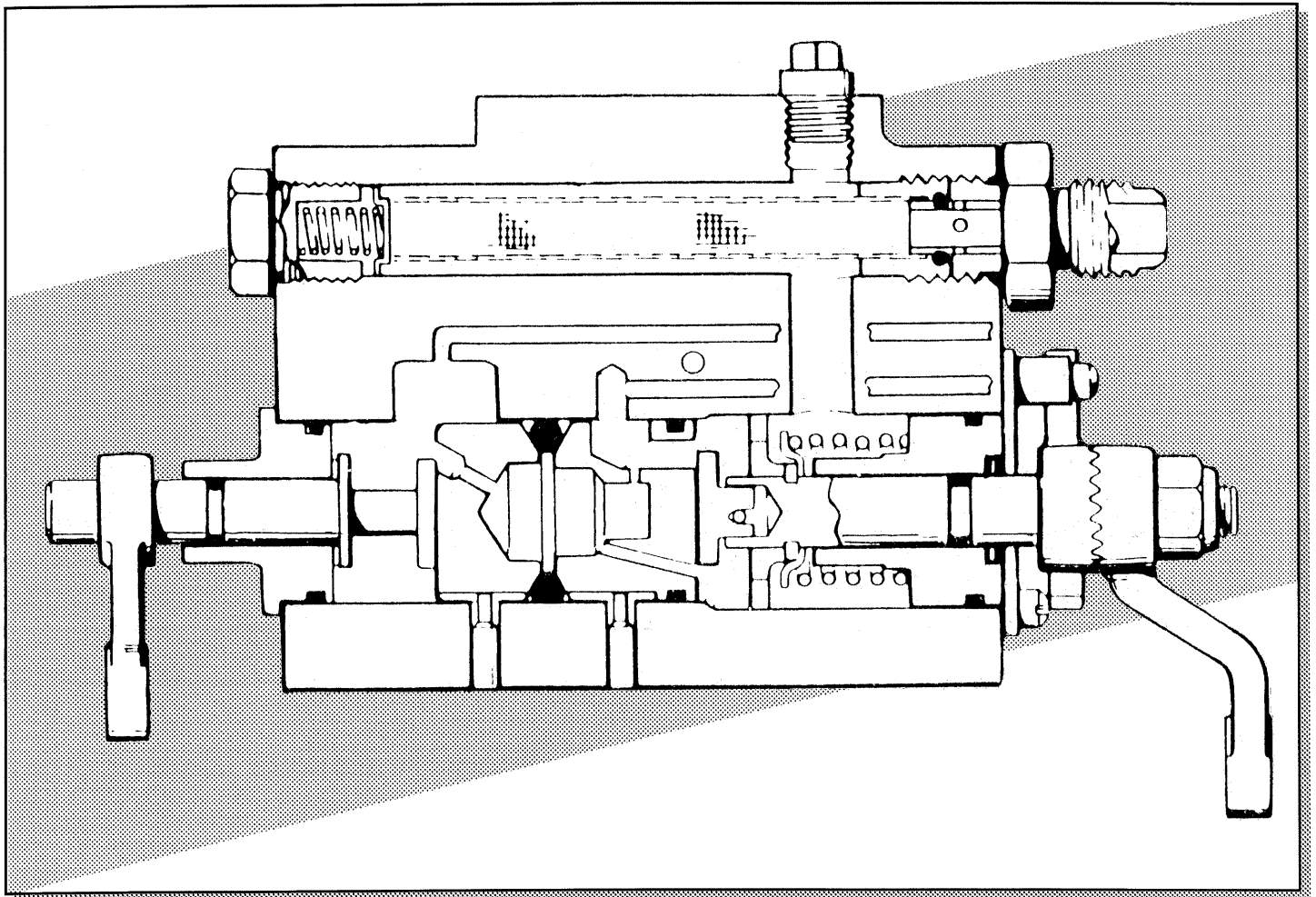


# TRAINING MANUAL

## RSA Fuel Injection System



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Any questions or comments regarding information contained in this manual should be directed to:

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# REFERENCE FIGURE 1

Precision Airmotive Fuel Injection Systems are designed to meter fuel in direct ratio to the volume of air being consumed by the engine at any given time. This is accomplished by sensing venturi suction and impact air pressures in the throttle body. Opening or closing the throttle valve results in a change in the volume of air being drawn into the engine. This results in a change in the velocity of air passing across the impact tubes and through the venturi. When air velocity increases, the pressure at the impact tubes remains relatively constant depending upon the inlet duct configuration, air figure location, etc. The pressure at the venturi throat decreases. This decrease creates a differential (impact minus suction) which is used over the entire range of operation of the fuel injection system as a measurement of the volume of air consumption.

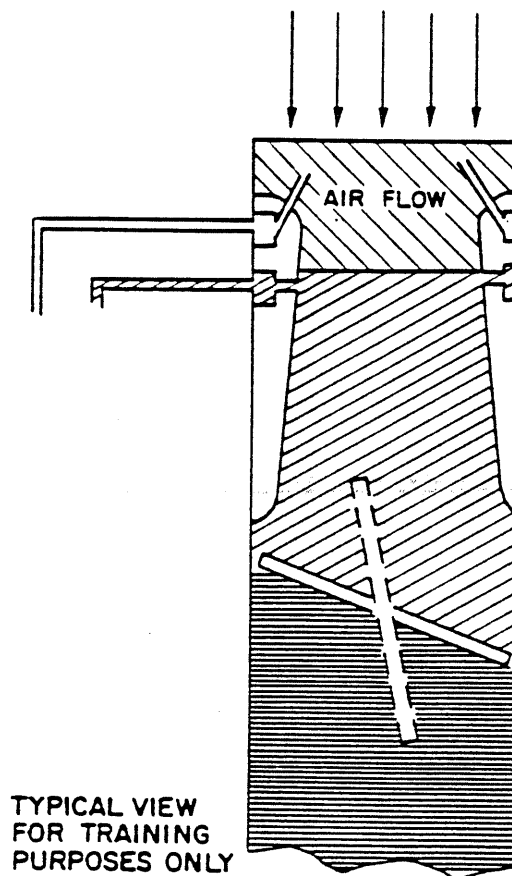


Figure 1.

## REFERENCE FIGURE 2

All reciprocating engines operate most efficiently in a very narrow range of air to fuel ( or fuel/air ) ratios. The Precision Airmotive injection system uses the measurement of air volume flow to generate a usable force which can be used to regulate the flow of fuel to the engine in proportion to the amount of air being consumed.

This is accomplished by channeling the impact and venturi suction pressures to opposite sides of a diaphragm. This difference between these two pressures then becomes a usable force which is equal to the area of the diaphragm times the pressure difference.

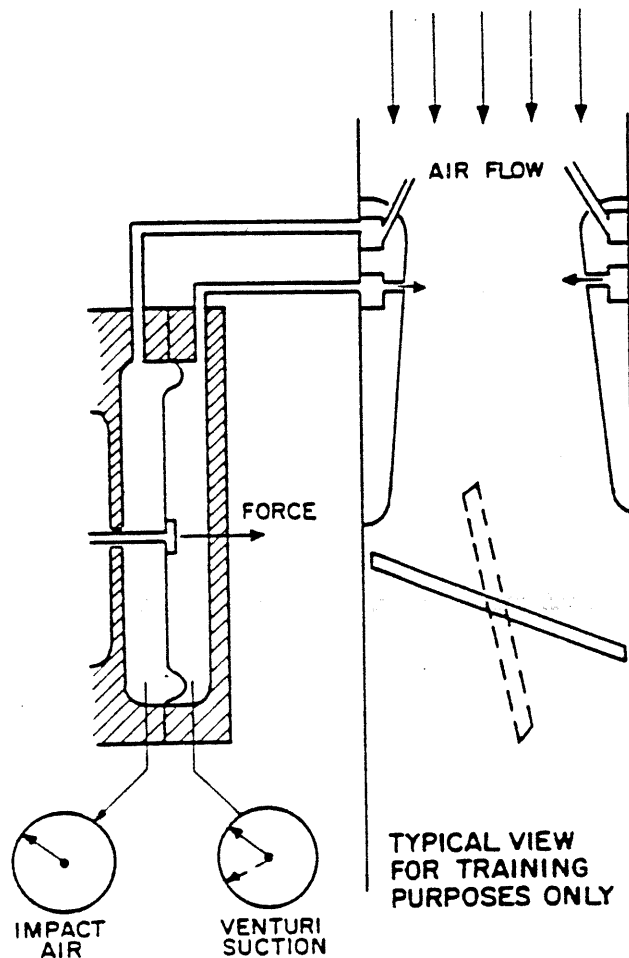


Figure 2.

