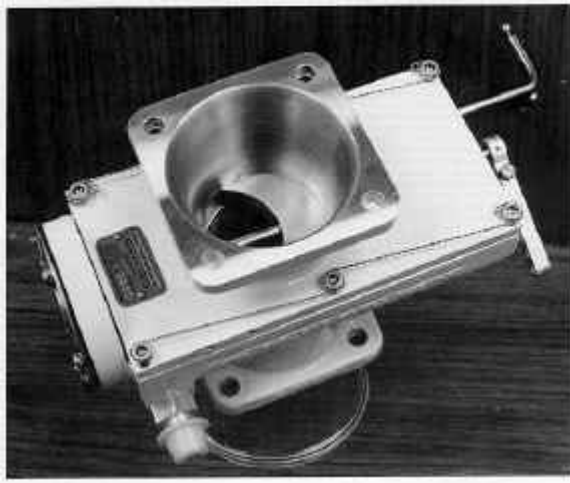




No, it's not a POSA!

By Ben Ellison, President, Ellison Fluid Systems, Inc.

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ALTHOUGH IT HAS obvious features in common with the Posa, Lake, and 200 other variable venturi brethren whose birth certificates are on file in the U.S. Patent Office, the Ellison Throttle Body Injector has enough personality of its own to earn its own certificates of legitimacy from Uncle Sam.

The Throttle Body Injector was originally developed as a solution to the hot starting problems encountered in fuel injected Pitts aircraft, but subsequent testing has revealed advantages that go far beyond start reliability. These advantages will be discussed in detail later in this article.

The unit pictured in Fig. 1 is our model EFS-4-5. The numbers in the model designation (EFS-4, EFS-4-5, etc.) refer to the SAE flange and bore configuration. This is similar to the nomenclature used by Marvel-Schebler (MA-4-5) and Bendix (PS-5, RSA-5, etc.). The letters EFS denote Ellison Fluid Systems Incorporated, the corporation formed to develop and market this product.

The Throttle Body Injector is a variable venturi device in which the fuel injection always occurs in the plane of maximum airflow velocity. Fuel injection occurs through a matrix of very small metering jets located in a tube extending across the entire width of the airflow passage. Fuel is admitted to this metering tube by a demand regulator designed to maintain a slightly negative fuel pressure. The metering tube is positioned in a bore through the throttle slide so that movement of the slide controls fuel flow as well as airflow by changing the number of jets exposed to the airstream.

Rotation of the metering tube through a maximum angle of 90 degrees changes the orientation of the fuel metering jets with respect to the airflow. This rotation serves as the pilot's mixture control. Idle cut-off occurs when the jets are facing directly into the on-coming airflow, and a progressively richer mixture is obtained as the jets are rotated away from the zero angle of attack position.

Because the fuel pressure in the metering tube is maintained below ambient pressure, fuel will not flow from the metering jets unless air is flowing through the induction system. This feature permits the engine to be shut down without the necessity of turning off the main fuel valve.

Idle fuel is dispensed through a separate jet remote from the metering tube and is adjusted by a

conventional needle valve. Idle fuel flow is cut off when the pilot's mixture control is placed in the full lean position, thus providing conventional idle cut-off behavior. Idle throttle setting is adjusted by a screw attached to the throttle control arm.

FUEL ECONOMY:

The uniformity with which fuel is distributed to the different cylinders is very critical to maximum power output as well as part throttle fuel economy. Poor fuel distribution is indicated by large cylinder to cylinder variations in exhaust gas temperature. In aircraft not equipped with multiple probe EGT systems, poor fuel distribution is indicated if engine roughness is encountered before or immediately after peak power when leaning. An engine equipped with a float carburetor, operating at part throttle cruise power, usually will not tolerate leaning more than 50 RPM on the lean side of peak power. A Throttle Body Injected engine however, may be leaned 100 to 150 RPM past peak power before roughness occurs.

In conventional float type carburetors, poor fuel distribution is caused by two design deficiencies;

1. The fuel is aspirated into the airstream in the form of a dense spray emanating from a single metering jet. In most engines the flow path length between the carburetor metering jet and the fork in the road where the mixture has to decide which cylinder it will go to, is too short to allow evaporation of the fuel. The liquid droplets, under the influence of centrifugal force, are hurled to the outside of any bends in the flow path where they impinge upon the walls forming puddles of liquid fuel.
2. At any throttle setting less than wide open, the butterfly valve functions as a turning vane, deflecting the unevaporated fuel droplets in favor of one or more cylinders. In order to prevent the lean cylinders from being too lean, the mixture control must be set significantly richer than would be the case with good fuel distribution.

In the EFS Throttle Body Injector, fuel is emitted from the metering tube in the form of a fine mist, distributed across the entire airflow passageway. The geometry of this flow pattern is not altered by changes in throttle opening. Fig. 4 illustrates fuel discharging from the metering tube of an EFS-4 installed on a Lycoming O-320 engine.



