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Old Faithful

The Marvel(ous) Schebler carburetor

By Randy Knuteson

Everything is simpler than you think and at the same time, more complex than you can imagine. These words were spoken some 200 years ago by a philosopher — not an aircraft technician straining to understand what went wrong with his carbureted engine.

A quick glance at a Marvel Schebler Carburetor might lead some to believe that these units are far too simplistic for today's modern aircraft. The obvious advantages associated with fuel injection (even fuel/air distribution, no carb icing concerns, etc.) seem to overshadow the value of the much-maligned carburetor. However, a closer, more scrutinizing look reveals an intricate relationship between various sub-systems within these carburetors. The details that comprise these systems vary from model to model. It is only when the functions of these systems are fully understood that one gains a renewed appreciation for their elegantly simple designs. These units have continued to serve us well through the passing of time.

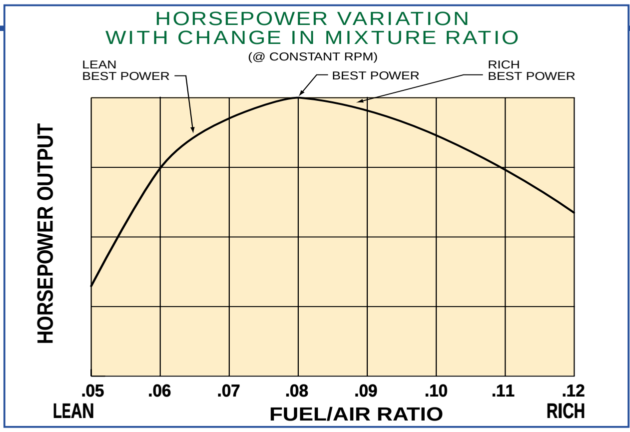
Principles of operation

In the most simple of terms, an aircraft carburetor is a device for introducing and mixing a metered amount of fuel to the cylinders. Unlike direct injection that provides a precise and uniform delivery of the charge directly into the intake port of each cylinder, the atomized fuel from the carburetor seeks the path of least resistance as it travels through the induction tubes. Fuel distribution is far from exact as indicated by split CHT and EGT readings. According to Lycoming, a variance of 150 degrees is not at all unusual. The job of the carburetor is to perform two very basic functions:

1. It measures out an appropriate amount of incoming air
2. It mixes that air with fuel to assure that a proper charge enters the cylinders under all operating conditions.

Fuel from the wing or header tanks is fed either by gravity or by a low-pressure pump to the inlet of the carburetor. The actual pressure available from a gravity feed system is about one PSI for each forty inches of head of fuel (as measured in distance from the surface of the fuel in the tank to the point of discharge into the carburetor). Low-wing aircraft or "Turbo-normalized" aircraft requires as much as six to nine PSI of pressure to perform at altitude. These installations would require a gravity feed of approximately some 240 inches of head pressure. Such distance renders the gravity-feed method impractical if not impossible.

As fuel rises in the float bowl chamber, it lifts a float that is hinged to the throttle body. The float fulcrum lever carries a needle valve, the point of which extends into a seat at the inlet of the carburetor. When the fuel level rises far enough in the bowl, the needle valve begins to partially restrict or close off fuel flow. The height of the fuel in the discharge nozzle is controlled by the position of the float and the needle valve in the float chamber. As fuel



This curve shows the relationship between power output and mixture ratios (based on weight, not volume). Combustion can occur with mixtures as rich as .125 (1 to 8); and as lean as .062 (1 to 16). Lean best power (economy) setting is 0.075, while rich best power is 0.087. Best performance is approximately 0.080. The exact shape of this curve varies from engine to engine.

is discharged from the carburetor, the float lowers and allows more fuel to fill the bowl. In this manner, optimum fuel level is always maintained so long as the float level has been properly set at overhaul.

A partial vacuum created by the piston during the intake stroke draws air through the carburetor. The air passages in both the carburetor and the manifold are designed to admit a sufficient amount of air to fill the cylinders by the end of the intake stroke. The throttle plates' function is to regulate the admission of air to the cylinders, thereby controlling the power output of the engine.