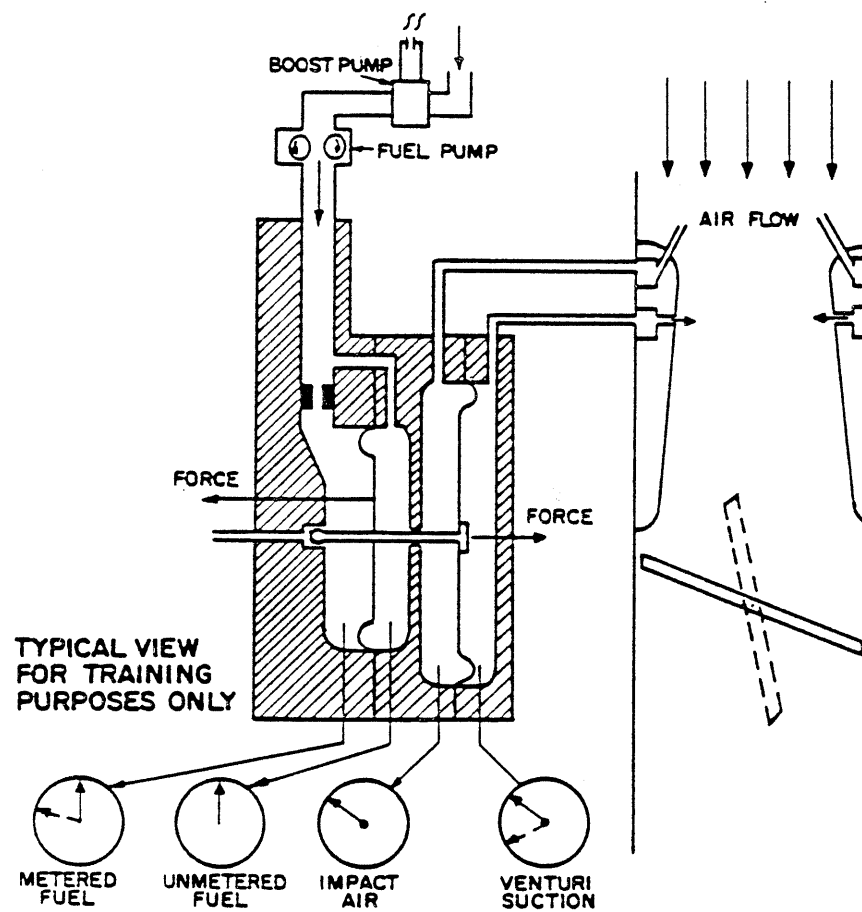


Figure 3.

LA-8504

### REFERENCE FIGURE 3

Fuel is supplied to the engine from the aircraft fuel system. This system usually includes a boost pump located either in the fuel tank or the fuel line between the tank and the engine. The engine driven fuel pump receives fuel from the aircraft system (including the boost pump) and supplies that fuel at a relatively constant pressure to the fuel injector servo inlet. The engine manufacturer specifies the fuel pump pressure setting applicable to the specific fuel injector installation. The fuel injectors are calibrated at that inlet pressure setting. The settings are checked to assure that metered fuel flow will not be affected by changes in inlet fuel pressure caused by normal boost pump ON or OFF operation.

Precision's fuel injection system will, if properly assembled and calibrated, meet all performance requirements over an extremely wide range of inlet fuel pressures. Its heart is the servo pressure regulator.

The easiest way to explain the operation of this regulator and its relationship to the main metering jet is to describe a power change which requires a fuel flow change.

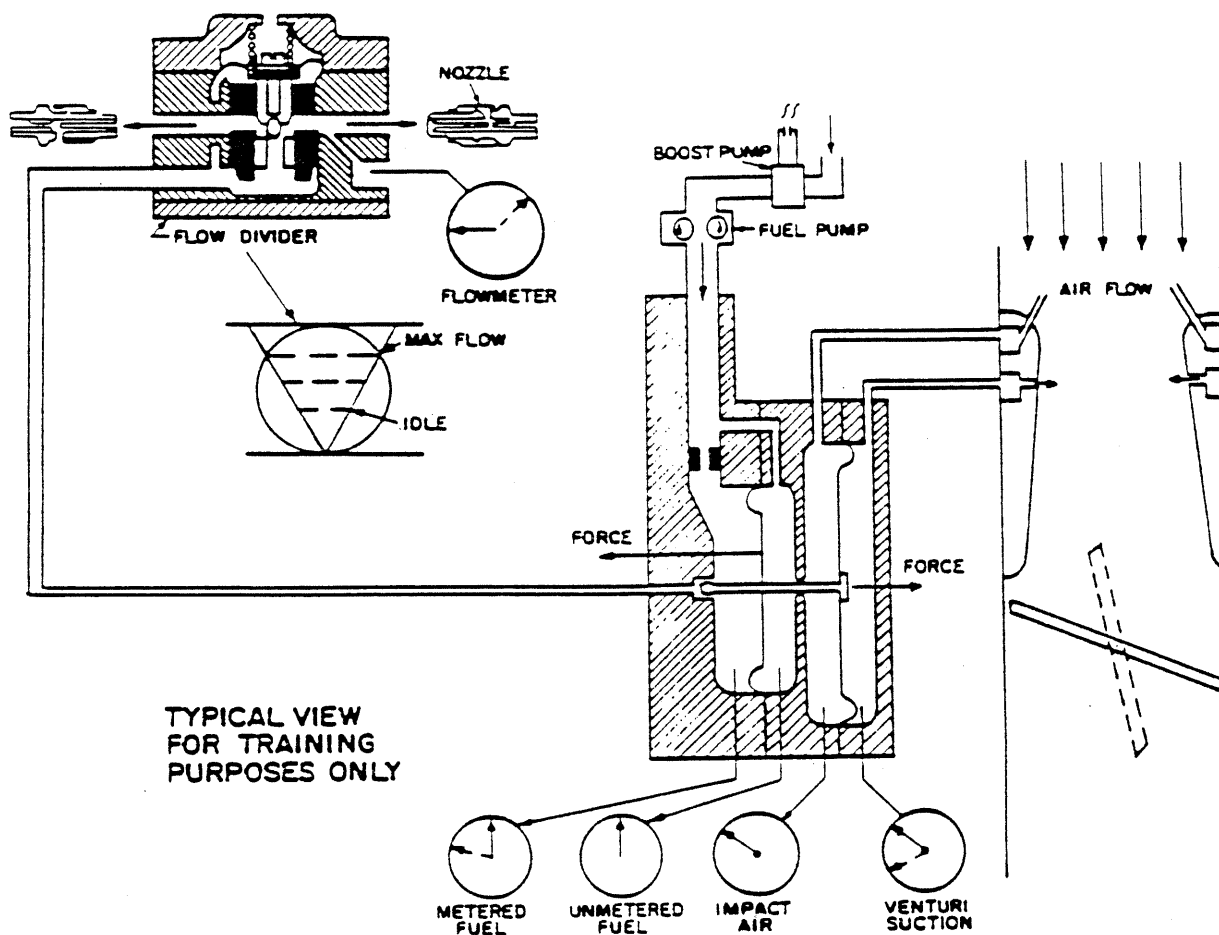
To begin this explanation, we will start from a cruise condition where air velocity through the throttle body is generating an impact pressure minus venturi suction pressure differential at a theoretical value of "2". This air pressure differential "2" is exerting a force to the right as shown in Figure 3.

