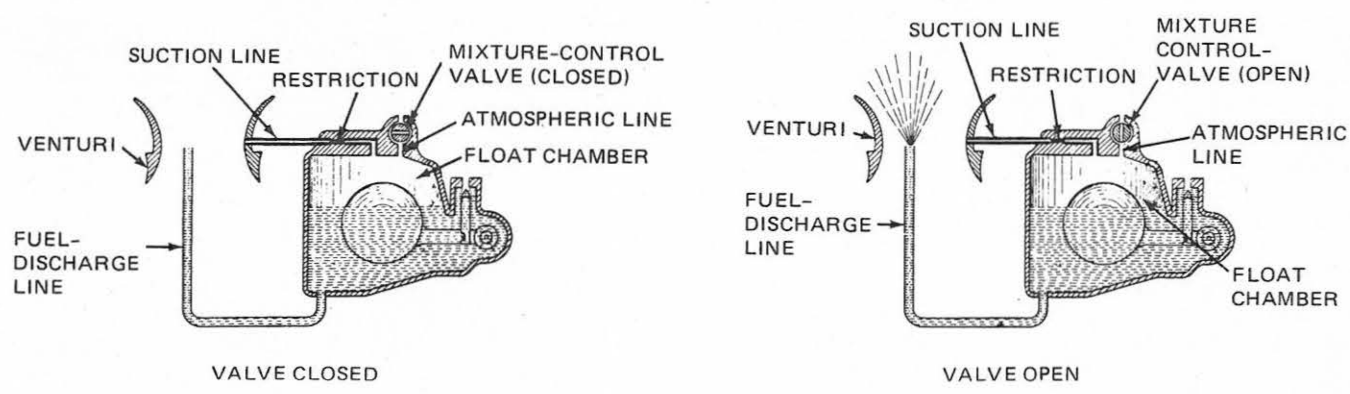


FIG. 6–37 Back-suction-type mixture control.

system. The left view shows the mixture control valve in the closed position. This cuts off the atmospheric pressure from the space above the fuel in the fuel chamber. Since the float chamber is connected to the low-pressure area in the venturi of the carburetor, the pressure above the fuel in the float chamber will be reduced until fuel is no longer delivered from the discharge nozzle. This acts as an idle cutoff and stops the engine. In some carburetors, the end of the back-suction tube is located where the pressure is somewhat higher than that at the nozzle, thus making it possible for the mixture control valve to be completely closed without stopping the flow of fuel. The fuel flow is varied by adjusting the opening of the mixture control valve. To lean the mixture, the valve is moved toward the closed position; to enrich the mixture, the valve is moved toward the open position. The right-hand drawing in Fig. 6–37 shows the valve in the full rich position.

To reduce the sensitivity of the back-suction mixture control, a disk-type valve is sometimes used. This valve is constructed so that a portion of the valve opening can be closed rapidly at first and the remainder of the opening can be closed gradually. A disk-type mixture control valve is shown in Fig. 6–38. This assembly is called an **altitude-control-valve disk and plate.** The arrangement of the mixture control for an NA-S3A1 carburetor is shown in Fig. 6–39.

A needle-type mixture control is shown in Fig. 6–40. In this control, the needle is used to restrict the fuel passage through the main metering jet. When the mixture control is in the full rich position, the needle is in the fully raised position and the fuel is accurately measured by the main metering jet. The needle valve is lowered into the needle valve seat to lean the mixture, thus reducing the supply of fuel to the main discharge nozzle. Even though the needle valve is completely closed, a small bypass hole from the float chamber to the fuel passage allows some fuel to flow; therefore, the size of this bypass hole determines the control range.

The air-port type of mixture control, illustrated in Fig. 6–41, has an air passage leading from the region between the venturi tube and the throttle valve to atmospheric pressure. In the air passage is a butterfly valve which is manually controlled by the pilot in the cockpit. Obviously, when the pilot opens the butterfly valve in the air passage, air which has not been mixed with fuel will be injected into the F/A mixture. At the same time, the suction in the intake manifold will be reduced, thereby reducing the velocity of the air coming through the venturi tube. This will further reduce the amount of fuel being drawn into the intake manifold.

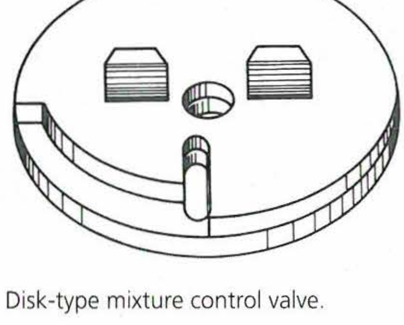


FIG. 6–38 Disk-type mixture control valve.

Idle Cutoff. The term "idle cutoff" has been mentioned previously; it describes the position of certain mixture controls in which the control is enabled to stop the flow of fuel into the intake airstream. Some float-type carburetors and the majority of pressure-type carburetors incorporate the IDLE CUTOFF position in the mixture control system.

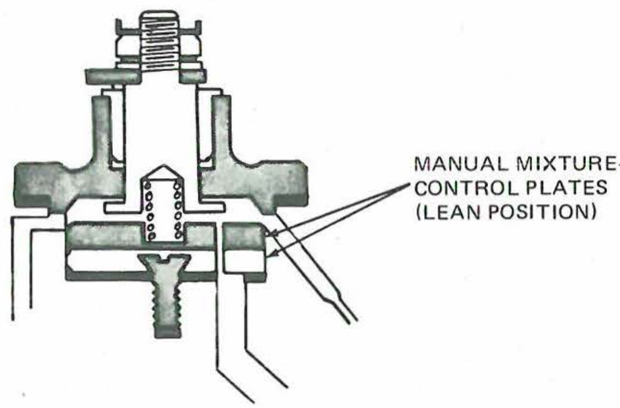


FIG. 6–39 Mixture control for NA-S3A1 carburetor.

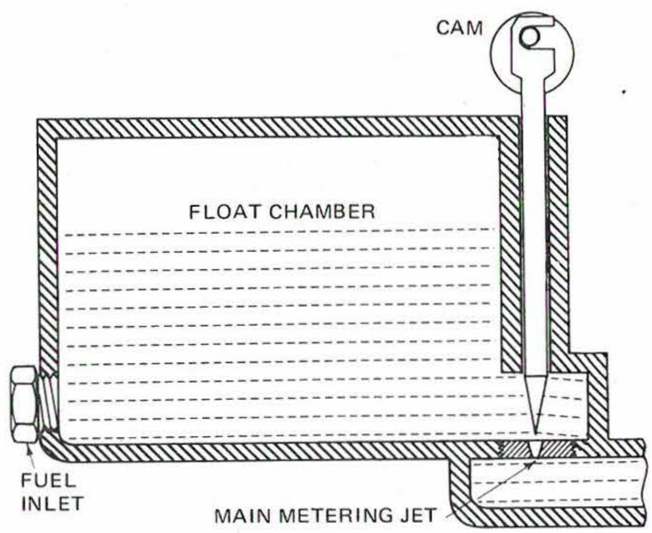


FIG. 6–40 Needle-type mixture control.

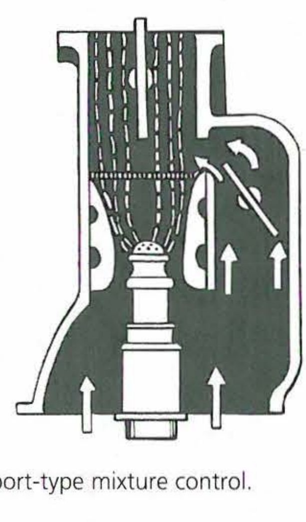


FIG. 6–41 Air-port-type mixture control.

Essentially, the idle cutoff system stops the flow of fuel from the discharge nozzle and is therefore used to stop the engine. This provides an important safety factor, because it eliminates the combustible mixture in the intake manifold and prevents the engine from firing as a result of a hot spot in one or more cylinders. In some cases, engines which have been stopped by turning off the ignition switch have kicked over after stopping, thus creating a hazard to someone who may move the propeller. In an engine equipped with the idle cutoff feature, the engine ignition switch is turned off *after* the engine is first stopped by means of moving the mixture control to the idle cutoff position. This procedure also eliminates the possibility of unburned fuel entering the cylinder and washing the oil film from the cylinder walls.

Automatic Mixture Control. Some of the more complex aircraft carburetors are often equipped with a device for automatically controlling the mixture as altitude changes. **Automatic mixture control (AMC) systems** may be operated on the back-suction principle and the needle valve principle or by throttling the air intake to the carburetor. In the latter type of AMC, the control regulates power output within certain limits in addition to exercising its function as a mixture control.

In AMC systems operating on the back-suction and needle valve principles, the control may be directly operated by the expansion and contraction of a pressure-sensitive evacuated bellows through a system of mechanical linkage. This is the simplest form of AMC and is generally found to be accurate, reliable, and easy to maintain. Some mixture control valves, such as the one illustrated in Fig. 6–42, are operated by a sealed bellows in a compartment vented to the atmosphere; therefore, the fuel flow is proportional to the atmospheric pressure. Figure 6–43 shows the bellows type of mixture control valve installed on a carburetor as a back-suction control device. As atmospheric pressure decreases, the bellows will expand and begin to close the opening into the fuel chamber. This will cause a reduction of pressure in the chamber, resulting in a decreased flow of fuel from the discharge nozzle. In some systems equipped with external superchargers (not illustrated here), both the fuel chamber and the bellows may be vented to the carburetor intake to obtain the correct mixtures of fuel and air.

Automatic controls often have more than one setting in order to obtain the correct mixtures for cruising and high-speed operation. In addition to the automatic control feature, there is usually a provision for manual control if the automatic control fails.

When the engine is equipped with a fixed-pitch propeller which allows the engine speed to change as the mixture changes, a manually operated mixture control can be adjusted by observing the change in engine rpm as the control is moved. Obviously, this will not work with a constant-speed propeller.

If a constant-speed propeller cannot be locked into fixed-pitch position, and if the extreme-pitch positions cause engine speeds outside the normal operating range in flight, it is necessary to have an instrument of some type that indicates the F/A ratio or power output.

If the propeller can be locked in a fixed-pitch position, and if this does not lead to engine speeds outside the normal flight operating range, the following expressions may be employed to describe the manual adjustments of the mixture control.

Full rich. The mixture control setting in the position for maximum fuel flow.

Rich best power. The mixture control setting which, at a given throttle setting, permits maximum engine rpm with the mixture control as far toward full rich as possible without reducing the rpm.

Lean best power. The mixture control setting which, at a given throttle setting, permits maximum engine rpm with the mixture control as far toward lean as possible without reducing the rpm.

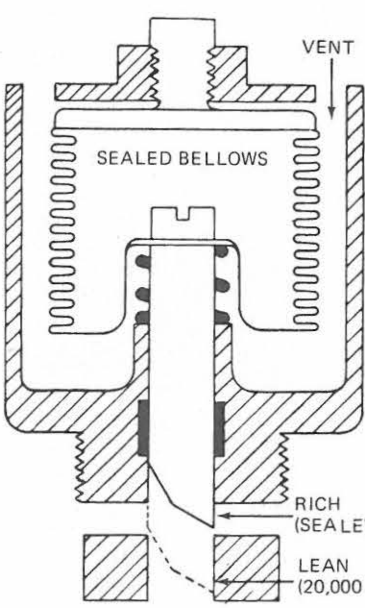


FIG. 6–42 AMC mechanism.

