

Chapter Four

Fuel Injection Systems

OBJECTIVE:

- 4.a. Describe the functional characteristics of the components comprising the TCM Fuel Injection System.
- 4.b. Adjust the Idle speed and Full Power fuel pump pressures on the gasoline flow bench.

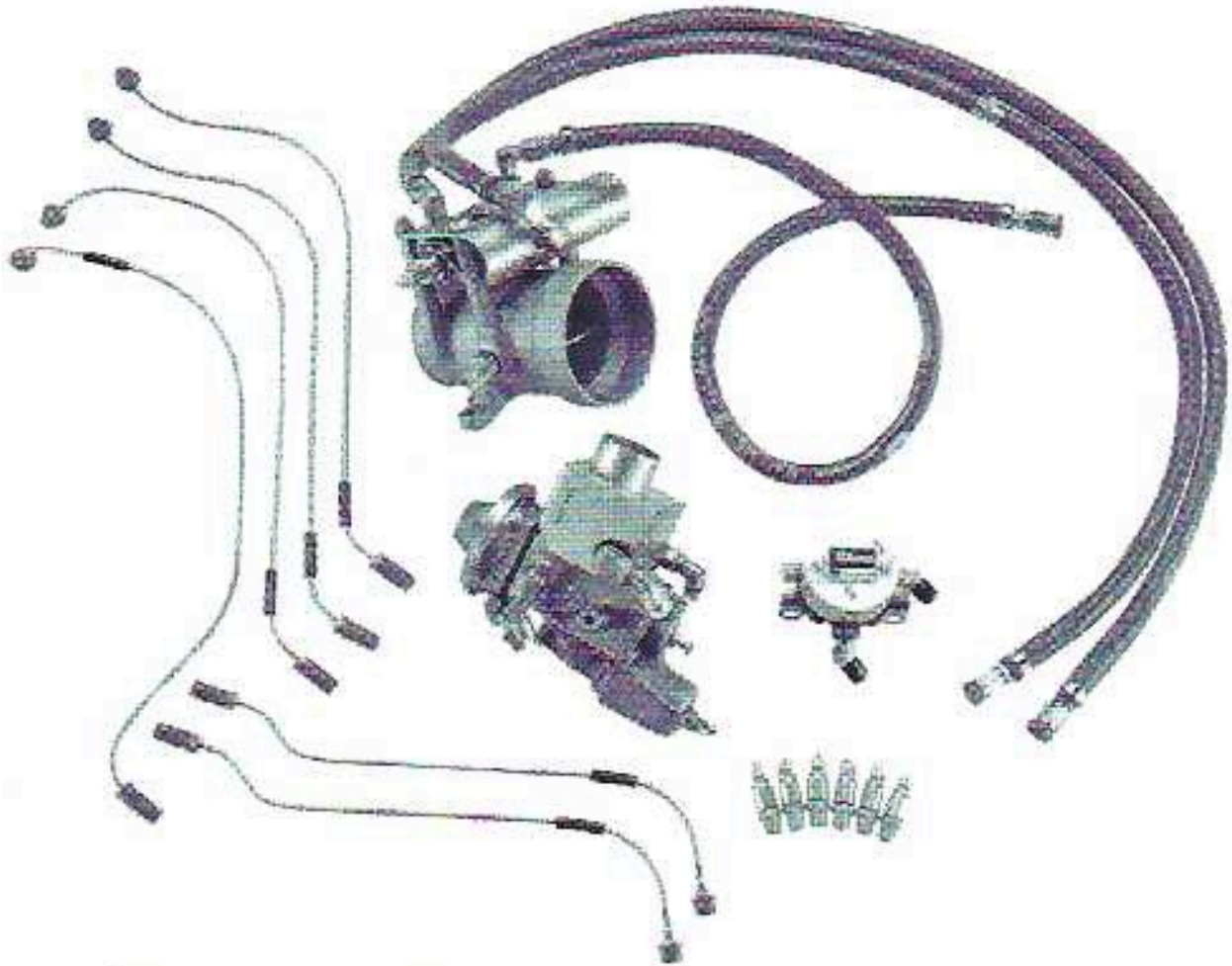


Figure 4-1. Typical Naturally Aspirated Fuel Injection System Components

INTRODUCTION

The Continental® Engine that is equipped with the TCM Continuous Flow Fuel Injection System has many advantages over the standard carbureted engine. Improved metering of fuel and even distribution to each cylinder will improve horsepower with the same fuel consumption. Engines that are Fuel Injected are free from the fuel vaporization icing that can occur with a carburetor.