Fuel flow to the engine, passing through the metering jet, generates a fuel pressure differential (unmetered fuel minus metered fuel pressure). This pressure differential, applied across a second (fuel) diaphragm is also creating a force with a value of 2. This value of "2" is exerting a force to the left as shown in Figure 3.

The two opposing forces (fuel and air differentials) are equal, and the regulator servo valve (which is connected to both diaphragms by a stem) is held at a fixed position that allows discharge of just enough metered fuel to maintain pressure balance. If the throttle is opened to increase power, air flow immediately increases. This results in an increase in the pressure differential across the air diaphragm to a theoretical value of "3". Immediate result is a movement of the regulator servo valve to the right. This increased servo valve opening causes a decrease in pressure in the metered fuel chamber, and an increase in fuel pressure differential across the main metering jet. When this increasing fuel differential pressure force reaches a value of "3" (equaling the air diaphragm force), the regulator stops moving and the servo valve stabilizes at a position which will maintain the balance of pressure differentials, i.e., air and fuel, each equaling 3.

Fuel flow to the engine is increased to support the higher power level requested. The fuel diaphragm force being generated by the pressure drop across the main metering jet is equal to the air diaphragm force being generated by the venturi.

This sequence of operation is true for all regimes of power operation and all power changes. The regulator servo valve responds to changes in effective air diaphragm differential pressure forces and adjusts the position of the servo valve to regulate unmetered to metered fuel pressure differential forces accordingly. Fuel flow through the metering jet, and to the engine, is a function of its size and the pressure differential across it. The servo valve does not meter fuel. It only controls pressure differential across the metering jet.



LA-8505

Figure 4.

#### REFERENCE FIGURE 4

Metered fuel flow is delivered from the fuel injector servo unit to the engine through a system which usually includes a flow divider and a set of discharge nozzles (one nozzle per cylinder). A few engine installations do not use a flow divider. On these engines, the fuel flow is divided by either a single four-way fitting (4-cylinder engines) or tee which divides the fuel flow into two separate paths. Each path incorporates a three-way fitting (6-cylinder engines).

The flow divider consists of a valve, sleeve, a diaphragm and a spring. The valve is spring loaded to the closed position in the sleeve. This effectively closes the path of fuel flow from the fuel injector servo to the nozzles and at the same time isolates each nozzle from all of the others at engine shut down. The two primary functions of the flow divider are:

To assure equal distribution of metered fuel to the nozzles at and just above idle; and

To provide isolation of each nozzle from all the others for clean engine shut down.

The area of the fuel discharge jet in the fuel nozzles is sized to accommodate the maximum fuel flow required at rated horsepower without exceeding the regulated fuel pressure range capability of the servo pressure regulator.

The area of the jet in the nozzle is such that metered fuel pressure at the nozzle is negligible at the low fuel flows required at and just above idle. Metered fuel from the injector servo enters the flow divider and is channeled to a chamber beneath the diaphragm. At idle, fuel pressure is only sufficient to move the flow divider valve slightly open, exposing the bottom of a "V" slot in the exit to each nozzle. This position provides the accuracy of fuel distribution needed for smooth idle. As the engine is accelerated, metered fuel pressure at the flow divider inlet and in the nozzle lines increases. It gradually moves the flow divider valve open against the spring pressure until the area of the "V" slot opening to each nozzle is greater than the area of the fuel restrictor in the nozzle. At that point, responsibility for equal distribution of metered fuel flow is assumed by the nozzles. Since metered fuel pressure (nozzle pressure) increases in direct proportion to metered fuel flow, a simple pressure gage can be used as a flowmeter indicator. If the fuel restrictor in one or more nozzles becomes partially plugged by contaminant, the total exit path for metered fuel flow is reduced. The fuel injector servo will continue to deliver the same amount of total fuel flow. Therefore, nozzle pressure will increase, giving an indication of fuel flow increase on the flowmeter gage.

The cylinder(s) having restricted nozzles will be running lean and the remaining cylinders will be rich. RESULT: Rough engine accompanied by high fuel flow indication. Problem may be caused by partially plugged nozzle(s).

When the mixture control is placed in cut off, fuel pressure to the flow divider drops to zero. The spring forces the flow divider valve to the closed position and immediately interrupts the flow of fuel to each nozzle. This breaks the path of capillary flow which would allow manifold suction to continue to draw fuel in dribbles from one or more nozzle lines as the engine coasts down. Without the flow divider, this "dribbling" of fuel into one or more cylinders could keep the engine running for a minute or more.



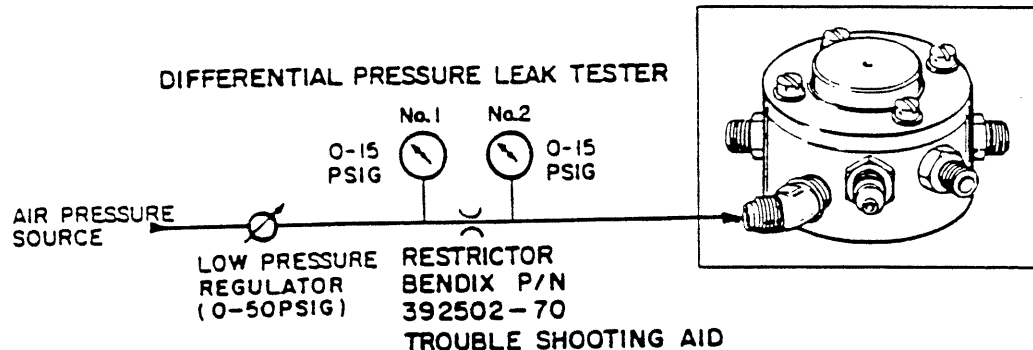
REFERENCE FIGURE 5

**CAUTION:** THE FOLLOWING TESTS ARE INTENDED AS TROUBLESHOOTING AIDS ONLY AND SHOULD NOT BE CONSTRUED AS CALIBRATION CHECKS OF THE FLOW DIVIDER. SHOULD A QUESTION EXIST REGARDING SERVICEABILITY OF A GIVEN FLOW DIVIDER, IT MUST BE SENT TO A CERTIFIED OVERHAUL/REPAIR FACILITY.

The flow divider can be disassembled in the field for cleaning and inspection. A scored valve or one that drags could cause fuel distribution problems very similar to nozzle problems. Do not attempt to polish the valve or sleeve with any abrasive agent. The valve and sleeve are a matched assembly. The valve is not procurable and if damaged, the entire flow divider will have to be replaced. The flow divider can be checked for proper operation and for distribution problems caused by contamination plugging one or more of the outlets. The simplest method to do this is with the beaker check described for nozzles later in this presentation. An alternate method would require a locally manufactured differential pressure tester.

If the tester is connected to the flow divider inlet and regulated pressure is slowly increased from zero, the flow divider valve should open almost immediately (1/2 psig). When it begins to open a difference in pressure will be seen between the two gages.

If the valve does not open immediately, which is indicated by equally increasing pressure on both gages, it is probably dragging in its sleeve. After determining that it is opening normally, install caps on all of the outlet fittings except one. Increase the inlet pressure slowly to 20 psig. Note and record the pressure observed on gage #2 at each increment of four psig increase of inlet pressure. Remove one of the other caps and install it on the first fitting. Repeat the recording procedure. Repeat this procedure until all four (or six) outlets have been checked. Pressure readings on gage #2 should be approximately equal at each step for all of the outlets. If the pressure for one or more of the outlets is significantly higher, a restriction in that outlet is indicated.



LA-8506

Figure 5.

# REFERENCE FIGURE 6

Figure 6 shows the exact function and operation of the idle valve.

The idle valve is connected to the throttle linkage. It effectively reduces the area of the main metering jet for accurate metering of fuel in the idle range. It is externally adjustable and allows the mechanic to properly tune the fuel injector to the engine installation for proper idle mixture. Idle mixture is correct when the engine gains approximately 25 to 50 rpm from its idle speed setting as the mixture control is placed in cut off. Manual control of idle mixture is necessary because at the very low air flow through the venturi in the idle range, the air metering force is not sufficient to accurately control fuel flow.