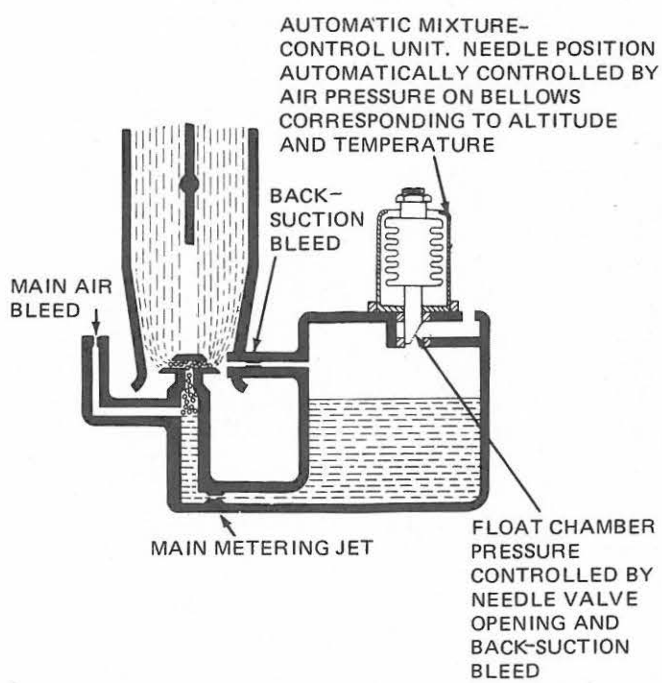


FIG. 6–43 AMC in operation.

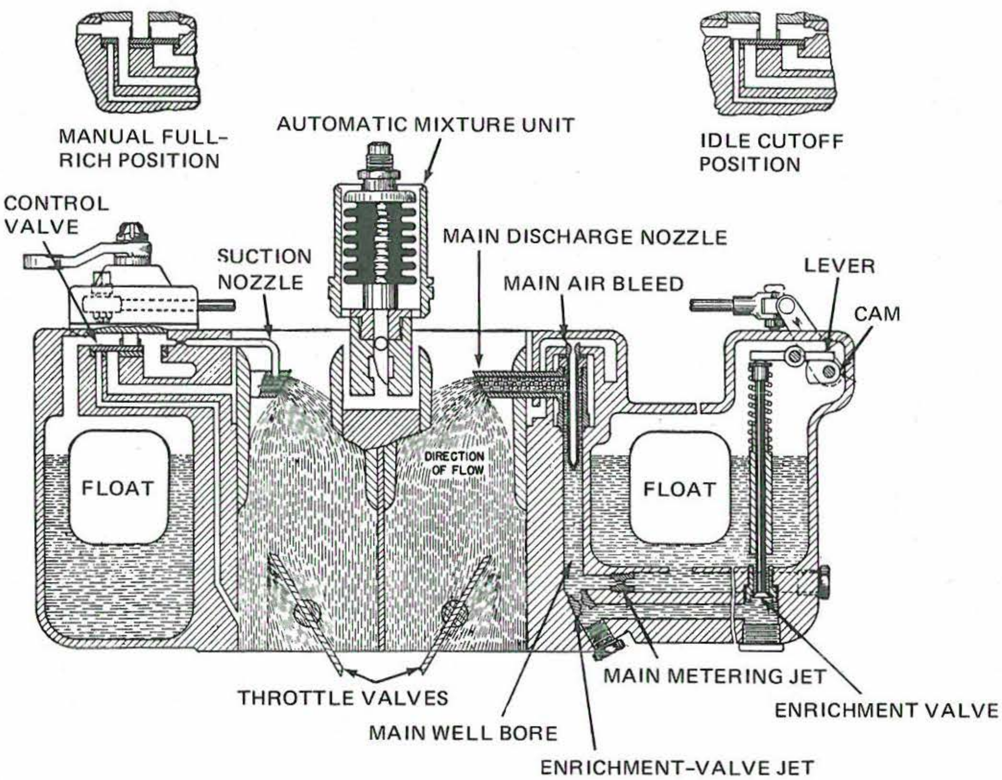


FIG. 6–44 Downdraft carburetor.

Downdraft Carburetors

So far we have principally dealt with updraft carburetors. Updraft means that the air through the carburetor is flowing upward. A **downdraft carburetor** (Fig. 6–44) takes air from above the engine and causes the air to flow down through the carburetor. Those who favor downdraft carburetors claim that they reduce fire hazard, provide better distribution of mixture to the cylinders of an upright engine, and have less tendency to pick up sand and dirt from the ground.

Downdraft carburetors are very similar in function and systems to the updraft types. Figure 6–44 illustrates one of several types of downdraft carburetors used for aircraft. This particular model has two float chambers, two throttle valves, and an AMC unit.

Figure 6–45 illustrates a portion of a downdraft carburetor and its idling system, emphasizing the path of the fuel leaving the float chamber and the position of the idle air bleed. When the engine is not operating, this air bleed, in addition to its other functions, prevents the siphoning of fuel. An average intake pressure to the mixture control system is supplied by the series of vents at the entrance to the venturi.

Model Designation

All Bendix-Stromberg float-type aircraft carburetors carry the general model designation NA followed by a hyphen; the next letter indicates the type, as shown in Fig. 6-46.

Following the type letter is a numeral that indicates the nominal rated size of the carburetor, starting at 1 in [2.54 cm], which is no. 1, and increasing in ¼-in [6.35-mm] steps. For example, a 2-in [5.08-cm] carburetor is rated no. 5. The actual diameter of the carburetor barrel opening is $\frac{3}{16}$ in [4.76 mm] greater than the nominal rated size, in accordance with the standards of the Society of Automotive Engineers (SAE). A final letter is used to designate various models of a given type. This system of model designation applies to inverted or downdraft as well as updraft carburetors. The model designation and serial number are found on an aluminum tag riveted to the carburetor. There are so many Bendix-Stromberg carburetors that it is necessary to consult the publications of the manufacturer to learn the details of the designation system, but the explanation above is ample for ordinary purposes.

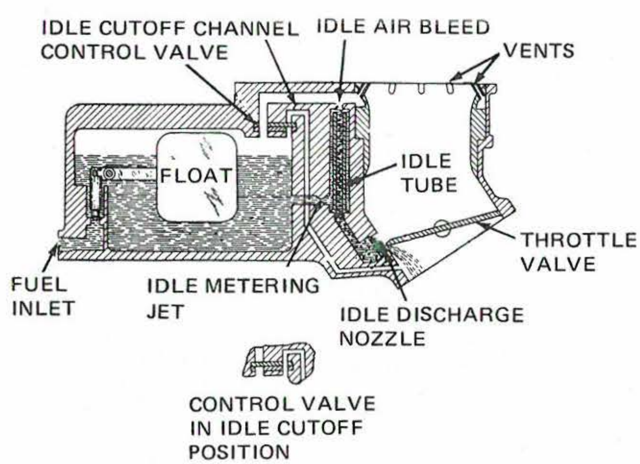


FIG. 6–45 Downdraft carburetor and its idling system.

Type letter	Type Description
S and R	Single barrel
D	Double barrel, float chamber to rear (obsolescent)
U	Double barrel, float chamber between barrels
Y	Double barrel, double chamber fore and aft of barrels
T	Triple barrel, double float chamber fore and aft of barrels
F	Four barrel, two separate float chambers

FIG. 6–46 Basic Bendix-Stromberg model designation system for carburetors.

Typical Float-Type Carburetors

A carburetor commonly used for light-aircraft engines is the Marvel-Schebler MA3, shown in Fig. 6–47. The MA3 carburetor has a double-float assembly hinged to the upper part of the carburetor. This upper part is called the **throttle body** because it contains the throttle assembly. The fuel inlet, the float needle valve, and two venturis are also contained in the throttle body.

The carburetor body-and-bowl assembly contains a crescent-shaped fuel chamber surrounding the main air passage. The main fuel discharge nozzle is installed at an angle in the air passage with the lower end leading into the main fuel passage. An accelerating pump is incorporated in one side of the body-and-bowl assembly. The pump receives fuel from the fuel chamber and discharges accelerating fuel through a special accelerating-pump discharge tube into the carburetor bore adjacent to the main discharge nozzle. The carburetor also includes an altitude mixture control unit.

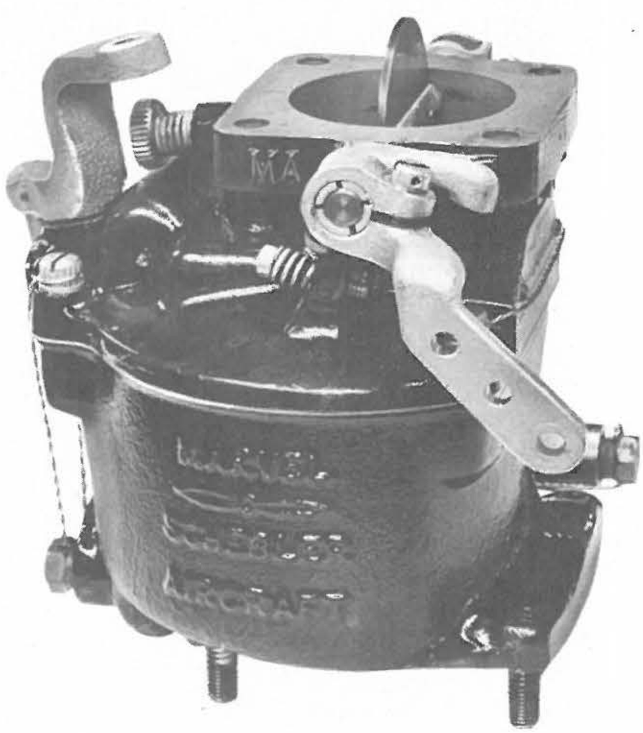


FIG. 6–47 Marvel-Schebler MA-3 carburetor.

In addition to the MA3 carburetor, the Facet Aerospace Products Co. manufactures the MA3-SPA, MA4-SPA, MA4-5, MA4-5AA, MA5, MA6-AA, and HA6 carburetors. These models are essentially the same as the MA3 in design and operation, but they are designed for larger engines. The HA6 carburetor employs the same float and control mechanism; however, the airflow is horizontal rather than updraft. The essential features of these carburetors are the same, but size and minor variations account for the different model numbers.

The HA6 carburetor, having horizontal airflow, is mounted on the rear of the oil sump of the engine for which it is designed. The F/A mixture then passes through the oil sump where it picks up heat from the oil, which provides better vaporization of the fuel.

A simplified drawing of the arrangement and operation of an MA-type carburetor is given in Fig. 6–48.