Probably the most significant feature of the TCM Continuous Flow Fuel Injection System is its design simplicity. In fact, most carburetors have many more operating systems than the TCM Continuous Flow Fuel Injection System.

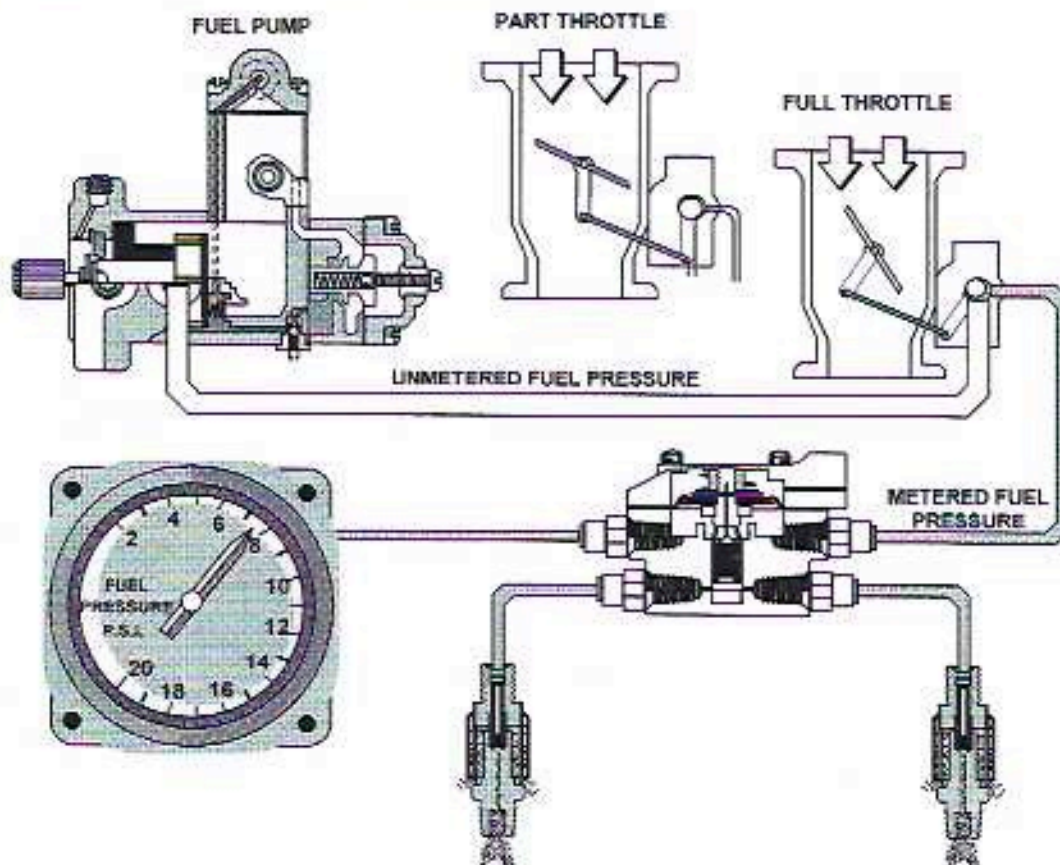


Figure 4-2. Continental Continuous Flow Fuel Injection System Basic Diagram

The Continental Continuous Flow Fuel Injection System has only four basic systems. The Fuel Injection Pump, the metering unit, the fuel manifold valve and the injector nozzle.