On some engines, according to specific installation requirements, an enrichment jet is added in parallel with the main metering jet. On these installations, the sliding (rotating) idle valve begins to uncover the enrichment jet at a preset throttle position. This parallel flow path increases the fuel/air mixture strength to provide for "fuel cooling" of the engine in the high power range. In simple terms, this is trading increased fuel consumption for added engine life.

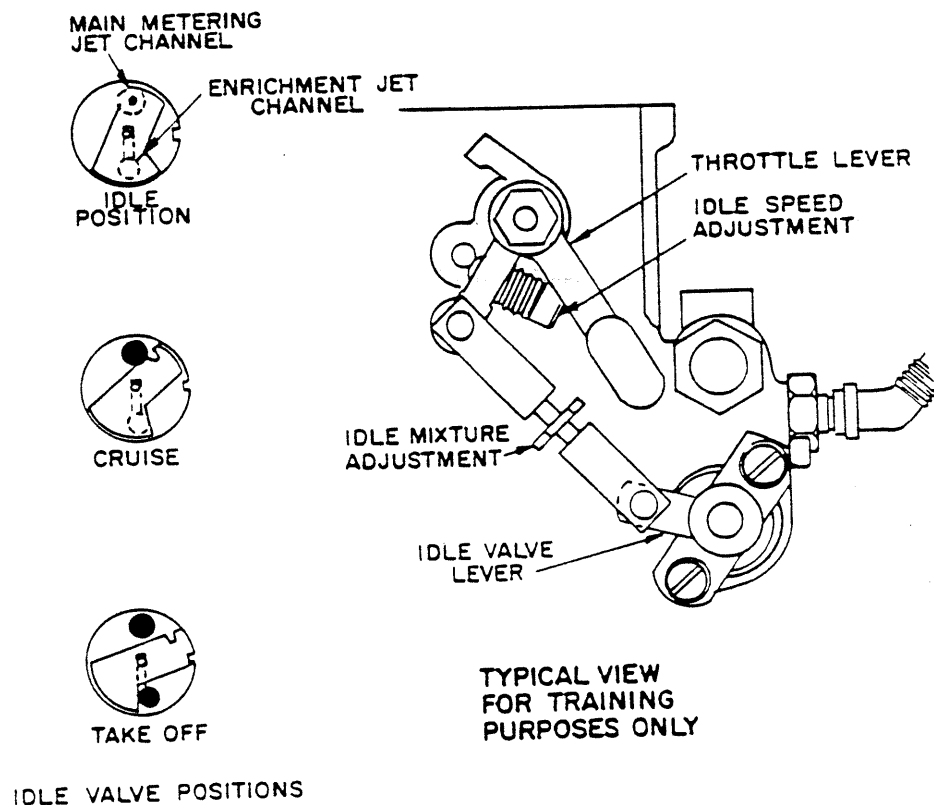
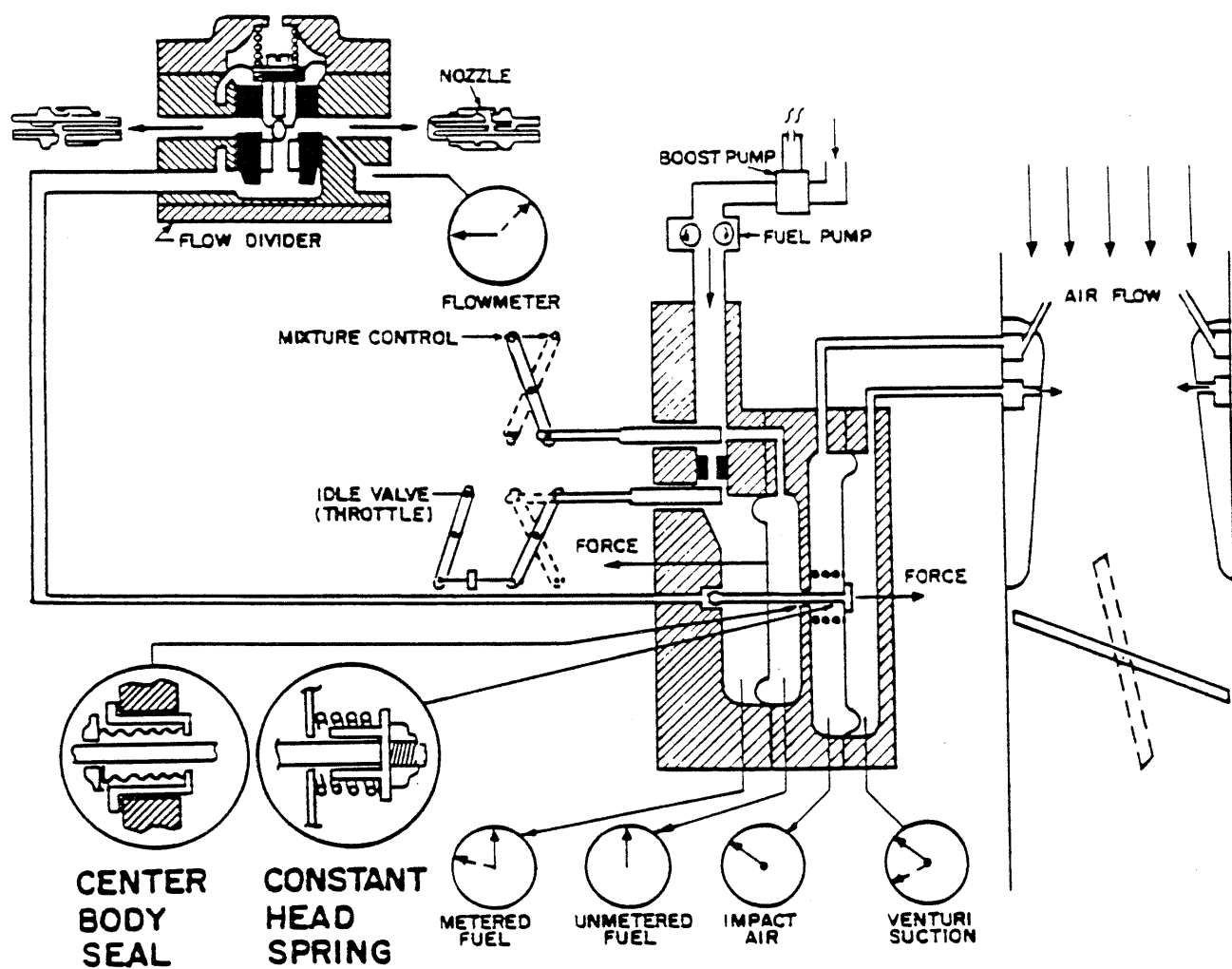


Figure 6.

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**TYPICAL VIEW  
FOR TRAINING  
PURPOSES ONLY**

LA-8508

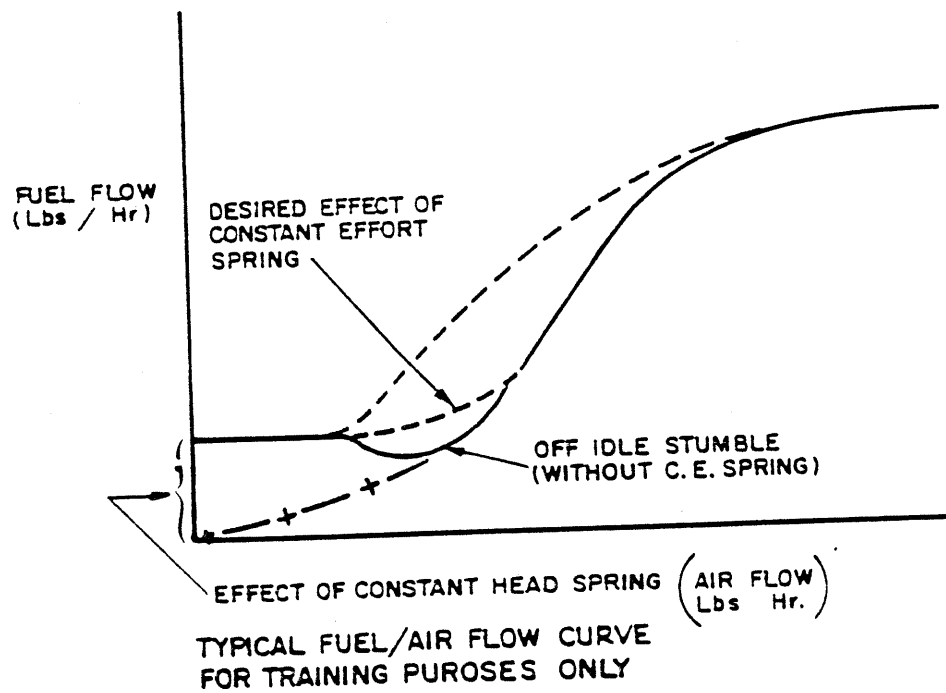
Figure 7.