The principal features of a more complex carburetor are illustrated in Fig. 6–49. This is a Bendix-Stromberg NAR-type carburetor, which includes all the systems explained previously. The operation of these systems can be easily understood through a careful study of the drawing. Observe particularly the float and needle valve, needle-type mixture control, economizer system, accelerating pump, idle system, main metering system, and air bleeds. The names of all the principal parts are included in the illustration.

Disadvantages of Float-Type Carburetors

Float-type carburetors have been improved steadily by their manufacturers, but they have two important disadvantages or limitations: (1) The fuel-flow disturbances in aircraft maneuvers may interfere with the functions of the float mechanism, resulting in erratic fuel delivery, sometimes causing engine failure. (2) When icing conditions are present, the discharge of fuel into the airstream ahead of the throttle causes a drop of temperature and a resulting formation of ice at the throttle valve.

CARBURETOR ICING

Water Vapor in Air

In addition to gases, the air always contains some water vapor, but there is an upper limit to the amount of water vapor (as an invisible gas) that can be contained in air at a given temperature. The capacity of air to hold water increases with temperature. When air contains the maximum possible amount of moisture at a given temperature in a given space, the pressure exerted by the water vapor is also at a maximum and the space is said to be **saturated.**

Humidity

Humidity, in simple terms, is moisture or dampness. The **relative humidity** of air is the ratio of the amount of moisture actually in the air to the amount the air could contain, usually expressed as a percentage. For example, if we have saturated air at 20°F [−6.67°C] and the temperature is increased to 40°F [4.44°C], the relative humidity will drop to 43 percent if the barometric pressure has remained unchanged. If this same air is heated further without removing or adding moisture, its capacity for holding water vapor will increase and its relative humidity will decrease.

Lowering the temperature of air reduces its capacity to hold moisture. For example, if air at 80°F [26.67°C] has a

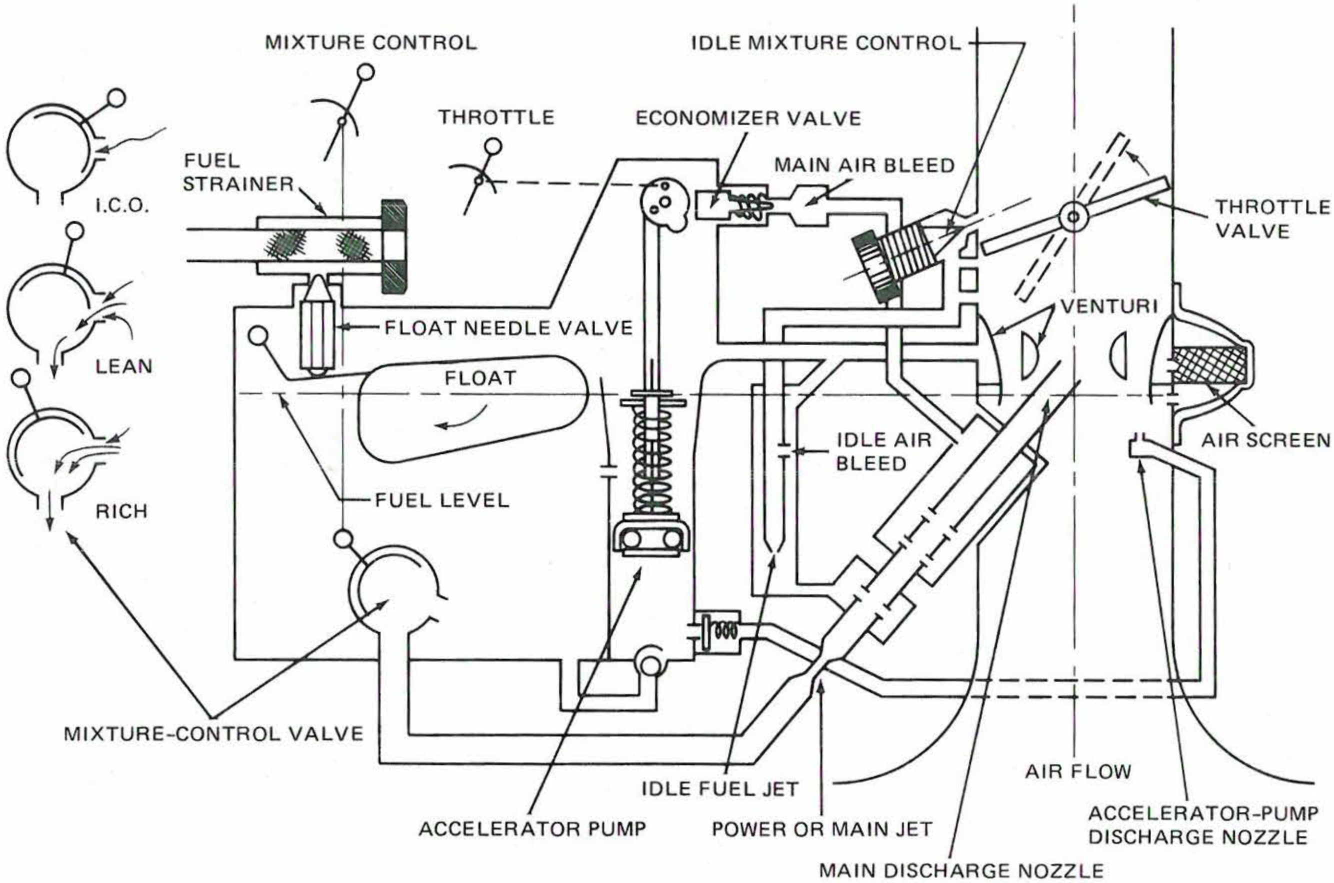


FIG. 6–48 Simplified drawing of Marvel-Schebler carburetor.

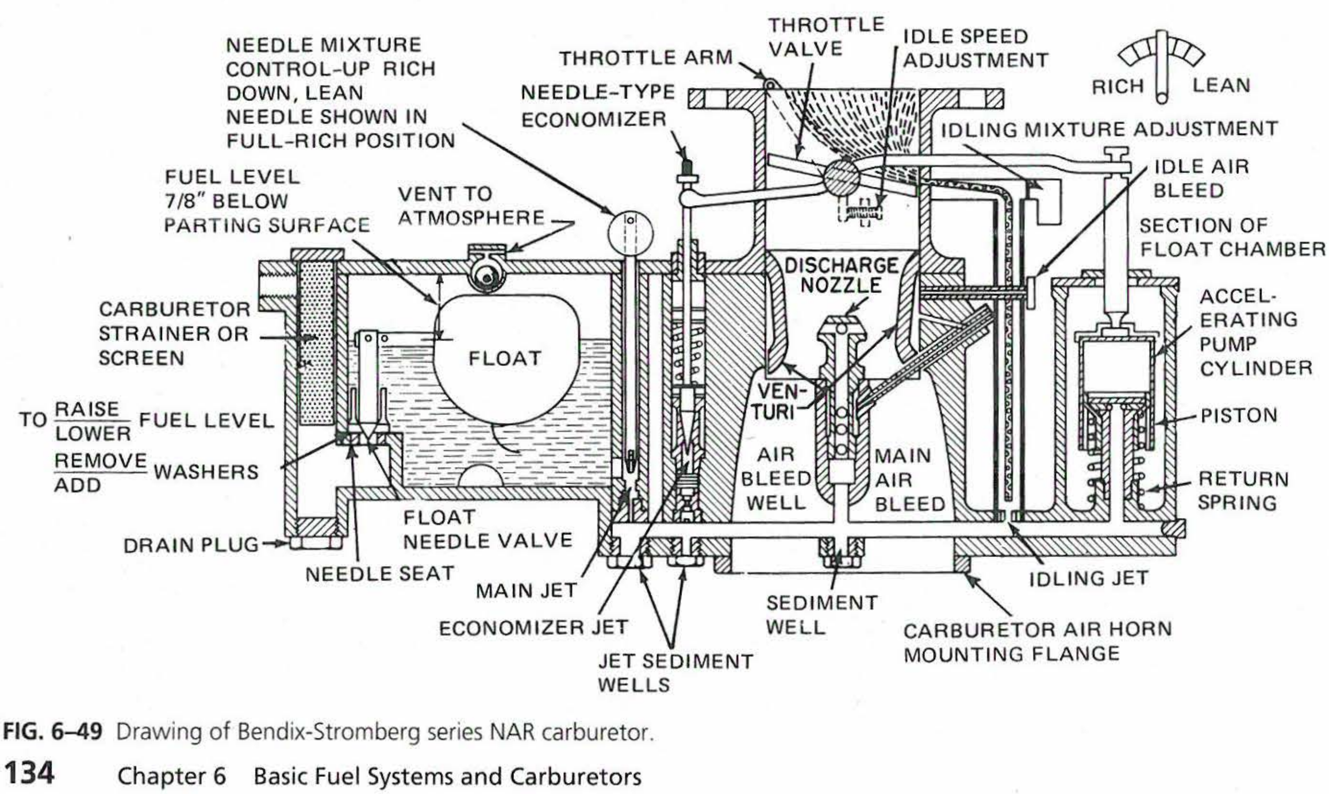


FIG. 6–49 Drawing of Bendix-Stromberg series NAR carburetor.

relative humidity of 49 percent and is suddenly cooled to 62°F [16.67°C], the relative humidity is then 100 percent because cooling the air has increased its relative humidity.

In the case just mentioned, a relative humidity of 100 percent means that the air is saturated; that is, the air contains all the moisture that it can hold. If the air should be cooled still more, further decreasing its moisture capacity, some of the water vapor will condense. The temperature at which the moisture in the air begins to condense is called the **dew point.**

Vaporization

The addition of heat can change a solid into a liquid or a liquid into a gas or vapor. The process of converting a liquid to a vapor is called **vaporization.** As the liquid is heated, the more rapidly moving molecules escape from the surface in a process called **evaporation.** Thus, when a pan of water is put on a hot stove, bubbles of water vapor begin to form at the bottom of the pan and rise through the cooler water above them and then collapse. When all the water in the pan is hot enough for the bubbles to reach the surface easily, vaporization takes place throughout the water, accompanied by a violent disturbance. This vaporization is commonly called **boiling.**

Latent Heat of Vaporization

When a liquid evaporates, it uses heat. If 1 gram (g) of water is raised from 0°C [32°F] to 100°C [212°F], 100 calories (cal) is required. (A **calorie** is defined as the quantity of heat required to raise the temperature of 1 g of water 1 degree C.)