- The Fuel Injection Pump is a positive displacement, vane type pump. Being engine driven, its output volume and pressure vary with engine RPM. It is the only continual moving part in the fuel injection system. The primary functions of the fuel injection pump include supplying fuel under pressure to the rest of injection system and performing certain metering functions that will be discussed in detail later on.
- The Fuel Metering unit correctly proportions the fuel to air mixture and the amount of fuel to flow as engine requirements are changed at the throttle.

- The Fuel Manifold Valve equally distributes fuel flow to all of the engine cylinders by dividing the metered fuel flow equally between the number of nozzles in the system. It also serves as a positive idle cut-off valve whenever the engine is shut down.
- The Fuel Injector Nozzle is responsible for atomization and subsequent vaporization of the raw metered fuel. The nozzle sprays fuel continuously into the intake chamber of the engine cylinder head. There is no timing involved. Heat from the cylinder head quickly accomplishes vaporization of the atomized fuel. Much more complete vaporization of the fuel and cooler running intake valves are two more examples of the superiority of continuous flow fuel injection.

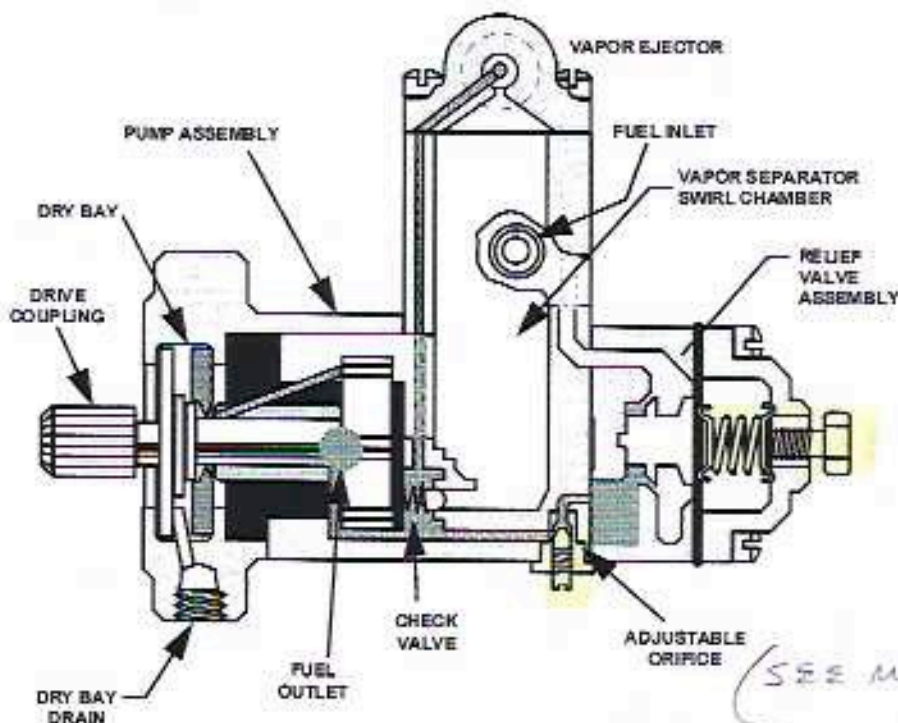


Figure 4-3. Typical Naturally Aspirated Fuel Pump

Fuel Pump - Since the fuel pump must deliver more fuel than the engine can use, a return line will be necessary to recirculate the excess fuel. The recirculation path will reduce the fuel pump output pressure so an orifice in the return line develops the pressure and allows the pump to maintain excess capacity. The faster the pump runs, the greater will be its output. Because the orifice in the fuel return line remains fixed, any increase in pump output will also increase pump output pressure. Since the pump is driven by the engine, the pump's output will be in direct proportion to engine RPM.

The fuel pump will actually meter fuel in direct proportion to engine RPM. The fixed orifice in the return fuel path plays an important role in fuel metering. Should the orifice become partially or completely restricted, excessive output pressure will result and upset the balance of proper fuel metering and subsequent fuel flow.