Figure 4

The operational benefits of these improvements over conventional carburetors is that the extra fuel that was originally keeping the rich cylinder rich, now remains in the fuel tank. Herb Sanders, who has been running an EFS-4 on his Long-EZ, N81HM, for over a year, claims fuel consumption reductions at cruise of 1 to 1.5 gallons per hour. He reports the ability to lean 150 RPM on the lean side of peak power without encountering engine roughness.

HIGHER FULL THROTTLE MANIFOLD PRESSURE:

In conventional carburetors, the venturi diameter is defined by the minimum signal pressures required to draw fuel from the float chamber at low, off idle throttle settings. Fuel metering in the Throttle Body Injector is accomplished with unusually low signal pressures, permitting a larger throat diameter than used in either the MA series of carburetors or the Bendix injectors. This larger inlet area results in a measurable increase in full throttle manifold pressure at the engine's maximum power rating. This benefit is apparent in the following back to back test data taken with a MA-4 carburetor and then repeated with an EFS-4.

Long-EZ Lycoming O-320160 HP Full Throttle Level Flight

Altitude	IAS MA4/EFS4	RPM MA4/EFS4	MP MA4/EFS4	OAT
3000	186/190	2990/3060	24.9/26.1	+4C
5000	178/181	2950/3010	23.4/24.2	0
6000	174/176	2940/3000	22.5/23.2	-1
7000	171/171	2910/2980	21.6/22.5	-3

8000	166/168	2890/2960	20.9/21.5	-4
10000	154/158	2840/2940	19.2/19.8	+1

The above engine installation operates at RPMs which greatly tax the breathing capacity of the MA-4 carburetor.

In installations which respect the 2700 RPM redline limit of the engine, a Throttle Body Injector would provide about 1/2 inch increase in manifold pressure at maximum power and RPM.

In verification of this extra power, Fig. 5 shows inlet pressure loss of the EFS-4 Throttle Body Injector compared to the Marvel-Schebler MA-4 carburetor. These curves can be related to manifold pressure at the full throttle, red line RPM flight condition as follows:

For a comparison of the EFS-4 with the MA-4, the inlet loss for each unit is read from Fig. 5 at the engine's maximum airflow. For the Lycoming 150 HP O-320 engine the maximum air consumption is 1050 lbs. per hour at sea level, full throttle, 2700 RPM. At that condition the inlet loss for the MA-4 is 15.0 inches of water while the loss for the EFS-4 is only 7.8 inches of water. The difference in loss between these two systems is:

$$15.0 - 7.8 = 7.2 \text{ inches of water.}$$

This difference is divided by 13.6 to get its equivalent value in inches of mercury.

$$7.2 / 13.6 = .53 \text{ inches of mercury}$$

This shows that an increase in full throttle manifold pressure of about 0.5 inches of mercury would be obtained by removing a MA-4 carburetor and replacing it with a EFS-4 Throttle Body Injector.

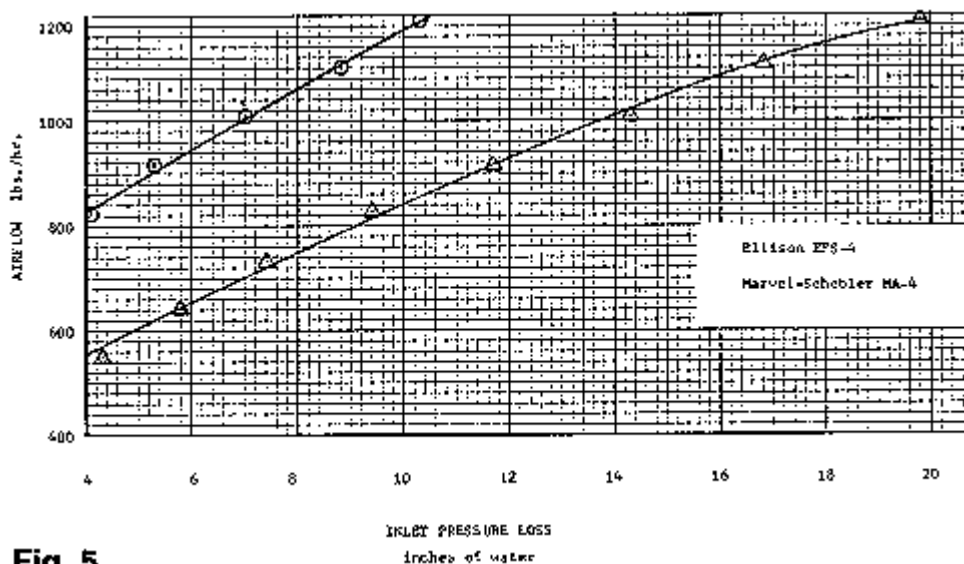


Fig. 5

Figure 5

STARTING:

Cold starting an engine equipped with a Throttle Body Injector requires priming the induction system with a conventional primer. The primed engine, after being pulled through 3 blades with the ignition switch off, will start on the first or second compression stroke.