Basic Bernoulli

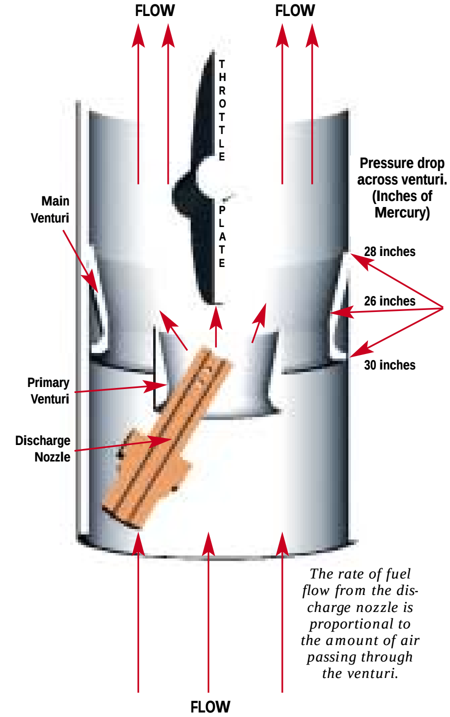
Two pressures work together to discharge fuel from the carburetor bowl. The atmospheric pressures in the bowl chamber exert a downward force on the fuel within the bowl. And there is also a drop in pressure (a vacuum) at the neck of the discharge nozzle caused by the action of the venturi in the throat of the carburetor. The resulting pressure-differential works to create a push/pull action on the fuel.

Proper fuel metering is accomplished by the strategic placement of the discharge nozzle in the venturi tube. The venturi is situated in the intake airstream at the point of mean velocity immediately upstream of the throttle valve.

Imagine an aircraft wing rolled into a cylinder, dramatically reduced in size, then placed into the bore of a carburetor. In essence, you have formed the aircraft wing into a venturi. The basic law of physics discovered by Bernoulli is as active in the throat of a carburetor as it is across the surface of an aircraft wing. A venturi tube correctly positioned in the throat of a carburetor causes air to move at a much faster rate as it passes through the constriction (See diagram, right). As air velocity increases, a reduction in static pressure (pressure drop) causes a suction force to draw fuel up the discharge nozzle. The amount of fuel drawn up the discharge nozzle is dependent upon the speed and condition of the air sweeping through the venturi. The greater the velocity, the greater the suction on the fuel in the discharge nozzle.

Unimpeded Airflow

The onrush of air through the throttle body serves to mix and atomize the fuel as it makes its way to the cylinder intakes. This mixing of fuel and air in the throat of the carburetor helps to convert much of the liquid fuel into a gaseous state. Engine speed, efficiency and power are greatly influenced by the quantity and nature of this homogenous charge. Because of this, its extremely important that airflow be unimpeded by sharp bends in the induction or gasket material protruding into the airstream. Such obstacles can produce



The rate of fuel flow from the discharge nozzle is proportional to the amount of air passing through the venturi.

unsteady or turbulent airflows directly affecting the fuel metered through the discharge nozzle. The quality of the airstream directly influences the metering of fuel. A small piece of gasket material, a damaged or restricted air filter, a loose venturi, or any foreign object lodged in the carburetor throat can ruin the metering ability of the carburetor.

Mixture Control

Fuel is always metered in relation to the weight, not the volume of air passing through the carburetor. As the aircraft ascends in altitude it passes through atmosphere that is constantly changing. Pressure, temperature, and density steadily declines. Since thinner air is less dense, each pound of air occupies a greater volume of space. So, as the airplane gains altitude, the volume of air passing through the carburetor will continue to remain proportional to suction in the manifold, but the weight of the air will decrease as ambient air density decreases. Since the air is less dense, a nat-

Left: Brass discharge nozzles. Top nozzle is of the pepper-box design. This atomizing design is frequently installed in the smaller TCM carbs to correct erratic fuel flows associated with the installation of the single-piece venturi (Precision S.B.s MSA-7, MSA-8, MSA9).