When more heat is applied, the liquid water at 100°C [212°F] is changed to water vapor at 100°C [212°F]. This evaporation requires 539 cal. The temperature of the water does not rise during this process of changing from a liquid to a gas; therefore, 539 cal is required for the change of state. The reverse is also true; that is, when 1 g of water vapor is condensed to liquid water, 539 cal are given off. This energy (539 cal) required for the change of state from liquid to vapor or from vapor to liquid is called the **latent heat of vaporization or condensation.**

Laws of Evaporation

There are six **laws of evaporation** which have a bearing on the formation of ice in carburetors:

1. *The rate of evaporation increases as the temperature increases.* Heat increases the rate at which molecules move; therefore, hot water evaporates faster than cold water.
2. *The rate of evaporation increases with an increase of the surface area of the liquid.* More molecules can escape in a given time from a large surface than from a small surface; therefore, water in a big pan will evaporate faster than it will in a small vase.
3. *The rate of evaporation increases when the atmospheric pressure decreases.* As the weight of the air above a body of water decreases, the escaping water molecules encounter less resistance. In other words, evaporation is faster under low pressure than under high pressure. For example, it is possible to freeze water by the cooling effect of evaporation if a stream of dry air is passed over water in a partial vacuum.
4. *The rate of evaporation varies with the nature of the exposed liquid.* For example, alcohol evaporates faster than water.
5. *The rate of evaporation of water is decreased when the humidity of the air is increased.* The escaping molecules of water can get away more easily if there are only a few molecules of water already in the air above the water. Conversely, if the humidity is high, the escaping molecules encounter more resistance to their departure from the water.
6. *The rate of evaporation increases with the rate of change of the air in contact with the surface of the liquid.* Wet clothes dry faster on a windy day than on a day when the air is calm.

Cooling Effect of Evaporation

Every gram of water that evaporates from the skin takes heat from the skin, and the body is cooled. This is the function of human perspiration. If a person stands in a breeze, the perspiration evaporates more rapidly and the body is cooled faster. If the relative humidity is great, a person suffers from the heat on a hot day because the perspiration does not evaporate fast enough to have a noticeable cooling effect.

Carburetor Ice Formation

When fuel is discharged into the low-pressure area in the carburetor venturi, the fuel evaporates rapidly. This evaporation of the fuel cools the air, the walls, and the water vapor. If the humidity (moisture content) of the air is high and the metal of the carburetor is cooled below 32°F [0°C], ice forms and interferes with the operation of the engine. The fuel-air passages are clogged, the mixture flow is reduced, and the power output drops. Eventually, if the condition is not corrected, the drop in power output may cause engine failure. Ice formation in the carburetor may be indicated by a gradual loss of engine speed, a loss of MAP, or both, without change in the throttle position.

It is extremely important that a pilot recognize the symptoms of carburetor icing and the weather conditions which may be conducive to icing. The principal effects of icing are the loss of power (drop in MAP without a change in throttle position), engine roughness, and backfiring. The backfiring is caused when the discharge nozzle is partially blocked, which causes a leaning of the mixture.

Standard safety procedures with respect to icing involve (1) checking carburetor heater operation before takeoff, (2) turning on the carburetor heater when power is reduced for gliding or landing, and (3) using carburetor heat whenever icing conditions are believed to exist.

If the mixture temperature is slightly above freezing, there is little danger of carburetor icing. For this reason, a **mixture thermometer** [carburetor air temperature (CAT) gage] is sometimes installed between the carburetor and the intake valve. This instrument not only indicates low temperatures in the carburetor venturi, which lead to icing conditions, but also is used to monitor temperature when a carburetor air intake heater is used to avoid excessively high temperatures, which causes detonation, preignition, and loss of power.

In general, ice may form in a carburetor system by any one of three processes: (1) The cooling effect of the evaporation of the fuel after being introduced into the airstream may produce fuel ice or fuel evaporation ice. (2) Water in suspension in the atmosphere coming in contact with engine parts at a temperature below 32°F [0°C] may produce impact ice or atmospheric ice. (3) Freezing of the condensed water vapor of the air at or near the throttle forms throttle ice or expansion ice.

Throttle Ice. **Throttle ice** is most likely to form when the throttle is partially closed, such as during letdown for a landing. The air pressure is decreased, and the velocity is increased as the air passes the throttle.

The rate of ice accumulation within and immediately downstream from the carburetor venturi and throttle butterfly valve is a function of the amount of entrained moisture in the air. If this icing condition is allowed to continue, the ice may build up until it effectively throttles the engine. Visible moisture in the air is not necessary for this type of icing, sometimes making it difficult for pilots to believe that it occurs unless they are fully aware of its effect. The result of throttle icing is a progressive decline in the power delivered by the engine. With a fixed-pitch propeller, this is evidenced by a decrease in engine rpm and a loss of altitude or airspeed unless the throttle is slowly advanced. With a constant-speed propeller, there will normally be no change in rpm, but a decrease in MAP or EGT will occur before any noticeable decrease in engine and airplane performance. If the pilot fails to note these signs and no corrective action is taken, the decline in engine power will continue and engine roughness will occur, probably followed by backfiring. Beyond this stage, insufficient power may be available to maintain flight, and complete stoppage may occur, especially if the throttle is moved abruptly.

Fuel Vaporization Ice. **Fuel vaporization ice** usually occurs in conjunction with throttle icing. It is most prevalent with conventional float-type carburetors. It occurs with pressure carburetors, to a lesser degree, when the F/A mixture reaches a freezing temperature as a result of the cooling of the mixture during the expansion process between the carburetor and engine manifold. This does not present a problem for systems which inject fuel at a location beyond which the passages are kept warm by engine heat. Thus the injection of fuel directly into each cylinder intake port, or air heated by a supercharger, generally precludes such icing. Vaporization icing may occur at temperatures from 32°F [0°C] to as high as 100°F [37.8°C] when relative humidity is 50 percent or above.

Impact Ice. **Impact ice** is formed by moisture-laden air at temperatures below freezing when the air strikes and freezes on elements of the induction system which are at temperatures of 32°F [0°C] or below. Under these conditions, ice may build up on such components as the air scoops, heat or alternate air valves, intake screens, and protrusions in the carburetor. The ambient temperature at which impact ice can be expected to build up most rapidly is about 25°F [–3.9°C], at which the supercooled moisture in the air is still in a semiliquid state. This type of icing affects an engine with fuel injection as well as carbureted engines. It is usually preferable to use carburetor heat or alternate air as an ice prevention means, rather than as a deicer, because fast-forming ice, which is not immediately recognized by the pilot, may significantly lower the heat available from the carburetor heating system. Impact icing is unlikely under extremely cold conditions, because the relative humidity is usually low in cold air and because the moisture present usually consists of ice crystals which pass through the air system harmlessly.

Icing Prevention Procedures

Remember that **induction system icing** is possible, particularly with float-type carburetors, at temperatures as high as 100°F [37.8°C] and relative humidity as low as 50 percent. It is more likely, however, at temperatures below 70°F [21.1°C] and the relative humidity above 80 percent. The likelihood of icing increases as the temperature decreases (down to 32°F [0°C]) and as the relative humidity increases.

When no carburetor air or mixture temperature instrumentation is available, the general practice for smaller engines should be to use full heat whenever carburetor heat is applied. With higher-output engines, however, especially those with superchargers, discrimination in the use of heat should be exercised because of the possible engine overheating and detonation hazard involved. In any airplane, the excessive use of heat during full-power operations, such as takeoffs or emergency go-arounds, may result in a serious reduction in the power developed as well as engine damage. Note that carburetor heat is rarely needed for brief high-power operations.

Carburetor Air Intake Heaters

The exhaust type of carburetor air intake heater is essentially a jacket or tube through which the hot exhaust gases of the engine are passed to warm the air flowing over the heated surface before the air enters the carburetor system. The principal value of carburetor air heat is to eliminate or prevent carburetor icing. The amount of warm air entering the system can be controlled by an adjustable valve.

The **alternate air inlet heating system** has a two-position valve and an air scoop. When the passage from the scoop is closed, warm air from the engine compartment is admitted to the carburetor system. When the passage from the scoop is open, cold air comes from the scoop.

In a third type of carburetor air intake heater, the air is heated by the compression which occurs in the external supercharger, but the air becomes so hot that it is passed through an **intercooler** to reduce its temperature before it enters the carburetor. Shutters at the rear of the intercooler can be opened or closed to regulate the degree of cooling to which the air warmed by the supercharger is subjected. Air entering the engine at too high a temperature can lead to detonation.

Excessively High CAT

At first thought, it seems foolish to first heat the air and then cool it when the purpose is to raise its temperature to avoid icing the carburetor. However, as stated earlier, excessively high CAT values are not wanted. Air expands when heated, and its density is reduced. Lowering the density of the air reduces the mass; that is, it cuts down the *weight* of the fuel-air charge in the engine cylinder, thus reducing volumetric efficiency. This results in a loss of power, because power depends on the weight of the F/A mixture burned in the engine. Note also that since the weight of the air is decreased while the fuel weight remains essentially unchanged, the mixture is enriched and power is decreased when carburetor heat is turned on.

Another danger inherent in a high fuel-air temperature is detonation. If the air temperature is such that further compression in the cylinder raises the temperature to the combustion level of the fuel, detonation will occur.

INSPECTION AND OVERHAUL OF FLOAT-TYPE CARBURETORS

Inspection in Airplane

Remove the carburetor strainer and clean it frequently. Flush the strainer chamber with gasoline to remove any foreign matter or water. Inspect the fuel lines to make certain that they are tight and in good condition. Inspect the carburetor to be sure that all safety wires, cotter pins, etc., are in place and that all parts are tight. On those models having economizers or accelerating pumps, clean the operating mechanism frequently, and put a small quantity of oil on the moving parts.

When you are inspecting the carburetor and associated parts, it is particularly important to examine the mounting flange closely for cracks or other damage. The mounting studs and safety devices should be checked carefully for security. If there is an air leak between the mounting surfaces or an air leak because of a crack, the F/A mixture may become so lean that the engine will fail. A very small leak can cause overheating of the cylinders and power loss.

Disassembly

Great care must be taken in disassembling a float-type carburetor to make sure that parts are not damaged. The sequence described in the manufacturer's overhaul manual should be followed, if a manual is available. This sequence is designed to ensure that parts still on the assembly will not interfere with parts to be removed. As parts are removed, they should be placed in a tray with compartments, to keep the components of each assembly together. When this is done, there is much less likelihood of installing parts in the wrong position when the carburetor is reassembled.

The tools used in the disassembly of a carburetor should be of the proper type. Screwdrivers should have the blades properly ground to avoid slipping in screw slots and damaging the screw heads or gouging the aluminum body of the carburetor. Metering jets and other specially shaped parts within the carburetor should be removed with the tools designed for the purpose. A screwdriver should not be used for prying, except where specific instructions are given to do so.

Cleaning

The cleaning of carburetor parts is usually described in the manufacturer's overhaul manual, but certain general principles may be followed. The first step is to remove oil and grease by using a standard petroleum solvent, such as Stoddard Solvent (Federal Specification P-S-661 or the equivalent). The parts to be cleaned should be immersed in the solvent for 10 to 15 min, rinsed in the solvent, and then dried.

To remove carbon and gum from the carburetor parts, a suitable carbon remover should be employed. Carbon remover MIL-C-5546A or the equivalent may be used. The remover should be heated to about 140°F [60°C] and the parts immersed in it for 30 min. The parts should then be rinsed thoroughly in hot water (about 176°F [80°C]) and dried with clean, dry compressed air, with particular attention paid to internal passages and recesses.

Wiping cloths or rags should never be used to dry carburetor parts because of the lint which will be deposited on the parts. Small particles of lint can obstruct jets, jam close-fitting parts, and cause valves to leak.