Hot starts are made in the same way except that the addition of prime fuel usually is not necessary.

To convince skeptical Pitts drivers of the system's start reliability, Fig. 6 documents 35 consecutive starts of an IO-360 equipped with an ESF-4-5. The horizontal coordinate of each point represents the elapsed time since hot engine shut-down. The vertical coordinate represents the number of propping attempts necessary for starting. Each start was accomplished after the engine had initially been flown, then shut-down and allowed to heat-soak for the time indicated. This data was taken with ambient temperatures equal to or greater than 80 degrees F.

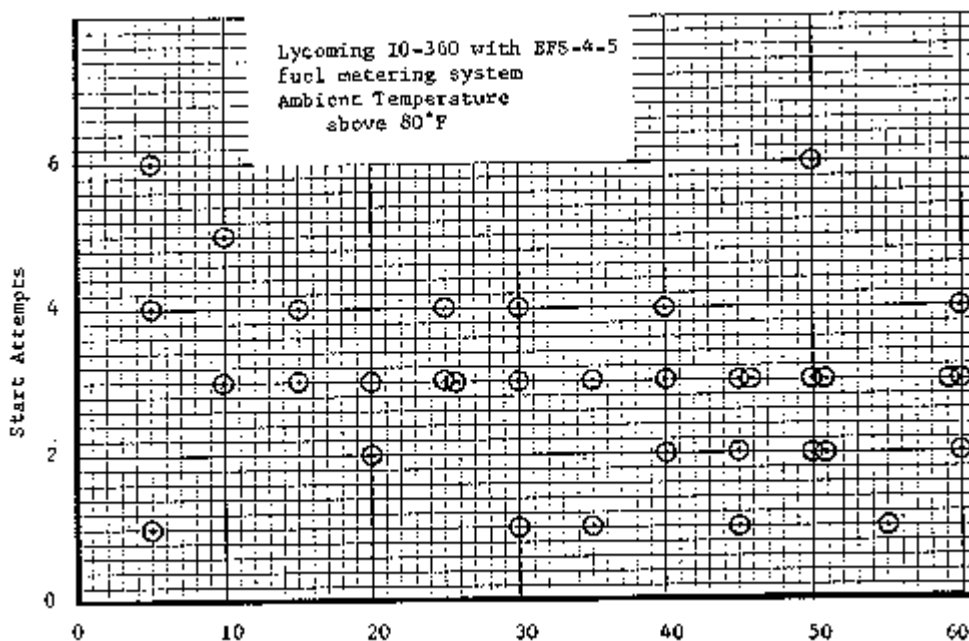


Figure 6

FUEL PRESSURE:

The Throttle Body Injector is usually operated with a conventional 4 to 6 psi A/C diaphragm fuel pump. It can, however, be configured to give satisfactory performance in gravity feed fuel systems.

ALL ATTITUDE OPERATION:

Since the Throttle Body Injector operates without a float chamber, it doesn't mind being mounted right side up, upside down, or sideways. Additional installation flexibility is available by positioning

the throttle arm as well as the fuel inlet fitting on either side of the body.

The system's insensitivity to orientation makes it suitable for acrobatic operation, given, of course, the availability of an inverted fuel and oil system.

SIMPLICITY:

A picture is worth a thousand words. Figures 7 through 9 show the Throttle Body Injector, and two conventional fuel metering units disassembled.

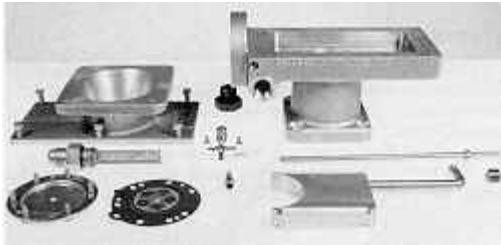


Figure 7



Figure 8



Figure 9

WEIGHT:

The weights of the three TBI models along with other popular fuel metering systems are listed below.

Manufacturer	Model	Weight (lbs)
Marvel-Schebler	MA-3SPA	3.0
	MA-4SPA	3.1
	MA-4-5	5.25
Bendix	PS-5	6.85
	RSA-5	7.64
Ellison	EFS-3	2.25
	EFS-4	2.8
	EFS-4-5	3.0

FUEL FILTRATION:

A 150 mesh removable finger screen is built into the Throttle Body Injector and serves as a "last chance" filter. In accordance with good design practice, an airframe mounted filter of equivalent or finer mesh is usually installed elsewhere in the aircraft's fuel system.