Right: Kelly Aerospace Power Systems manufactures discharge nozzles from a single piece of stock (top). Older discharge nozzles are welded where the neck meets the wrenching flats. Heavy porosity or a side load on the neck may compromise these welds. Visually inspect the integrity of the nozzles to assure that the neck will not separate from the body. The neck of the nozzle would be ingested into the engine if such a separation occurred.

ural richening of the fuel/air ratio occurs. A manual mixture control enables the pilot to alter the ratio of fuel to air. At any given throttle setting, the mixture may require some adjustment to compensate for ever-changing conditions from sea level to altitude. The mixture control also provides a secondary function of completely closing off fuel flow at ICO.

Idle Circuit

At low rpms, the idling system is independent of the main metering jet. At idle speeds and up to approximately 1,000 to 1,300 rpm the main jet has little or no fuel passing through it. This is because the throttle valve is almost closed and there is little air swept past the discharge nozzle. At this point, fuel is drawn up the idle bleed tube in the bowl and then through the idle emulsion channel within the throttle casting to ports adjacent to the upper edge of the throttle valve. As the throttle valve is opened, suction at the idle mixture port decreases and the main jet takes over entirely. Fly-holes in line with the mixture port aid in the smooth transition from idle to full power. As the throttle opens it progressively unveils these secondary and tertiary bleed ports. Any sudden opening of the throttle results in a lag between the time the idling circuit stops functioning and the main jet takes over. This is because there isn't sufficient air flowing through the carburetor throat to draw fuel from the main discharge nozzle. An accelerator pump is used to compensate for this delay and eliminate sudden flat spots created by temporary lean mixtures. The accelerator pump is mechanically linked to the throttle and discharges fuel through a tube adjoining the main nozzle. The accelerator tube protrudes into the airflow just inside the primary venturi in the smaller carbs and inside the main venturi in the larger carbs.

Looking up the throat of the MA-4SPA Carburetor. This vantage point reveals the proper placement of the pump discharge tube. The tube must be positioned just within the center ring of the primary venturi.

Any fuel-borne contamination or corrosion latently within the carburetor can migrate to these idle passages and create a lean condition at low power settings. If the contamination is significant, it will not allow for proper fuel/ air ratios at idle. At sea-level, mixture rise as indicated on the tach should be approximately 25 to 50 rpm. At higher field elevations of 5000-ft. or more, the mixture rise will be more in the neighborhood of 75 to 100 rpm. An idle adjustment screw that requires more than four turns out to achieve a proper mixture rise at ICO is a good indication of contamination in the idle circuit.

Don't touch that jet!

A restriction at the base of the discharge nozzle serves as the main jet in MA series carburetors. In HA-6 (horizontal side-draft) series carburetors, the power jet in the base of the bowl performs the same function. Some well-meaning technical writers have instructed mechanics to hone these jets in an effort to cool cylinder head or exhaust gas temperatures. Apparently they believe this to be a "cure-all" for lean running engines. A mechanic would be ill-advised to follow such instructions since no process approval exists for opening these jets in the field. Furthermore, tampering with the jet size could mask other serious problems. An induction leak, an incorrectly sized economizer jet, an incorrect float setting, or perhaps even the wrong choice of carburetor could all contribute to a "lean" running engine. Another problem with this mode of attack is that the jets vary in design. Some jets are straight, while others are contoured or stepped. A mechanic who takes a drill bit, a ream, or sandpaper to the entrance of a stepped opening may soon regret that decision. Fuel flows could exponentially increase by merely breaking the stepped edge and thereby creating a venturi entrance. By contouring a stepped jet we've managed to decrease the pressure and increase the velocity of the fuel through the jet.

When you start boring out nozzles, several things can happen. As you begin to see appreciable results – the tendency is to take out more and more material. "If a little bit is good, a lot may be better." Wrong!