The fuel injection pump must provide adequate fuel flow and pressure at low engine speed as well as the higher ranges. Remember the output pressure of this pump will vary with engine speed. Therefore, at idle speeds the output will be considerably less. The orifice that worked for us at the higher speeds will not be able to maintain the outlet fuel pressure in the low to idle speed range.

By adding a small relief valve in series with the adjustable orifice, we can now have sufficient outlet pressure in the idle range, and without disturbing the relationship of the orifice to output pressure in the higher engine RPM ranges. This relief valve is adjustable and its adjustment is important. When set too high, excessive pressure and flow will occur at idle and throughout the entire range of engine speeds.

A vapor separator tower is also added to the fuel injection pump and inlet fuel enters near the top of the tower. The fuel enters a cylindrical chamber inside the tower. The swirling action created in this cylindrical chamber tends to centrifuge the liquid fuel causing the vapors to rise to the top of the separator tower. This process helps to insure that only liquid fuel will reach the vanes of the fuel pump. A vapor jet and return line is added to the top of the separator tower. Fuel rushing through the small orifice in the jet actually creates a small low pressure and as a result, will perform a pumping action. It will transfer any vapors and excess fuel back to the aircraft fuel tank from which the fuel was pumped.

A by-pass check valve is added. The aircraft's fuel system incorporates an electric fuel pump for starting, ground checking, and possible emergencies. For example, when priming before starting, fuel under pressure from the electric pump enters the injection pump in the usual manner. When the injection pump is at rest, the fuel by-passes the vane portion of the pump by way of the by-pass check valve to reach the metering unit.

When fuel under pressure is being supplied by the auxiliary electric pump all of the other circuits of the injection pump continue to function. Fuel is passing through the adjustable orifice, the relief valve is functioning, the vapor ejector is at work, and fuel under pressure is leaving the injection pump for the mixture control and Fuel Metering unit.

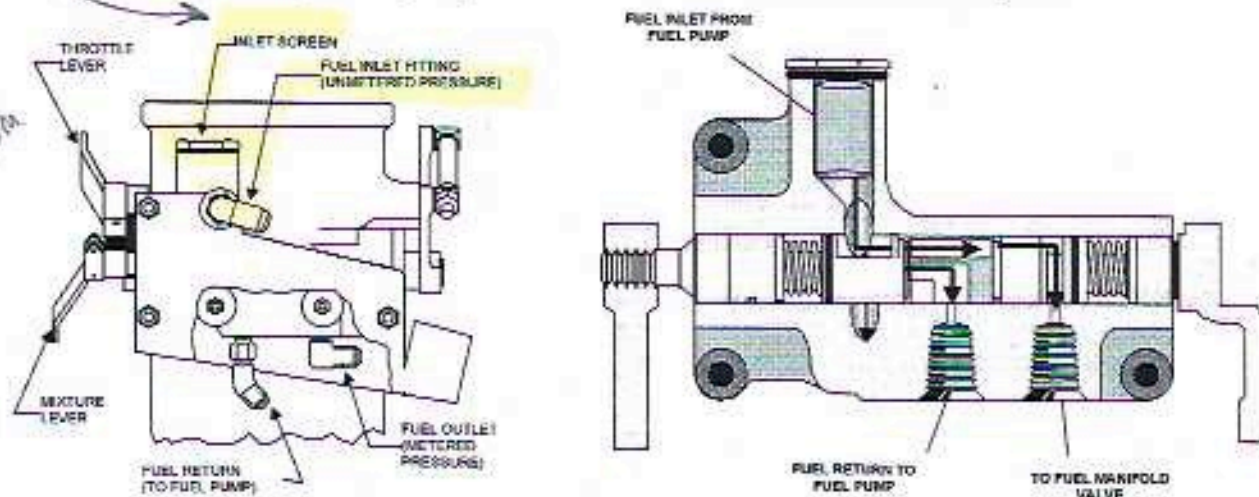


Figure 4-3. Typical Fuel Control Unit

Fuel Control Unit - The fuel leaves the injection pump and travels through fuel lines to the Fuel Control unit. The fuel enters the control unit through a fuel screen where it is filtered. The filtered fuel advances into the mixture control valve. With the mixture control in the IDLE CUT-OFF position, all of the fuel entering the control unit will return to the fuel pump. When in the FULL RICH position most of the fuel is passing to the throttle control valve. A small amount will still pass through the return system. The throttle control valve is linked directly to the air throttle and moves in direct proportion to the air throttle. The mixture ratio will remain constant through all movement of the throttle.