#### REFERENCE FIGURE 7

Figure 7 shows the further operation of the manual mixture control, constant head, constant effort springs, and center body seal.

The manual mixture control, shown in Figure 7 as a sliding valve, can be used by the pilot to effectively reduce the size of the metering jet. With the servo pressure regulator functioning to maintain a differential pressure across the metering jet in proportion to the volume of air flow, the flow through the jet may be varied by changing its effective size. This allows the pilot the option to manually lean the mixture for best cruise power or best specific fuel consumption. It also provides the means to shut off fuel flow to the engine at engine shut down.

The constant head idle spring augments the force of the air diaphragm in the idle and off idle range where the air pressure differential is not sufficient to move the servo valve open. The idle spring assures that the regulator servo valve is open sufficiently to allow fuel being metered by the idle valve to flow out to the flow divider. As air flow increases above idle, the air diaphragm will begin to move to the right in response to increasing air pressure differential. It will compress the constant head idle spring until its retainer and guide contact the diaphragm plate. From this point onward, in terms of air flow, fuel flow, or power, the constant head idle spring assembly is a solid member moving with the air diaphragm and exerts no force of its own. The constant head spring is furnished in a selection of strengths so the overhaul technician can properly calibrate the injector for idle fuel flow and for the transition to servo regulator controlled fuel flow.



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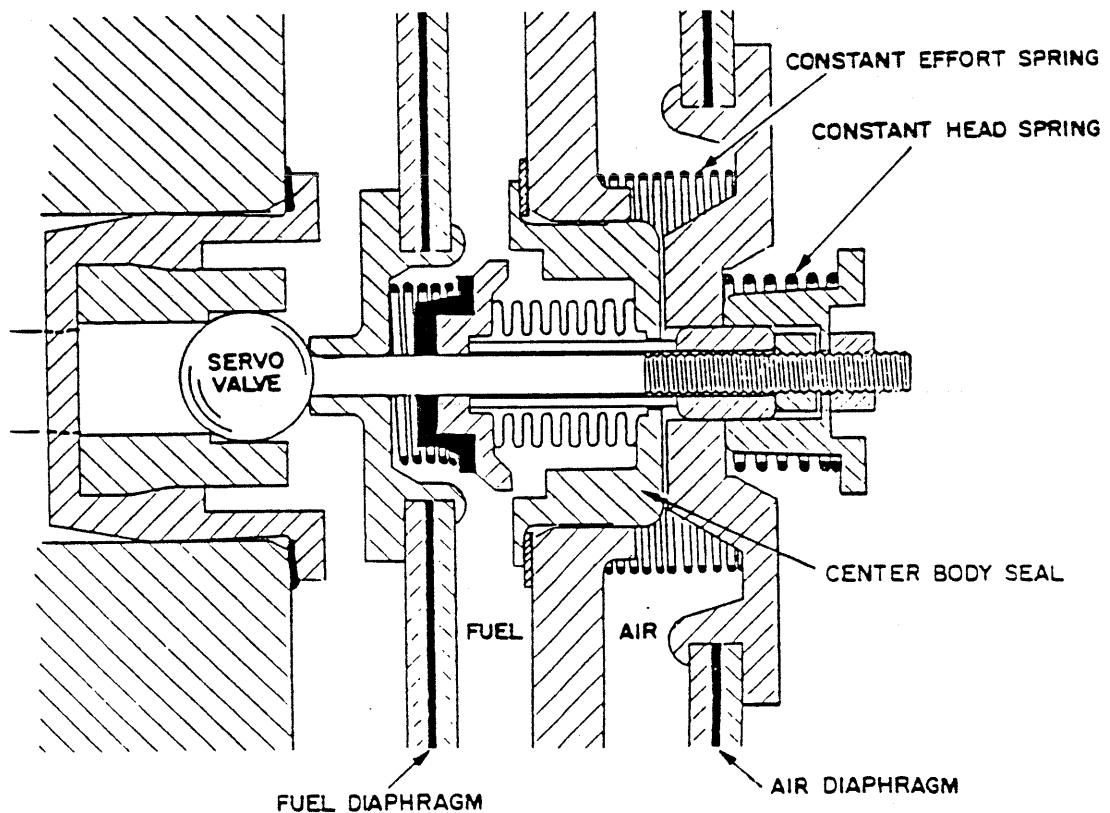
Figure 8.

REFERENCE FIGURES 8 AND 9

In most installations, the transition from idle to servo regulator controlled fuel flow has to be supplemented with a constant effort spring. This spring also assists the air diaphragm to move smoothly from the low air flow idle range to the higher power range of operation. It is also furnished in a selection of strengths to be utilized by the overhaul technician for proper calibration of the unit.

The fuel section of the servo pressure regulator is separated from the air section by a center body seal assembly. In 1979, a product improvement was made to the seal changing the design from a rubber diaphragm to bellows type. This bellows seal, as shown in Figure 9, is presently used in all current production and newly overhauled-type fuel injectors.

Leakage through the center body seal causes extremely rich operation and poor cut off. The presence of raw fuel out the impact tubes may indicate possible seal leakage. Failure of this seal requires repair in an overhaul shop. It cannot be replaced in the field.



TYPICAL VIEW  
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LA-8510

Figure 9.

# REFERENCE FIGURE 10

Precision Airmotive nozzles are furnished under several different part numbers. The part number generally identifies the specific installation requirement for the engine, i.e., normally aspirated, which requires the simple nozzle assembly with the air bleed screen and shroud pressed in place, or the configuration of the shroud assembly to accept the supercharger air pressure signal to the nozzle.

All nozzles are of the air bleed type. This means that the fuel is discharged inside the nozzle body into a chamber which is vented to either atmospheric air pressure or to supercharger air pressure (injector top deck pressure). The nozzle is mounted into the intake valve plenum of the cylinder head. It's exit is always exposed to manifold pressure, which on a normally aspirated engine is always less than atmospheric. This results in air being drawn in through the air bleed and mixed with fuel in the fuel/air chamber to provide for fuel atomization. This is particularly important to the idle and low power ranges where manifold pressure is weakest and bleed air intake is greatest. A plugged air bleed in this range allows the exit of the fuel restrictor to be exposed to manifold suction, which effectively increases the pressure differential across the restrictor and causes an increase in fuel flow through that nozzle. Since this nozzle is now, in effect, stealing fuel from the other nozzles (injector servo output flow will remain the same) this cylinder will run rich and the other cylinders will be correspondingly lean. A net decrease in metered fuel pressure will result and show up on the flowmeter as a lower fuel flow indication. RESULT: Rough idle with low fuel flow indication and higher than normal RPM rise when going into cut-off. The engine will also have very poor cut off, tending to continue chugging for several seconds following movement of the mixture control to cut off.