Carb Icing

Carburetor icing remains a serious problem for light aircraft as evidenced by the number of incidences reported annually. Charles Lindbergh experienced icing while crossing the continental divide in The Spirit of St. Louis as he prepared for his historic flight across the Atlantic. To correct this problem, Lindbergh's mechanics equipped the plane with a carburetor air heater.

The formation of ice on the throttle shaft and plate is a natural byproduct of the pressure drop across the venturi when certain atmospheric conditions exist. The typical temperature drop within the throat of the carburetor is 40 to 60 degrees. This temperature drop causes the dew point to drop and the air to become increasingly dense. Moisture in the air forms into water droplets that adhere to the cold surfaces in the throat of the carburetor. Carb icing can readily occur when outside air temps are as high as 90 degrees. In fact, it is often at these OATs that carb icing is most menacing because warm air is capable of sustaining more moisture.

A 1971 report by the National Research Council (NRC) of Canada revealed that Carburetor ice could be reduced by the use of gasoline soluble inhibitors. The study selected temperatures, humidity and throttle plate settings that would cause the most severe icing conditions. It was found that the positioning of the throttle plate at approximately 40 deg (70 percent of max opening, or approx. cruise configuration) produced the optimum build-up of ice. Manifold vacuum readings were used as a means of assessing ice build-up. Visual observations provided a secondary form of measurement. The study determined that "ice formation occurred preferentially on the edges of the throttle plate and spread progressively across the plate face." The use of ethylene glycol monoethyl ether at 0.15 percent proved an effective deterrent to ice build-up. Of more interest however, was the discovery that coating the throttle plate and shaft with 0.00125 layer of Teflon "produced a marked reduction in ice formation." "The throttle plate was virtually clear." What is not clear is why in the ensuing years the manufacturers never utilized this data.

EGME is currently available under the name "Prist® PF205 Low-Flow", and is said to be a practical anti-ice additive. A device called a carb temp probe is also available. The probe enables the pilot to monitor temps within the carburetor and to detect when conditions are most conducive to icing. For additional information regarding carb-ice formation refer to *Pilot Precautions and Procedures to be Taken in Preventing Aircraft Reciprocating Engine Induction System and Fuel System Icing Problems* (FAA AC-20-112) and consult your POH.

Photo shows a collapsed brass float. Never introduce shop air to the inlet fitting, discharge nozzle, or fly holes in the throat of the carburetor — the high pressure might collapse the float.

Sure, your high-end fuel flows begin to look better and so do your CHTs and EGTs. But unfortunately, mid-range fuel flows may become exceedingly rich. This rich condition is especially apparent as you transition between idle and full power. An engine that bogs down rich may surprise a pilot forced to do a go-around when on short final. Actuating the throttle causes the pump plunger to spray an additional slug of fuel into the carb throat. Thoughtful engineers have carefully tailored the idle circuit, the accelerator pump, and main jet for optimum performance. A modified nozzle jet may cause the air/fuel ratio to be overly rich. There is a point of diminishing returns, where high-end fuel flows no longer increase but mid-range fuel/air ratios become too rich. And once this occurs, your wallet becomes increasingly lean as you shell out additional dollars for a replacement nozzle!

Venturis. The two-piece venturi (above left), is subject to annual and 100-hr. inspections as per AD 98-01-06. Single piece venturi (above right) requires no recurrent inspections. Carburetor data tags with 'V' stamped on them indicate that the single piece venturi has been installed.

Choosing the correct carburetor

A common misunderstanding through the years has been that an engine/carburetor combination that works well in one airplane will function as well in another style airframe. Additionally, it is believed that if the system performs well in a test cell, then it will perform equally well in flight. Unfortunately, to the chagrin of many a homebuilder, this is not always the case. Airframe performance, cowling configurations, baffling, and choice of air-box, all contribute dramatically to fuel/air ratios and to engine cooling.