On some Continental fuel injection systems, the mixture control is designed into the injection pump. When moved away from the FULL RICH position, the mixture control reduces the pump outlet pressure thus dropping the flow through the Fuel Control Unit. The end result to the cylinders in terms of mixture ratio will be the same as with the other type mixture control built into the Fuel Control unit.

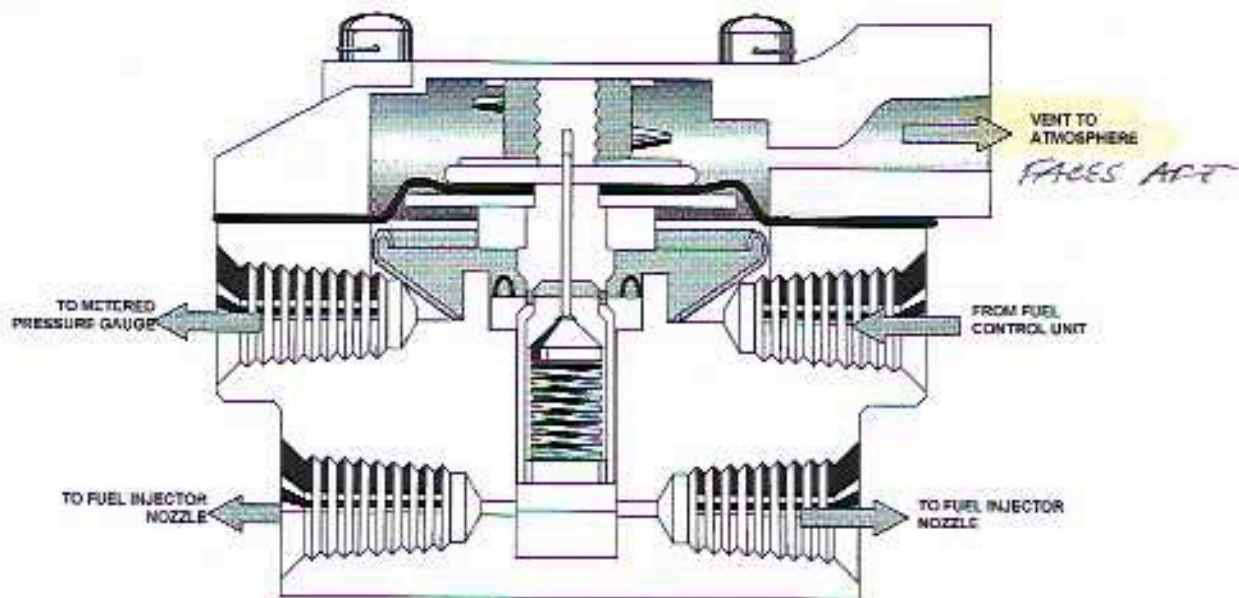


Figure 4-4. Fuel Manifold Valve

① **Fuel Manifold Valve** - The third component in our continuous flow fuel injection system is the fuel manifold valve. This valve serves two basic functions, each of which will be explained separately. The first function of this valve is to provide positive fuel cut-off between the Fuel Control unit and the nozzles during engine shutdown and when the injection system is not in operation. Referring to Figure 4-4, you can see the diaphragm that is attached to the top of the valve to create two separate chambers. The spring serves to counteract the force of fuel pressure acting on the opposite side of the diaphragm. The upper chamber is vented to atmosphere while the lower chamber interacts with fuel under pressure from the metering unit. This positive fuel pressure will open the cut-off valve and permit fuel to flow. A valve rated at 4 PSI will actually begin to open at 3.5 PSI. It will be fully open at 4 PSI. Fuel entering the lower chamber under pressure pushes the diaphragm and attached valve up. This action uncovers the entrance ports in the valve permitting fuel to flow into the interior of the valve and out the distributor ports to the nozzles.