If aluminum parts are not corroded but still have some deposits of carbon, these deposits may be removed with No. 600 wet-or-dry paper used with water. After this, the parts should be rinsed with hot water and air dried.

Aluminum parts that are corroded can be cleaned by immersion in an alkaline cleaner such as Formula T or an equivalent agent inhibited against attack on aluminum.

Inspection of Parts

Before assembly of the carburetor, all parts should be inspected for damage and wear. Inspections for a typical carburetor are as follows:

1. Check all parts for bends, breaks, cracks, or crossed threads.
2. Inspect the fuel strainer assembly for foreign matter or a broken screen.
3. Inspect the float needle and seat for excessive wear, dents, scratches, or pits.
4. Inspect the mixture control plates for scoring or improper seating.
5. Inspect the float assembly for leaks by immersing it in hot water. Bubbles will issue from a point of leakage.
6. Inspect the throttle shaft's end clearance and the play in the shaft bushings.

In addition, certain assemblies must be checked for fits and clearances. Among these are the fulcrum bushing in the float, the fulcrum pin, the slot in the float needle, the pin in the float assembly, the bushing in the cover assembly, the mixture control stem, and the throttle shaft and bushings. The limits for these assemblies are given in the Table of Tolerance Values in the manufacturer's overhaul manual.

The foregoing inspections are specified for the Bendix-Stromberg NA-S3A1 carburetor. For other carburetors, such as the Marvel-Schebler MA3, MA4, and MA6 series, additional inspections are specified in the overhaul manual. In each case the manufacturer's instructions should be followed carefully.

Inspection of Metering Jets

The sizes of the metering jets in a carburetor are usually correct because these sizes are established by the manufacturer. Sometimes a jet may be changed or drilled to increase its size, so it is always a good idea to check the sizes when the carburetor is overhauled. The correct sizes are given in the specifications of the manufacturer in the overhaul manual, and the size numbers are usually stamped on the jet. The number on the jet corresponds to a numbered drill shank; therefore, it is possible to check the size of the jet by inserting the *shank* of a numbered drill into the jet, as shown in Fig. 6–50. If the drill shank fits the jet without excessive play, the jet size is correct. The number of the jet should also be checked against the specifications in the overhaul manual to see that the correct jet is installed. Metering jets should be examined closely to see that there are no scratches, burrs, or other obstructions in the jet passages, because these will cause local turbulence, which interferes with normal fuel flow. If a metering jet is defective in any way, it should be replaced by a new one of the correct size.

Repair and Replacement

The repair and replacement of parts for a carburetor depend on the make and model being overhauled and should be performed in accordance with the manufacturer's instructions. It is always good practice to replace gaskets and fiber washers and any other part which shows substantial signs of wear or damage. When clearances and other dimensions are not within the specified limits, the parts involved must be repaired or replaced.

A carburetor float is usually made of formed brass sheet and can be checked for leaks by immersing it in hot water. The heat will cause the air and any fuel fumes in the float to expand, thus making a stream of bubbles emerge from the leak.

If the float has leaks, the leaks should be marked with a pencil or other means which will not cause damage. A small hole may then be drilled in the float to permit the removal of any fuel which may have been trapped inside.

FIG. 6–50 Checking metering jet for size.

After the hole is drilled, the fuel should be drained and the float then immersed in boiling water until all fuel fumes have evaporated from the inside. This will permit soldering of the leaks without risking the danger of explosion. As a further precaution, the float should never be soldered with an open flame. The small leaks should be soldered before the drilled hole is sealed. Care must be taken to apply only a minimum of solder to the float, because its weight must not be increased more than necessary. An increase in the weight of the float will cause an increase in the fuel level which, in turn, will increase fuel consumption.

After the float is repaired, it should be immersed in hot water, to determine that all leaks have been sealed properly.

Checking the Float Level

As explained previously, the fuel in the float chamber of a carburetor must be maintained at a level which will establish the correct fuel flow from the main discharge nozzle while the carburetor is in operation. The fuel level in the discharge nozzle is usually from $\frac{3}{16}$ to $\frac{1}{8}$ in [4.76 to 3.18 mm] below the opening in the nozzle.

After the carburetor is partially assembled according to the manufacturer's instructions, the float level may be checked. In a Bendix-Stromberg carburetor where the float needle seat is in the lower part of the carburetor, the float level may be tested as follows:

1. Mount the assembled main body in a suitable fixture so that it is level when checked with a small spirit level.
2. Connect a fuel supply line to the fuel inlet in the main body, and regulate the fuel pressure to the value given on the applicable specification sheet. This pressure is $\frac{1}{2}$ psi [3.45 kPa] for an NA-S3A1 carburetor used in a gravity-feed fuel system. When the fuel supply is turned on, the float chamber will begin to fill with fuel and the flow will continue until it is stopped by the float needle on its seat.
3. Using a depth gage, measure the distance from the parting surface of the main body to the level of the fuel in the float chamber approximately $\frac{1}{2}$ in [12.7 mm] from the side wall of the chamber, as shown in Fig. 6–51. If the measurement is taken adjacent to the side of the float chamber, a false reading will be obtained. The fuel level for the NA-S3A1 carburetor should be $\frac{13}{32} \pm \frac{1}{64}$ in [10.32 ± 0.397 mm] from the parting surface.
4. If the level of the float is not correct, remove the needle and seat and install a thicker washer under the seat to lower the level or a thinner washer to raise the level. A change in washer thickness of $\frac{1}{64}$ in [0.397 mm] will change the level approximately $\frac{5}{64}$ in [1.98 mm] for the NA-S3A1 carburetor.

Two different test procedures are used to establish the correct float level and float valve operation for the Marvel-Schebler MA series carburetors. The first is carried out during assembly after the float and lever assembly is installed. The throttle body is placed in an upside-down position, as shown in Fig. 6–52. The height of the lower surface of each float above the gasket and screen assembly is then measured. For the MA3 and MA4 carburetors, this distance should be $\frac{7}{32}$ in [5.56 mm]. For the MA4-5 carburetor, the distance is $\frac{13}{64}$ in [5.16 mm]. When the throttle body is placed in the upside-down position, the float needle is bearing against the float valve and holding it in the closed posi-

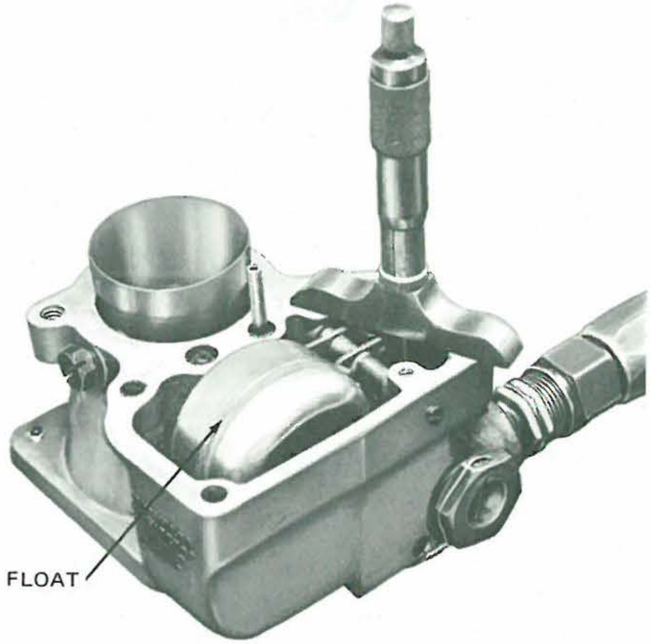


FIG. 6–51 Checking float level.

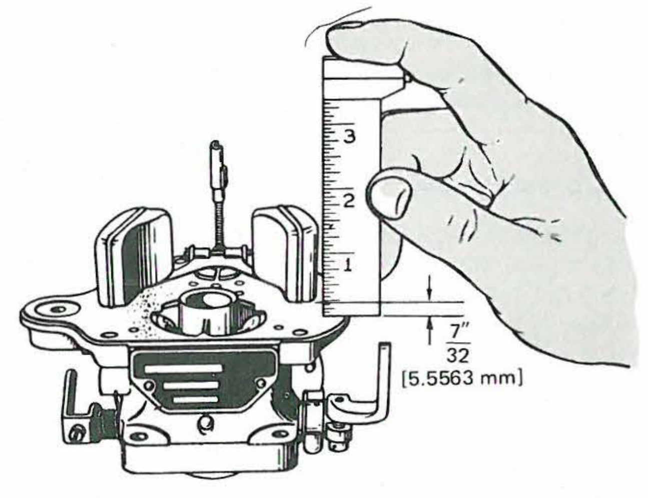


FIG. 6–52 Measuring float distance on MA-3 carburetor.

tion. This is the same position taken by the float when the carburetor is in the normal operating position and the float chamber is filled with fuel.

The method for testing float valve operation is illustrated in Fig. 6–53 and is performed after the carburetor is completely assembled. The procedure is as follows:

1. Connect the inlet fitting of the carburetor to a fuel pressure supply of 0.4 psi [2.76 kPa].
2. Remove the bowl drain plug, and connect a glass tube to the carburetor drain connection with a piece of rubber hose. The glass tubing should be positioned vertically beside the carburetor.
3. Allow the fuel pressure at 0.4 psi [2.76 kPa] to remain for at least 15 min, and then raise the fuel pressure to 6.0 psi [41.37 kPa]. (There will be a slight rise in the fuel level as the pressure is increased.) Allow the 6.0-psi [41.37-kPa] pressure to remain for at least 5 min after the fuel level has stabilized.
4. If the fuel does not rise to the level of the parting surface of the castings or run out of the nozzle, which can be observed through the throttle bore, the float valve and seat are satisfactory. If fuel is observed running out the nozzle, the bowl and throttle body must be separated and the float valve and seat cleaned or replaced.

In Fig. 6–53 the fuel level, shown as DISTANCE "A," will automatically be correct if the float height is correct and the float valve does not leak.