When selecting a carburetor for your engine, always refer to both the engine and airframe type certification listings. Many have made the critical mistake of selecting a carburetor based solely on the part number(s) listed in the engine manufacturers parts and overhaul manuals. Some have selected a carburetor based on the part number currently installed in their airplane or on an airplane of the same model tied down on their airfield. Others have chosen a carb based on the OEM's application guide. All these methods will narrow down your search, but they will not with any certainty guarantee that you have selected the right unit for your particular airplane. Incomplete engine logs, the swapping of engines to airframes, and the uncertain history of some engines mandates a reliance on type certification data when deciding on the appropriate carburetor for your particular application.

To some, the theory and mechanical functions of carburetors may seem rather formidable. Yet, when each subsystem is viewed separately, it becomes readily apparent that these systems are easy to understand. In spite of all the intricacies associated with them, Marvel Schebler (Precision) carburetors remain the same efficient, reliable units our fathers and grandfathers flew behind with confidence for decades. AMT

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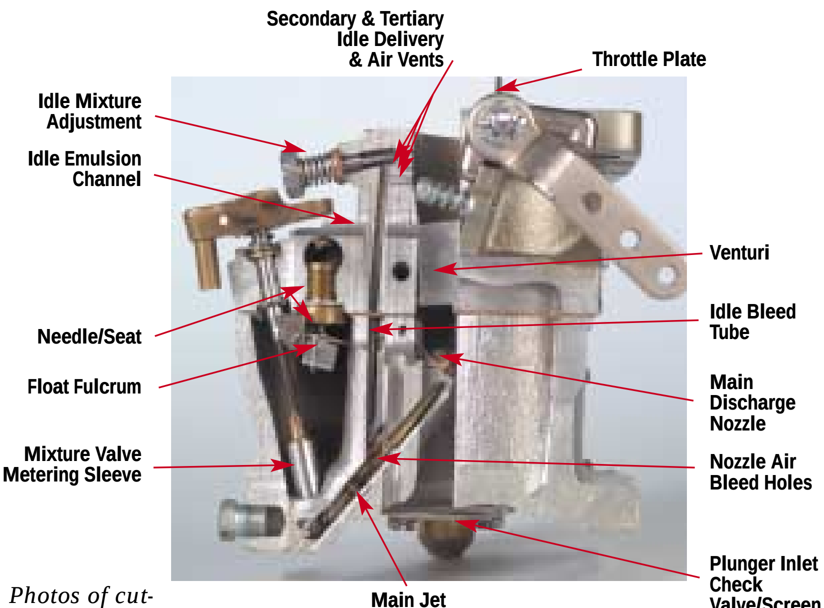

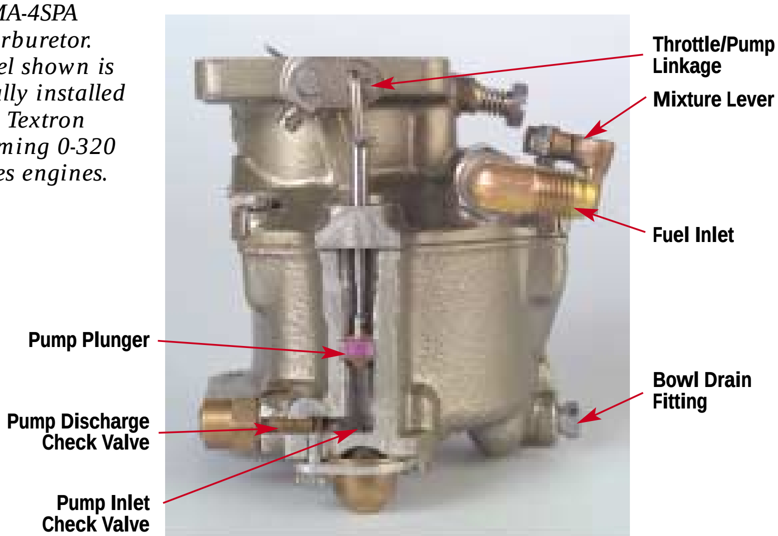

Photos of cut-away views of MA-4SPA Carburetor. Model shown is typically installed in Textron Lycoming 0-320 series engines.