Placing the mixture control in the IDLE CUT-OFF position will stop the flow of fuel to the manifold valve. Once fuel flow has stopped, the closing spring will push the plunger down into its bore, sealing off the distributor ports at the bottom and coming to rest against the cut-off seal at the top of the bore. This action provides a double seal and therefore positive cut-off to the nozzles.

Notice the function of the atmospheric vent. Each time the valve moves this upper chamber must be able to breathe. If this vent should become obstructed, the valve will not operate properly. The vent must always be open and facing away from the ram air entering the cowl.

② The second function is simply to provide equal fuel flow to all nozzles at all speeds and power settings. The bottom portion of the manifold valve contains the outlet ports. Fuel



lines of equal length connect these ports to the injector nozzles. This is the distributing function of the manifold valve.

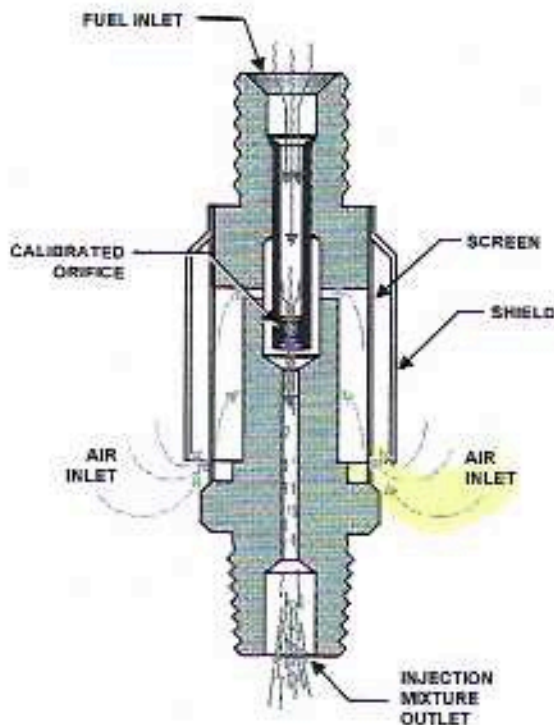


Figure 4-5. Fuel Injector Nozzle

Fuel Injector Nozzle - The basic nozzle consists of a fuel inlet for the line from the manifold valve. Drilled air openings are provided for the entrance of ambient air. A calibrated orifice assures that nozzles in the engine will flow exactly the same amount of fuel to each cylinder.

A screen fitted to the nozzle filters the ambient air entering the nozzle to mix with fuel and begin the process of atomization. A shroud is fitted over the outside of the filter screen to protect the screen from any possible damage.

At idle speed, fuel enters the nozzle from the manifold valve and ambient air enters at much greater pressure than existing manifold pressure. The liquid fuel is broken up and the first stage of vaporization begins. At higher operating engine speeds, much more fuel will pass through the nozzle. Less ambient air is entering the nozzle due to a lower differential between ambient and manifold

pressure. At higher engine speeds a much greater volume of air is entering the cylinders, and considerably more fuel is passing through the nozzles. The greater the flow through the nozzle, the better it will atomize. Therefore under high nozzle flow considerably less air is needed for internal mixing in the nozzle, and vaporization of the injected fuel will occur much quicker from the high heat of the cylinder heads.

The injector air openings serve more than to just improve atomization of the fuel. At low speed, low fuel flow conditions, the high manifold vacuum created during the intake stroke would suck the fuel out of the nozzles and upset proper operation of the manifold valve. The air bleeds in the nozzles prevent this from happening. Should these air bleeds or their air filter screens become obstructed with dirt, erratic and rough low speed engine operation will surely result.