The foregoing procedures are given as typical operations in the inspection and overhaul of float-type carburetors; however, it is not possible in this text to give complete, detailed overhaul instructions for specific float-type carburetors. When faced with the necessity of overhauling a particular carburetor, the technician should obtain the correct manufacturer's manual and all special bulletins pertaining to the carburetor. Also, the technician should check the

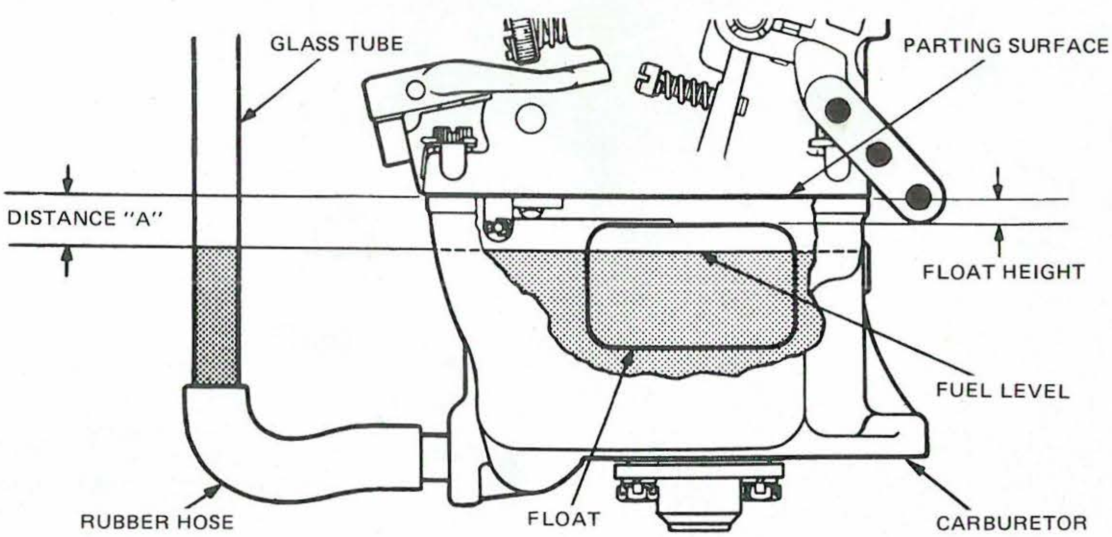


FIG. 6–53 Testing float valve operation.

FAA Engine Type Certificate Data Sheet for the particular engine on which the carburetor is to be used for any parts changes or modifications. The overhaul procedure should then be carried out according to the applicable instructions.

Troubleshooting

The troubleshooting chart presented as Fig. 6–54 provides some typical procedures for determining and correcting float-type carburetor malfunctions; however, it is not intended to cover all possible problems with the carburetor system. There are many types of carburetors, and among them are numerous variations in operational characteristics.

Installation of Carburetor

Before installing a carburetor on an engine, check it for proper lockwiring, and be sure that all shipping plugs have been removed from the carburetor openings. Put the mounting flange gasket in position. On some engines, bleed passages are found in the mounting pad. Install the gasket so that the bleed hole in the gasket aligns with the passage in the mounting flange.

Using the proper maintenance manual as a guide, tighten the carburetor mounting bolts to the value specified in the Table of Torque Limits found in the manual. Tighten securely the other nuts and bolts for the carburetor before connecting the throttle and mixture control levers.

TROUBLESHOOTING CHART

Trouble	Cause	Correction
Carburetor leaks when engine is stopped.	Float needle valve not seated properly because of dirt on seat.	Tap carburetor body with soft mallet while engine is running. Remove and clean carburetor. Check float level.
	Float needle valve worn.	Replace float needle valve.
Mixture too lean at idle.	Fuel pressure too low.	Adjust fuel pressure to correct level.
	Idle mixture control out of adjustment.	Adjust idle mixture control.
	Obstruction in idle metering jet.	Disassemble and clean carburetor.
	Air leak in the intake manifold.	Check intake manifold for tightness at all joints. Tighten assembly bolts.
Mixture too lean at cruising speed.	Air leak in the intake manifold.	Check intake manifold for tightness at all joints. Tighten assembly bolts.
	Automatic mixture control out of adjustment.	Adjust automatic mixture control.
	Float level too low.	Check and correct float level.
	Manual mixture control not set correctly.	Check setting of manual mixture control. Adjust linkage if necessary.
	Fuel strainer clogged.	Clean fuel strainer.
	Fuel pressure too low.	Adjust fuel-pump relief valve.
	Obstruction in fuel line.	Check fuel flow and clear any obstructions.
Mixture too lean at full-power setting.	Same causes as those for lean cruise.	Make corrections the same as those for lean cruise.
	Economizer not operating correctly.	Check economizer system for operation. Adjust or repair as required.
Mixture too rich at idle.	Fuel pressure too high.	Adjust fuel pressure to correct level.
	Idle mixture control out of adjustment.	Adjust idle mixture.
	Primer line open.	See that primer system is not feeding fuel to engine.
Mixture too rich at cruising speed.	Automatic mixture control out of adjustment.	Adjust automatic mixture control.
	Float level too high.	Adjust float level.
	Manual mixture control not set correctly.	Check setting of manual mixture control. Adjust linkage if necessary.
	Fuel pressure too high.	Adjust fuel pump relief valve for correct pressure.
	Economizer valve open.	Check economizer for correct operation. Quick acceleration may clear.
	Accelerating pump stuck open.	Quick acceleration of engine may remove foreign material from seat.
	Main air bleed clogged.	Disassemble carburetor and clean air bleed.
Poor acceleration. Engine backfires or misses when throttle is advanced.	Accelerating pump not operating properly.	Check accelerating pump linkage. Remove carburetor, disassemble, and repair accelerating pump.

FIG. 6–54 Troubleshooting chart for float carburetors.

After bolting the carburetor to the engine, check the throttle and mixture control lever on the unit for freedom of movement. Then connect the control cables or linkage.

Connect and adjust the carburetor or throttle controls of the fuel metering equipment so that full movement of the throttle corresponds to full movement of the control in the cockpit. Check and adjust the throttle control linkages so that springback on the throttle quadrant in the aircraft is equal for both FULL OPEN and FULL CLOSED positions. Finally, safety all controls properly to eliminate loosening during operation.

Adjusting Idle Speed and Idle Mixture

The correct idle speed and idle mixture are essential for the most efficient operation of an engine, particularly on the ground. The idle speed is established by the manufacturer at a level designed to keep the engine running smoothly, reduce overheating, and avoid spark plug fouling. A typical idle speed is 600 ± 25 rpm; however, this will vary somewhat among different aircraft.

The idle speed for an engine with a float-type carburetor is adjusted by turning the screw which bears against the throttle stop. Thus, the idle speed is established by varying the degree of throttle opening when the throttle lever is completely retarded. Usually, turning the screw to the right will increase the idle speed.

To adjust the idle mixture, do as follows:

1. Run the engine until it is operating at normal operating temperature.
2. Operate the engine at IDLE, and adjust for the correct idle speed.
3. Turn the idle mixture adjustment toward LEAN until the engine begins to run roughly.
4. Turn the mixture adjustment toward RICH until the engine is operating smoothly and the rpm has dropped slightly from its peak value.
5. Using the manual mixture control in the cockpit, move the control slightly toward LEAN. The rpm should increase slightly (about 25 rpm) before it begins to fall off and the engine starts to misfire. Returning the mixture control to FULL RICH should make engine operation smooth.

PRINCIPLES OF PRESSURE INJECTION

The **pressure injection carburetor** is a radical departure from float-type carburetor designs and takes an entirely different approach to aircraft engine fuel metering. It employs the simple method of metering the fuel through fixed orifices according to air venturi suction and air impact pressure, combined with the additional function of atomizing the fuel spray under positive pump pressure. Although pressure carburetors are not used on modern aircraft, they are discussed so that readers have a basic understanding of their operating principles. Many older aircraft still incorporate various types of pressure carburetors. Pressure carburetors do have some advantages over float-type carburetors; for instance, they operate during all types of flight maneuvers (including acrobatics), and carburetor icing is less of a problem.

Principles of Operation

The basic principle of the pressure injection carburetor can be explained briefly by stating that mass airflow is utilized to regulate the pressure of fuel to a metering system which in turn governs the fuel flow. The carburetor therefore increases fuel flow in proportion to mass airflow and maintains a correct F/A ratio in accordance with the throttle and mixture settings of the carburetor.

The fundamental operation of a pressure injection carburetor may be illustrated by the simplified diagram in Fig. 6–55. Shown in this diagram are four of the main parts of a pressure carburetor system: (1) the **throttle unit,** (2) the **regulator unit,** (3) the **fuel control unit,** and (4) the **discharge nozzle.**

When the carburetor is operating, the air flows through the throttle unit in an amount governed by the opening of the throttle. At the entrance to the air passage are impact tubes which develop a pressure proportional to the velocity of the incoming air. This pressure is applied to chamber A in the regulator unit. As the air flows through the venturi, a reduced pressure is developed in accordance with the velocity of the airflow. This reduced pressure is applied to chamber B in the regulator unit. The comparatively high pressure in chamber A and the low pressure in chamber B will create a differential of pressure across the diaphragm between the two chambers. The force of this pressure differential is called the **air metering force,** and as this force increases, it opens the poppet valve and allows fuel under pressure from the fuel pump to flow into chamber D. This unmetered fuel exerts force on the diaphragm between chamber D and chamber C and thus tends to close the poppet valve. The fuel flows through one or more metering jets in the fuel control unit and then to the discharge nozzle. Chamber C of the regulator unit is connected to the output of the fuel control unit to provide **metered fuel** pressure to act against the diaphragm between chambers C and D. Thus, unmetered fuel pressure acts against the D side of the diaphragm, and metered fuel pressure acts against the C

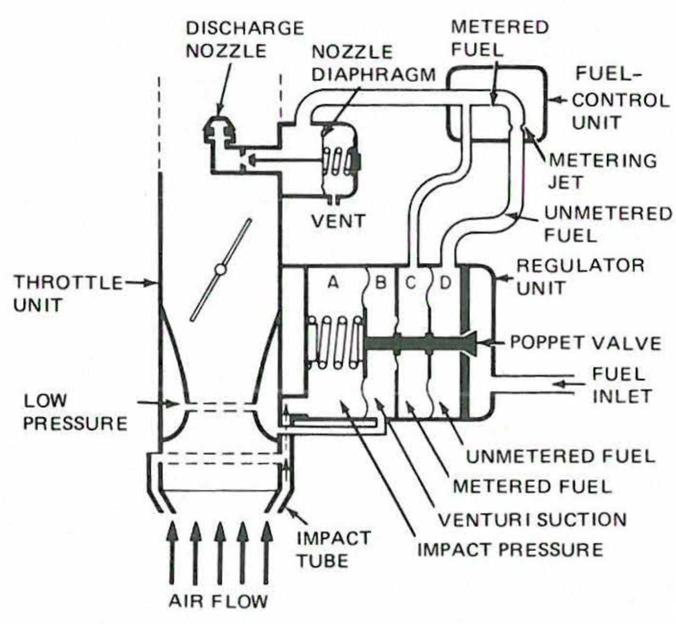


FIG. 6–55 Simplified diagram of a pressure injection carburetor.

side. The fuel pressure differential produces a force called the **fuel metering force.**

When the throttle opening is increased, the airflow through the carburetor is increased and the pressure in the venturi is decreased. Thus, the pressure in chamber B is lowered, the impact pressure to chamber A is increased, and the diaphragm between chambers A and B moves to the right because of the differential of pressure (air metering force). This movement opens the poppet valve and allows more fuel to flow into chamber D. This increases the pressure in chamber D and tends to move the diaphragm and the poppet valve to the left against the air metering force; however, this movement is modified by the pressure of metered fuel in chamber C. The pressure differential between chambers C and D (fuel metering force) is balanced against the air metering force at all times when the engine is operating at a given setting. The chamber C pressure is established at approximately 5 psi [34.48 kPa] by the spring-loaded, diaphragm-operated main discharge nozzle valve. This valve prevents leakage from the nozzle when the engine is not operating.