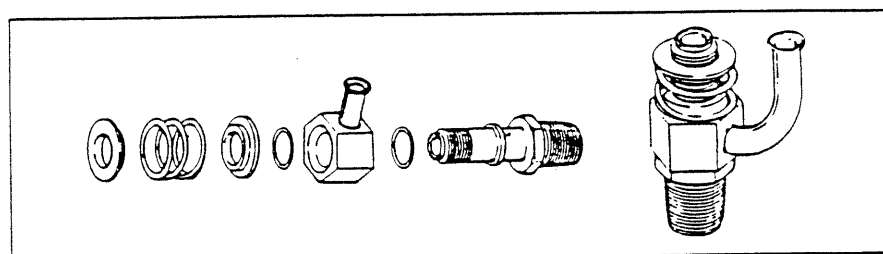
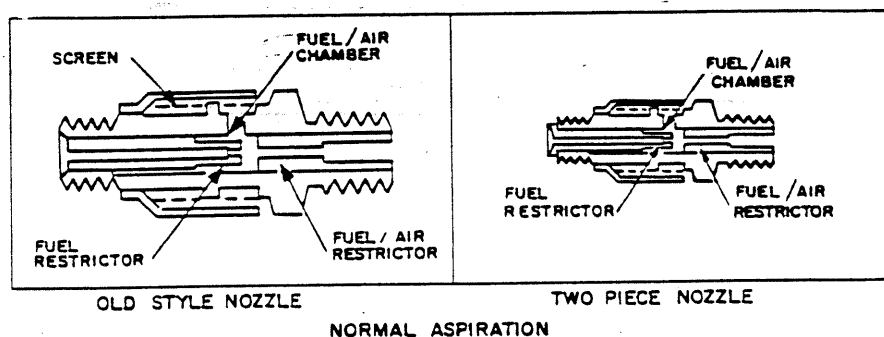
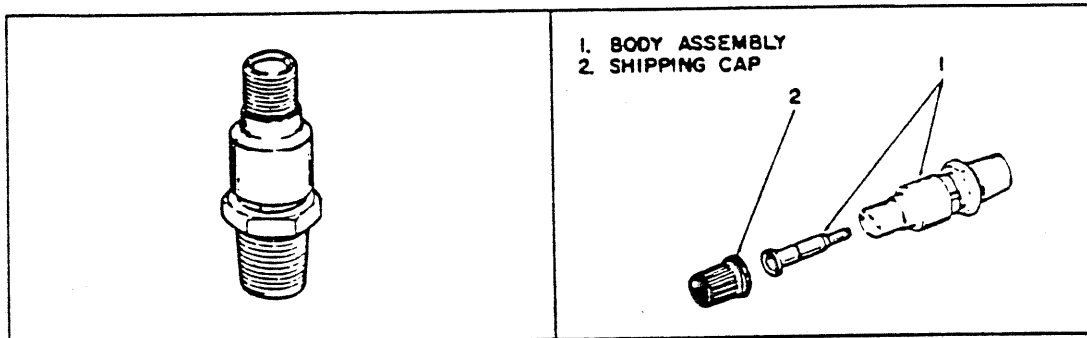


Figure 10.

LA-8511

TYPICAL VIEW  
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CHECKING FUEL NOZZLES

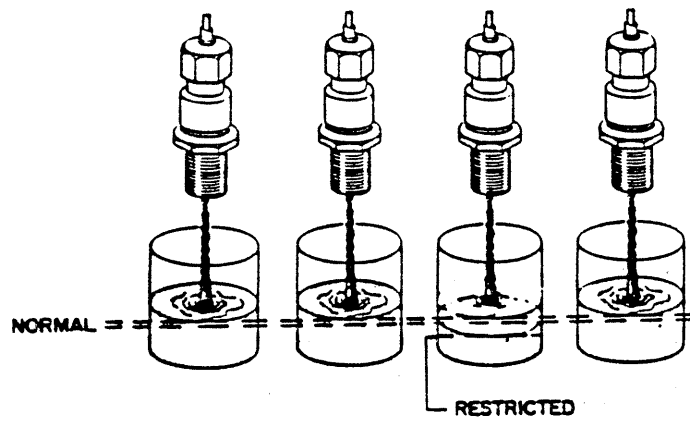


Figure 11.

LA-8512



REFERENCE FIGURE 11

CAUTION: THE FOLLOWING TEST IS INTENDED AS A TROUBLESHOOTING AID ONLY AND SHOULD NOT BE CONSTRUED AS A CALIBRATION CHECK OF THE NOZZLE ASSEMBLIES. SHOULD A QUESTION EXIST REGARDING SERVICEABILITY OF A GIVEN NOZZLE ASSEMBLY, THE UNIT MUST BE SENT TO A CERTIFIED OVERHAUL/REPAIR FACILITY.

PRIOR TO INSTALLING A NOZZLE ASSEMBLY, ALWAYS REFER TO THE ENGINE MANUFACTURER'S INSTRUCTION MANUALS FOR THE PROPER TORQUE VALUE OF NOZZLES AND LINES.

Most nozzles which are cylinder head installed are calibrated alike. For example, with exactly 12 psig inlet pressure applied flow should be 32 pph plus or minus 2%.

A comparison check of fuel flow from the nozzles installed on any given engine can be made as follows:

Remove nozzles from cylinder heads and reconnect them to their supply lines. Position equal size containers to capture the output of each nozzle. Turn on the boost pump and open the mixture control and throttle. When a good reference quantity of fuel has been collected in each container, close the mixture control and throttle and turn off the boost pump. Align the containers on a flat surface and compare the level of fuel captured. A noticeably low volume of fuel in one or more containers indicates restriction in the nozzle fuel restrictor, flow divider or lines. Switch nozzles around and repeat the test until the cause is isolated.

All current production nozzles are two piece configuration. The fuel restrictor is a flanged insert which can easily be removed for cleaning. It can also be easily lost during handling. A lost or damaged insert will require purchase of a new nozzle assembly because they are flow matched assemblies. On older production nozzles, the restrictor was pressed into the nozzle body and was not removable.

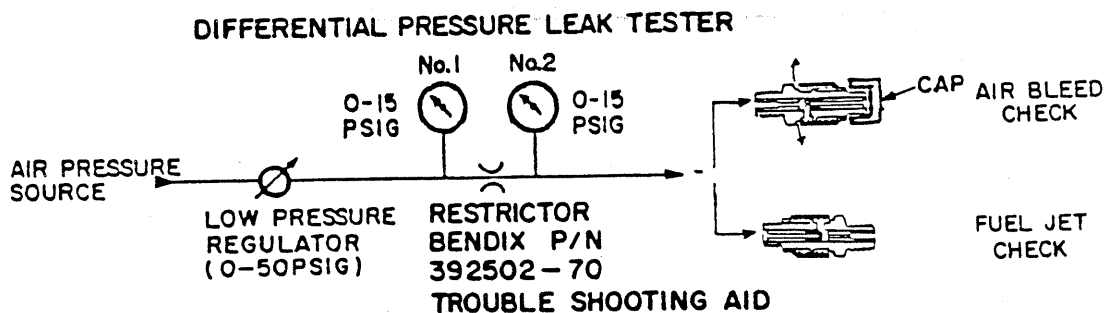
Over torque of the nut connecting the fuel line to the nozzle can result in pressing the insert deeper into the body and closing off the air bleed on the older nozzles. Over torque can crack the flange off of the insert on the newer type. In either case, the nozzle is destroyed. Correct torque for the nut is 25 to 50 inch-pounds. Over torque of the nozzle into the cylinder head results in distortion of the base of the nozzle and upsets its calibration and spray pattern. Correct torque is 60 inch-pounds maximum.

## REFERENCE FIGURE 12

A locally manufactured differential air pressure tester can also be used to verify the integrity and cleanliness of the nozzle fuel restrictor and air bleed opening. If 15 psig is supplied from the test kit regulator and to the fuel inlet of the nozzle, the pressure on gage #2 will be lower than 15 psig (gage #1). This pressure is lower because the flow through the nozzle produces a pressure differential across the orifice in the test kit. If a nozzle were completely plugged, the pressures would be equal on the two gages. A set of new or known to be good nozzles will provide a pressure reference to be used during troubleshooting. To determine if the air bleed is plugged, reverse the nozzle, to apply the air pressure to the exit (cylinder head end) and install a cap on the fuel inlet end.

While it is generally good practice to maintain a common configuration of a full set of one type of nozzles, installing one or more new type nozzles on an engine equipped with the older type should create no problem. Also, where possible, individual two-piece nozzles should be kept as matched assemblies. Intermixing these parts may not cause a problem; however, if or when a problem occurs as a result of intermixing, purchase of a new nozzle will probably be the only recourse.