When the throttle opening is reduced, the air metering force decreases and the fuel metering force starts to close the poppet valve. This causes a decrease in the fuel metering force until it is again balanced by the air metering force.

Note particularly that an increase in airflow through the carburetor results in an increase in the fuel metering pressure across the metering jets in the fuel control section, and this increase causes a greater flow of fuel to the discharge nozzle. A decrease in airflow has the converse effect.

It must be understood that the regulator section of a pressure injection carburetor cannot regulate fuel pressure accurately at idling speeds because the venturi suction and the air impact pressure are not effective at low values. Therefore, it is necessary to provide **idling valves** which are operated by the throttle linkage to meter fuel in the idling range and which have springs in the pressure regulators to keep the poppet valve from closing completely.

Types of Pressure Injection Carburetors

A number of different types of pressure injection carburetors have been manufactured, the majority having been developed by the Energy Controls Division of the Bendix Corporation. Models have been manufactured for almost all sizes of reciprocating engines.

The carburetor for small engines has a single venturi in a single barrel and is designated by the letters PS, meaning a pressure-type single-barrel carburetor.

A pressure carburetor for larger engines has a double barrel with boost venturis and is designated by the letters PD (for pressure-type, double-barrel). The triple-barrel carburetor is designated by the letters PT, and the rectangular-barrel carburetor is designated PR.

The numbers following the letter designation generally indicate the bore size of a carburetor or injection unit. Nominal bore sizes are designated in increments of ¼ in [6.35 mm], beginning with 1-in (2.54-cm) for the no. 1 bore size. The actual bore diameter is $\frac{3}{16}$ in [4.762 5 mm] larger than the nominal size. For example, the nominal diameter of the no. 10 size is 3.25 in [8.26 cm] ($9 \times \frac{1}{4} + 1 = 3.25$ in), but the actual bore diameter is 3/16 in [4.762 5 mm] larger than the nominal diameter, or 3.4375 in [8.731 3 cm].

PRESSURE CARBURETOR FOR SMALL ENGINES

To provide the benefits of pressure injection carburetion for small aircraft engines, the Bendix Products Division (now Energy Controls Division) developed the PS series of carburetors. Figure 6–56 illustrates the PS-5C carburetor used on the Continental O-470 series engines.

The PS-5C carburetor utilizes the principles previously explained in this chapter. It includes a throttle unit, regulator section, fuel control unit, discharge nozzle, manual mixture control, accelerating pump, and idle system.

General Description

The PS-5C injection carburetor is a single-barrel updraft unit that provides a closed fuel system from the engine fuel pump to the carburetor discharge nozzle. Its function is to meter fuel through a fixed jet to the engine in proportion to mass airflow. The discharge nozzle is located downstream of the throttle valve to prevent ice from forming in the carburetor. This carburetor provides positive fuel delivery regardless of aircraft altitude or attitude and maintains proper F/A ratios regardless of engine speed, propeller load, or throttle lever position.

PRESSURE CARBURETORS FOR LARGE ENGINES

A number of different models of pressure injection carburetors have been designed for large engines; however, they all utilize the principles explained previously. These carburetors vary in size, type of mixture control, type of enrichment valves, shape of throttle body, and type of discharge nozzle.

One example of this type of carburetor is the Bendix PR-58. This carburetor possesses most of the characteristics of the typical pressure injection carburetors for large engines, including both the PD and PT types. A drawing of this carburetor system is shown in Fig. 6–57.

Principal Units. To understand the operation of the complete carburetor, one should note the construction and operation of each unit and its function in relation to the other units. There are four basic units of the carburetor: (1) the throttle unit, (2) the pressure regulator unit, (3) the fuel control unit, and (4) the AMC unit. In addition, this particular model of PR-58 carburetor is equipped to operate with a water-alcohol ADI (antidetonant injection) system which includes the derichment valve in the fuel control unit and a separate water-alcohol (W/A) regulator.

WATER INJECTION

Water injection, also called **antidetonant injection** (ADI), is the use of water with the F/A mixture to provide cooling for the mixture and the cylinders so that additional power can be drawn from the engine without danger of detonation.

Instead of using pure water for the ADI system, it is necessary to use a water-alcohol mixture (methanol) with a small amount of water-soluble oil added. The alcohol prevents freezing of the water during cold weather and at high altitudes. The water-soluble oil is added to prevent the corrosion which would occur in the units of the system if they lacked oil. The water-alcohol-oil mixture is called **antidetonant injection fluid,** or simply **ADI fluid.** In servicing the ADI system, the technician must be sure that the correct mixture of fluid components is used. This information is contained in the manufacturer's service instructions.

Advantages

It is often necessary to use the maximum power which an engine can produce, such as for taking off from short fields and for go-arounds. A "dry" engine—that is, one without water injection—is limited in its power output by the detonation which results when operating limits are exceeded. The injection of water into the F/A mixture has the same effect as the addition of antiknock compounds in that it permits the engine to deliver greater power without danger of detonation.

The average engine operating without water injection requires a rich mixture of approximately 10 parts air to 1 part fuel by weight (F/A ratio of 0.10). With this mixture, a portion of the fuel is unburned and acts as a cooling agent. The additional unburned fuel subtracts from the power of the engine. But when water is added to the F/A mixture in proper quantities, the power of the engine can be increased. The water cools the F/A mixture, thus permitting a higher manifold pressure to be used. In addition, the F/A ratio can be reduced to the rich best-power mixture, thus deriving greater power from the fuel consumed. When water injection is employed, the F/A ratio can be reduced to approximately 0.08, which is a much more efficient mixture than the 0.10 ratio required otherwise.

The use of water injection permits an increase of 8 to 15 percent in takeoff horsepower.

The equipment required for water injection includes a storage tank, a pump, a water regulator, a derichment valve, and the necessary circuits and controls.

Principles of Operation

The **water-alcohol (W/A) regulator** is the unit which makes possible the injection of ADI fluid into the fuel at the fuel feed valve in a quantity which ensures a correct

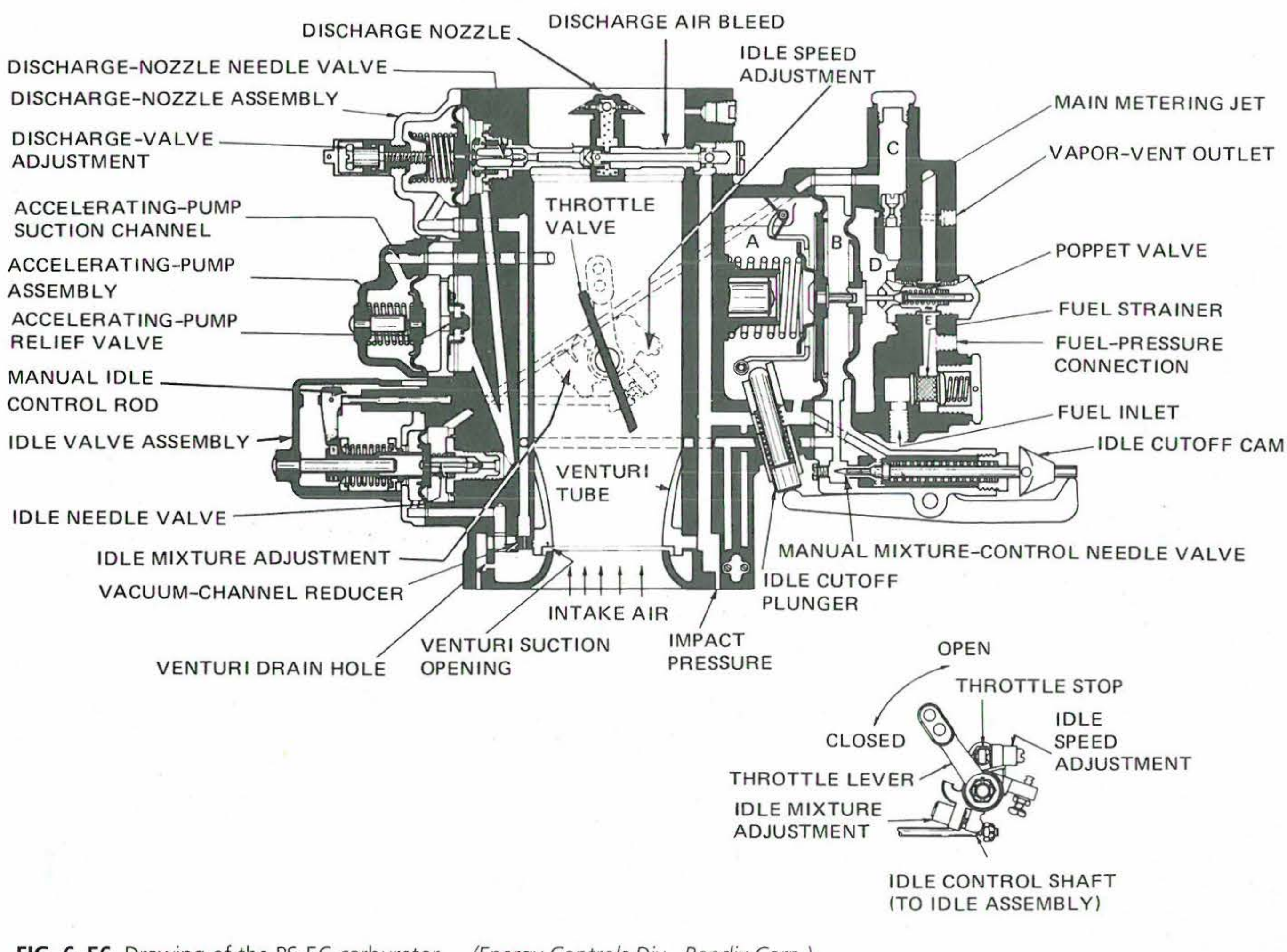


FIG. 6–56 Drawing of the PS-5C carburetor. *(Energy Controls Div., Bendix Corp.)*