The letter "A" found stamped on one flat of the wrenching hex is located 180 degrees from the air bleed hole in the nozzle body. After final installation torque, the air bleed should be positioned upward ("A" on the bottom) so that residual fuel in the line cannot drip out after engine shut down. A thorough periodic cleaning of the nozzle is recommended to ensure continued satisfactory operation of the nozzle to T.B.O. per Bendix RS-77 (latest revision).



LA-8513

Figure 12.

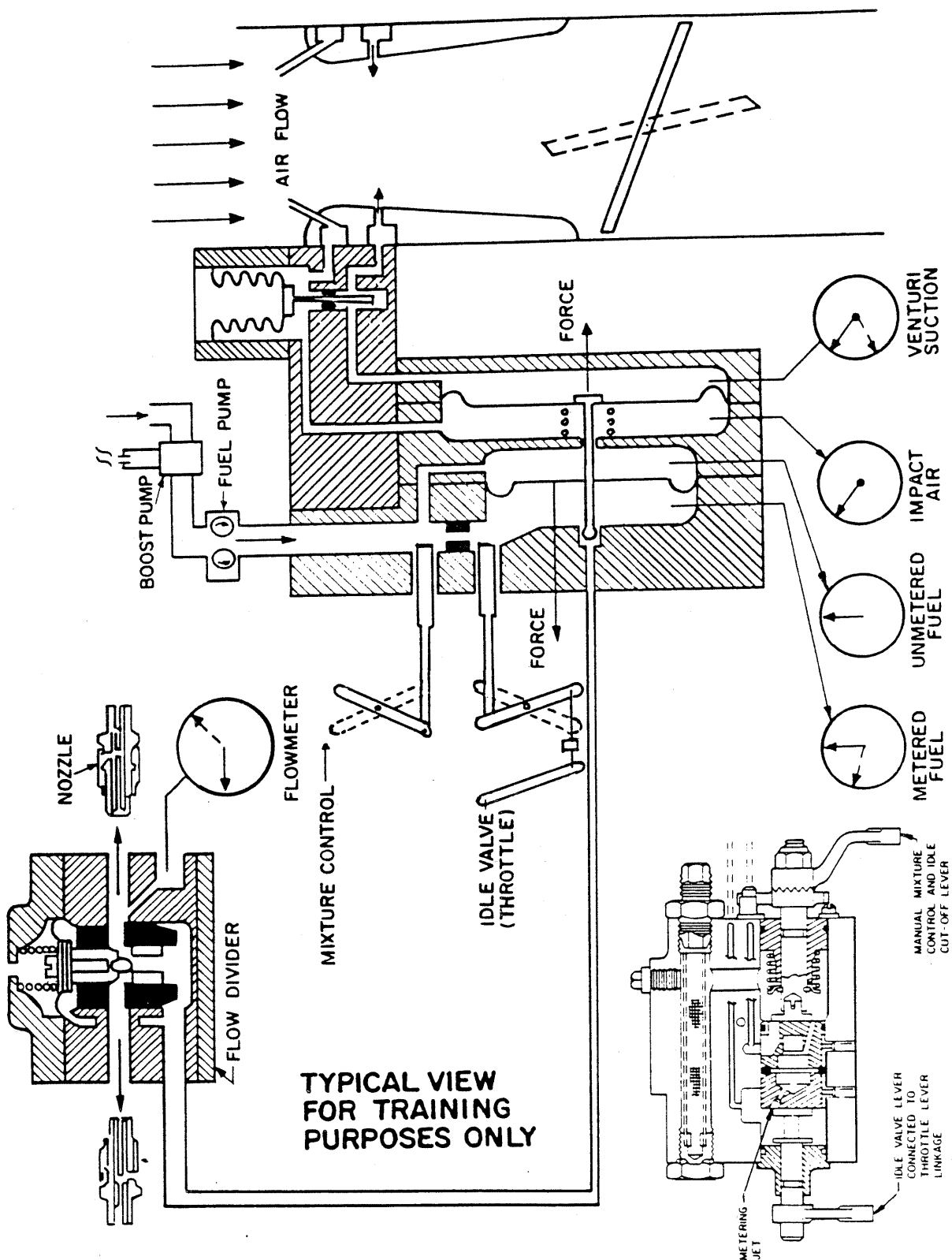


Figure 13.

LA-8514

### REFERENCE FIGURE 13

Figure 13 shows the function and operation of the automatic mixture control (AMC). It also expands the description of the manual mixture control and idle valves. The mixture control is shown in the full rich position and the idle valve fully open as it would be at cruise power or above. In the cutaway, the two rotating valve assemblies are spring loaded together back to back with an O-ring seal between. Fuel flows through the mixture control valve, through the idle valve and out to the regulator servo valve. The inlet strainer is located underneath the fuel inlet fitting and is installed spring end first so the open end is mated to the inlet fitting. If the screen becomes blocked by contaminant material, inlet pressure will force it away from the fitting, compressing the spring to allow fuel to bypass the screen if necessary. This screen filter is a mandatory 100% replacement item at overhaul. There is no approved method of cleaning this screen for reuse.

The AMC adjusts fuel/air ratio to compensate for the decreased air density as the aircraft climbs to altitude. Fuel/air ratio is expressed in pounds per hour of fuel and air respectively. The fuel injector meters fuel on a pounds per hour basis, referenced to the volume of air flow, which, converted to velocity passing through the venturi produces the air metering signal previously discussed.

An engine pumps air on the basis of volume, not weight. This volume is determined by the engine displacement, i.e., 10-540 cubic inches per complete four stroke cycle (intake, compression, power, exhaust for all six cylinders). So, a 10-540 at 2500 rpm would be consuming (pumping):

$$540 \times (2500/2) = 675000 \text{ cu. in. per min.}$$

$$675000/1728 = 390 \text{ cu. ft. per min.}$$

$$390 \times .0765 = 30 \text{ pounds per minute.}$$

$$30 \times 60 (\text{min}) = 1800 \text{ pph air flow.}$$

This would be equivalent to cruise power at sea level. A fuel/air ratio of 0.08 would result in:

$$1800 \times 0.08 = 150 \text{ pph fuel flow.}$$

As the aircraft climbs to altitude, the specific weight of air decreases from 0.0765 pounds per cubic foot until at 15,000 feet, air only weighs 0.0432 pounds per cubic foot. The engine at 2500 rpm would still be consuming 390 cubic feet per minute, resulting in:

$$(390 \times 0.0432) \times 60 = 1020 \text{ pph air flow.}$$

This 1020 pph air flow will produce the same air metering signal across the venturi that 1800 pph did at sea level. This air metering signal will maintain the 150 pph fuel flow which would result in:

$$150/1020 = 0.147 \text{ fuel air ratio.}$$

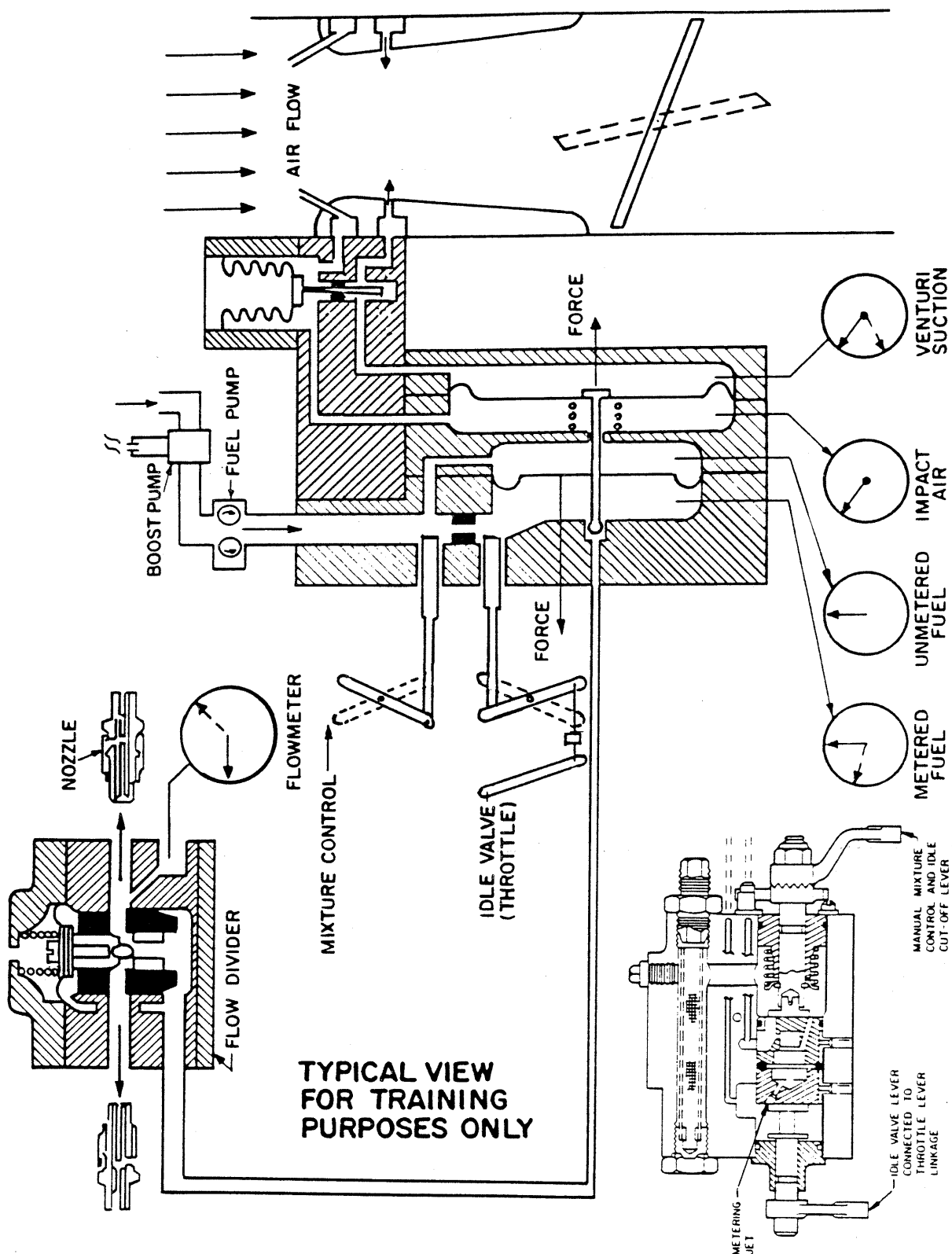


Figure 13A.

LA-8514

REFERENCE FIGURE 13A

Without an AMC, it would be necessary for the pilot to continually lean the mixture manually to maintain the desired 0.08 fuel/air ratio. The AMC works independently of, and in parallel with, the manual mixture control by providing a variable orifice between the two air pressure signals (impact and suction) to modify the air metering signal force.

The AMC assembly consists of a contoured needle that is moved in and out of an orifice by a bellows assembly. This bellows reacts to changes in air pressure and temperature, increasing in length as pressure altitude increases. At ground level, the needle is positioned in the AMC orifice so that the orifice is closed, or nearly closed, to allow the maximum impact pressure to the impact pressure side of the air diaphragm.

When the aircraft increases altitude, the AMC bellows elongates with air pressure decrease and the needle is moved into its orifice. This increases the orifice opening between impact air and venturi suction and allows impact air to bleed into the venturi suction channel. This reduces the air metering force across the air diaphragm.

The needle is contoured such that regardless of altitude (or air density) the correct air metering signal is established across the air diaphragm to maintain a relatively constant fuel/air ratio as air density changes with altitude.

The above description is applicable to the externally mounted AMC which is used on the RSA-5AB1 and the RS-10FB1.

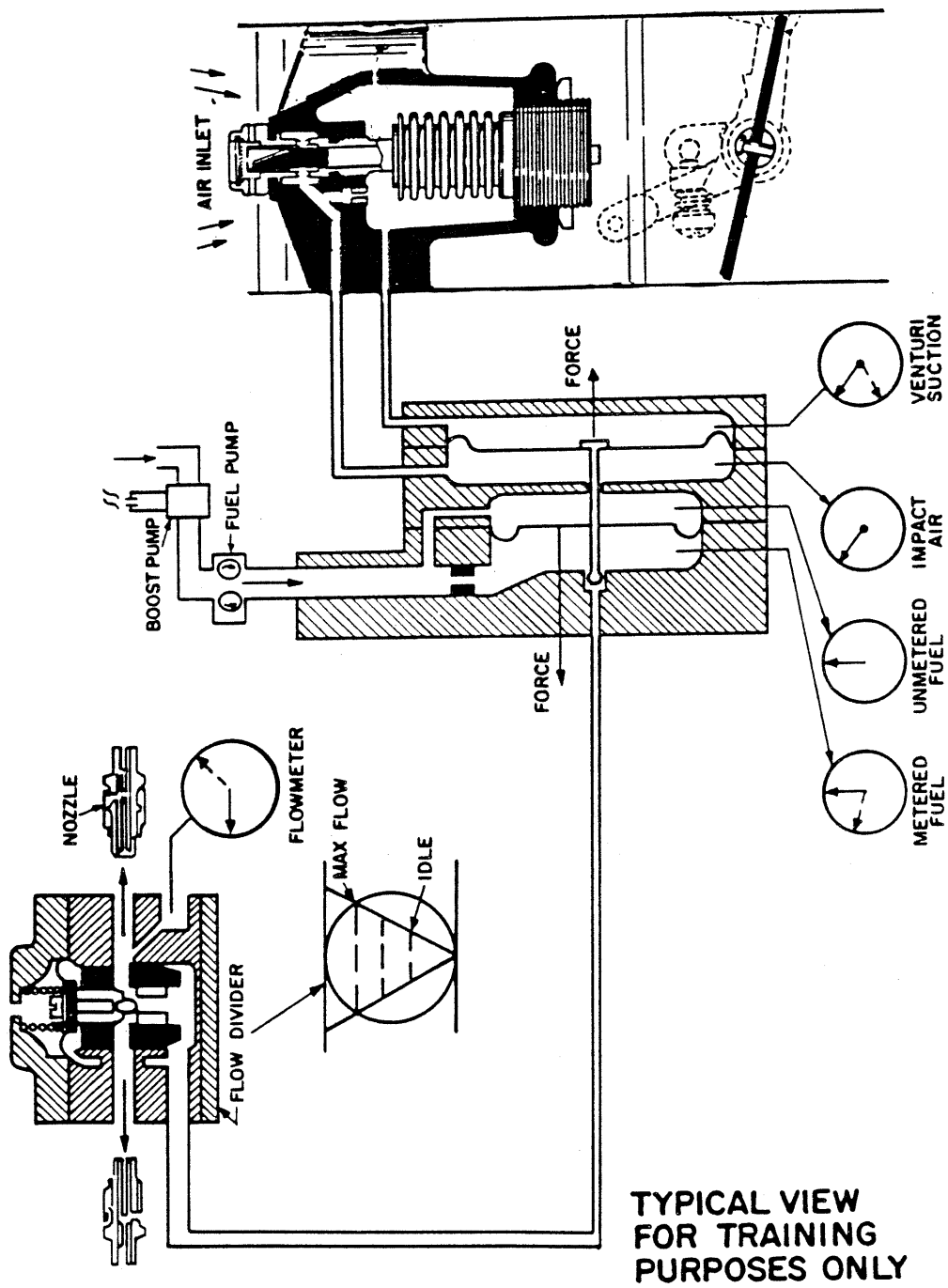


Figure 14.

LA-8515

#### REFERENCE FIGURE 14

Current production fuel injectors use a bullet-type AMC which is mounted in the bore of the throttle body. The outer diameter of this unit is contoured to perform the function of the venturi. The function performed and the principle of operation is exactly the same as the externally mounted unit. The basic differences are:

The bellows assembly is exposed to venturi suction rather than impact pressure.

As the needle is moved into its orifice, impact air pressure to the servo regulator is restricted, thus causing a reduction of the air metering force across the air diaphragm exactly as described above.

On fuel injectors with the bullet-type venturi which do not use an AMC, the bellows and needle assembly are not used and the interconnecting channeling between impact air and venturi suction are blocked off.



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