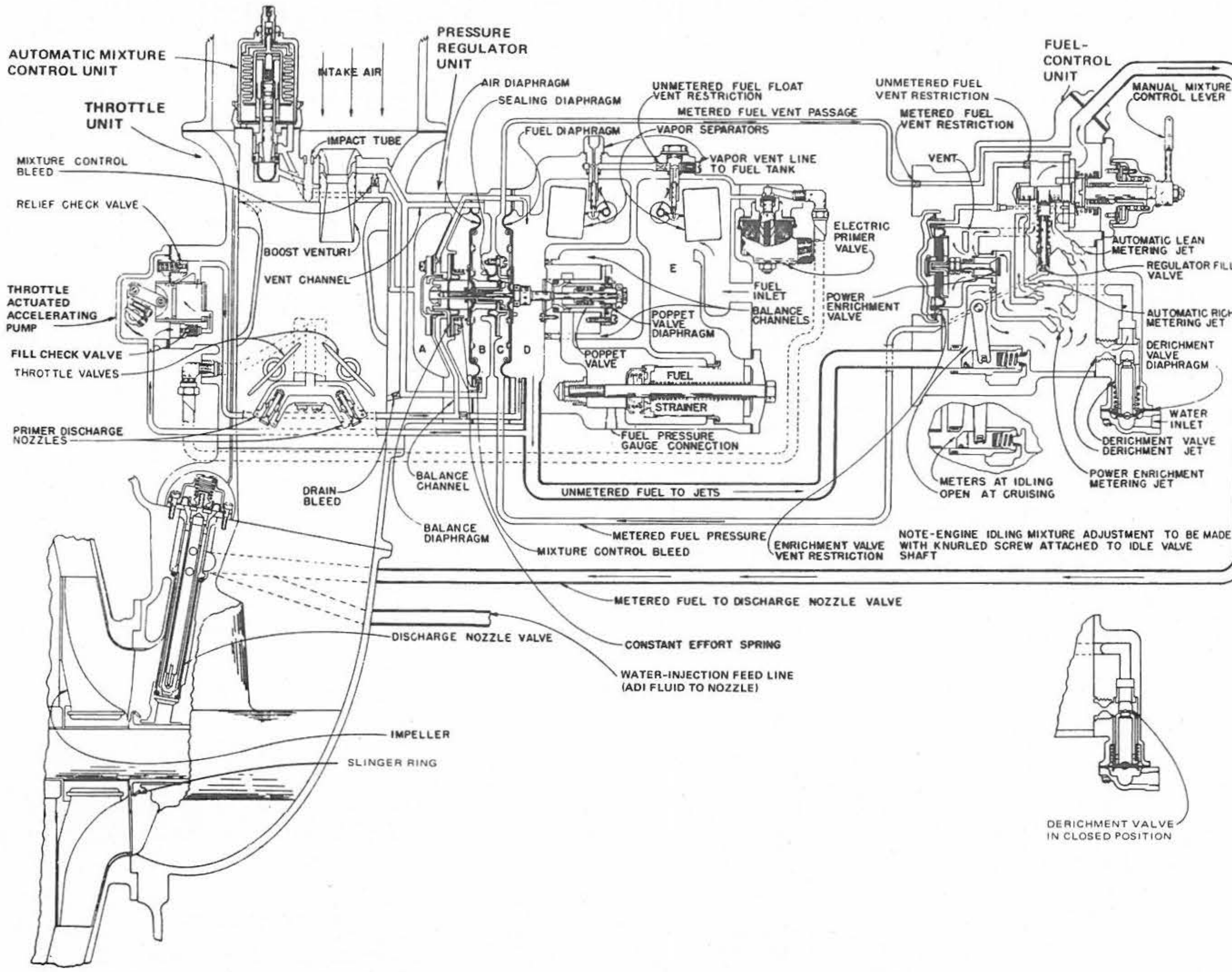


FIG. 6–57 Drawing of a Bendix PR-58 type of carburetor system. *(Energy Controls Div., Bendix Corp.)*

volume of the W/A mixture. If too much of the ADI fluid were injected, the cooling effect would reduce the power of the engine. If insufficient ADI fluid were injected, the engine would overheat and detonation would occur.

Figure 6–58 represents one particular type of W/A regulator, one similar to that used in the PR-58 type of carburetor on a P&W R2800 engine. This regulator includes three diaphragm-operated valves. These are the metering pressure control valve, the check valve, and the W/A enrichment valve.

The **metering pressure control valve** is operated by application of chamber D (unmetered) fuel pressure from the carburetor to one side of the diaphragm and W/A pump pressure to the opposite side. When the pilot turns on the ADI switch in the cockpit, ADI fluid flows from the pump to the regulator. The metering pressure control valve will be open because of the unmetered fuel pressure applied to the valve diaphragm. When pump pressure builds up to the level of unmetered fuel pressure, the valve will begin to close.

The **check valve** is normally closed when the system is not operating; however, it will begin to open slowly when pump pressure is applied to the diaphragm. The valve cannot open immediately because of the delay bleed. The **delay bleed** provides time for the derichment valve to close before the ADI fluid starts to discharge into the fuel feed valve.

When the system is *not* operating, the fuel backs up into the W/A feed line. Therefore, when the system is turned on, fuel will be the first substance injected into the fuel feed valve. If the carburetor is set for takeoff at FULL RICH or EMERGENCY RICH and additional fuel is injected from the W/A line, the overrich mixture will cause the engine to lose power and there will be a definite hesitation in the operation of the engine. The use of delay bleeds with the check valve prevents this situation because the derichment valve closes and leans the mixture before the extra fuel is injected from the W/A feed line. Because of the leaner mixture caused by the derichment valve, the extra fuel injected from the W/A line does not enrich the F/A mixture sufficiently to cause engine hesitation.

The **W/A enrichment valve** modifies the flow of ADI fluid in connection with the main W/A jet. This valve is closed when the system is not operating. The operation of the ADI system is initiated when the pilot turns on the ADI control switch in the cockpit. This switch is in series with a

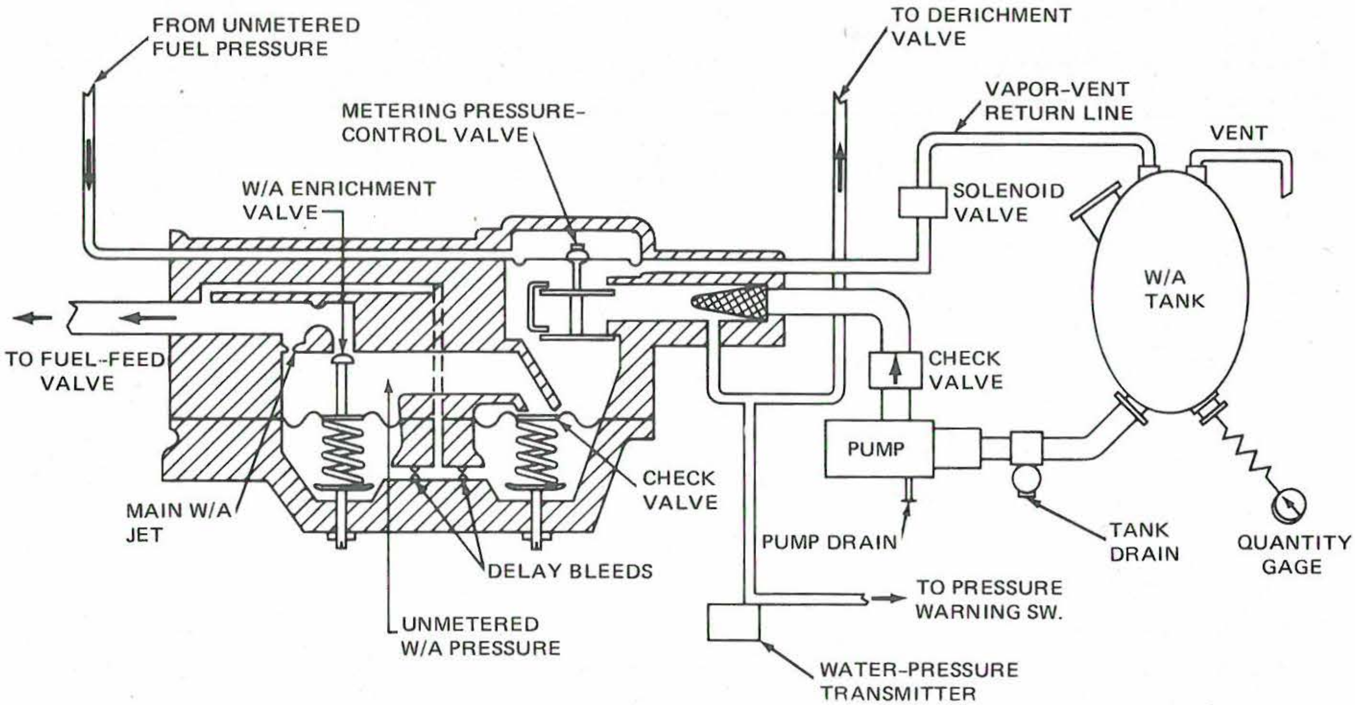


FIG. 6–58 Schematic diagram of water-alcohol (ADI) regulator.

pressure switch operated by engine oil pressure or MAP; the engine must therefore be operating at a comparatively high power setting before the electric power can be directed to the ADI pump. When the system is operating, a **water pressure transmitter** connected to the regulator sends electric signals to the **water pressure indicator** in the cockpit. Water pressure from the regulator is Also, directed to a pressure warning switch which controls the **water pressure warning light** in the cockpit. The light is on while the system is operating. If the ADI fluid supply should become exhausted while the system is operating, the pressure switch will open and the warning light in the cockpit will turn off. At the same time, the derichment valve will open and permit enrichment fuel to flow through the fuel control unit, thus providing the necessary cooling to avoid detonation.

Some systems utilize a float-operated switch to turn off the fluid pump before the fluid supply is exhausted. This is particularly important if a vane-type pump is employed. Such a pump can maintain pressure on the derichment valve even though the fluid supply is exhausted. In such a case, the valve would not open to allow enrichment fuel to flow, and the engine would still be operating on the best-power mixture. This would allow detonation to occur.

The ADI system is particularly advantageous under conditions of high humidity. The water vapor in humid air displaces oxygen, so that a particular F/A ratio will increase in richness as humidity increases. Therefore, when an aircraft taking off is using the emergency rich mixture, high humidity will further enrich the mixture and cause a substantial loss of power. When an aircraft takes off wet (with ADI), the F/A ratio is set for best power and the enrichment caused by high humidity is not great enough to cause an appreciable loss of power. The water injected into the fuel does not have an appreciable effect on the F/A ratio because the water does not displace the oxygen in the air.

REVIEW QUESTIONS

1. Explain the meanings of "octane number" and "performance number."

2. What is added to aviation fuel to improve its antiknock qualities?

3. Into what two principal sections may the fuel system of an aircraft be divided?

4. Why does an engine-driven fuel pump require a bypass system?

5. Explain vapor lock and list three primary causes.

6. What is the purpose of carburetion or fuel metering?

7. What are standard sea-level pressure and temperature?

8. How is the venturi tube utilized in a carburetor?

9. In what terms are F/A mixtures generally expressed?

10. Explain the best-economy mixture of fuel and air.

11. What is meant by the brake specific fuel consumption of an engine?

12. Define "flame propagation."

13. What atmospheric conditions affect air density?

14. How is the fuel discharge nozzle in a float-type carburetor located with respect to the fuel level in the float chamber?

15. Explain the use of an air bleed in a float-type carburetor.

16. Describe a throttle valve and its operation.

17. Explain the importance of float level in a carburetor.

18. Describe the main metering system in a carburetor.

19. What is idle cutoff?

20. Why is the F/A ratio enriched during the idle operation?

21. Why is an accelerating system needed?

22. What is the purpose of the economizer system in a carburetor?

23. What are the principal functions of the mixture control system?

24. Describe the purpose of an AMC.

25. Differentiate between updraft and downdraft carburetors.

26. What are the disadvantages of a float-type carburetor?

27. In what different ways may ice form in a carburetor system?

28. Describe methods for heating the carburetor intake air.

29. What are the effects of excessively high CAT?

30. How is the size of a metering jet checked?

31. Name the principal units of a pressure-type carburetor.

32. What is the purpose of water injection?