FUEL SYSTEMS WITH FUEL PUMP INTEGRAL MIXTURE CONTROL

The fuel injection system is a simple, low pressure system that injects fuel into the intake valve port in the cylinder head. It is designed for ready adaptation on engines of widely varying power ratings, displacement and number of cylinders. There are four basic elements in the fuel injection system: the fuel pump, fuel metering unit, fuel manifold valve and fuel nozzles. Fuel flows from the fuel pump to the fuel metering unit. The fuel then flows from the fuel metering unit to the fuel manifold valve where it is distributed to the four fuel injector nozzles.

*CLEAN INTERIOR
SCREENS AT
ANNUAL INSP.
USE
ACETONE*



A check valve is provided so that boost pressure to the system can by-pass the engine driven fuel pump during engine starting. This feature also aids in the suppression of vapor formation during high ambient temperature conditions. The check valve permits use of the airframe auxiliary fuel boost pump, in the unlikely event of an engine driven fuel pump malfunction.

Throttle and Fuel Metering Unit - The function of this assembly is to control engine air intake and to set the metered fuel pressure for proper fuel/air ratio. The air throttle is mounted at the air manifold inlet. The throttle valve controls the flow of air to the engine as positioned by the cockpit throttle control lever.

Fuel enters the fuel metering unit and passes to the metering cam. The rotary metering cam has a cam-shaped edge that mates with the fuel metering plug. The position of the cam at the fuel metering plug calibrated orifice controls fuel flow to the fuel manifold valve and fuel nozzles.

The fuel mixture is controlled by the manual mixture control lever in the cockpit which is connected to the mixture control valve in the fuel pump.

Fuel Metering Unit - The throttle body has a machined boss for attachment of the metering unit housing and a bushed bore for the throttle shaft. The throttle shaft is threaded on one end for attachment of a lever and has a lever throttle stop. The opposite end has a metering cam. The metering cam is located flush against a spring loaded metering plug. The metering plug has a drilled calibrated orifice that provides fuel passage from the fuel inlet to fuel outlet, depending on the throttle shaft and metering cam position. Fuel flow through the fuel metering plug calibrated orifice is controlled by the position of the eccentric cam connected to the throttle shaft and the adjusted position of the fuel metering plug. An idle mixture adjustment screw is located in the metering valve housing which slightly rotates the fuel metering plug changing flow clearance between the metering plug fuel passage and eccentric cam.

Fuel Manifold Valve - The fuel manifold valve body contains a fuel inlet, a diaphragm chamber and outlet ports for fuel lines to the individual nozzles. The spring loaded diaphragm carries a plunger in the central bore of the manifold body. The diaphragm is enclosed by a vented cover which retains the diaphragm loading spring. When the plunger is down in the body bore, fuel passages to the nozzles are closed off. The plunger is drilled for passage of fuel from the diaphragm chamber to its base and the valve within the plunger. As fuel flow increases pressure overcomes diaphragm spring tension causing the plunger to move to the open position and fuel flows from manifold valve outlets through fuel lines to the fuel nozzle assemblies.

Fuel Nozzle - The fuel discharge nozzle is located in the cylinder head. The nozzle outlet is screwed into the tapped fuel nozzle hole in the cylinder head. The nozzle body has a drilled central passage with a counterbore at each end. The lower end is the fuel outlet. The upper bore contains a removable jet for calibrating the nozzles. Near the top, radial holes connect the upper counterbore with the outside of the nozzle body for air admission. These holes enter the counterbore above the orifice and draw outside air through a cylindrical screen fitted over the nozzle body which keeps dirt and foreign material out of the interior of the nozzle. A press-fitted shield is mounted on the nozzle body and extends over the greater part of the filter screen, leaving an opening near the bottom. This provides both mechanical protection and an air path.

Nozzles are calibrated in several ranges and all nozzles furnished for one engine are of the same range identified by a letter stamped on the hex of the nozzle body.

470, 520 & 550 SERIES ENGINES NATURALLY ASPIRATED FUEL SYSTEM DESCRIPTION

Fuel flows from the fuel pump to the fuel control unit. The fuel then flows from the fuel control unit to the fuel manifold valve where it is distributed to the six fuel injector nozzles.

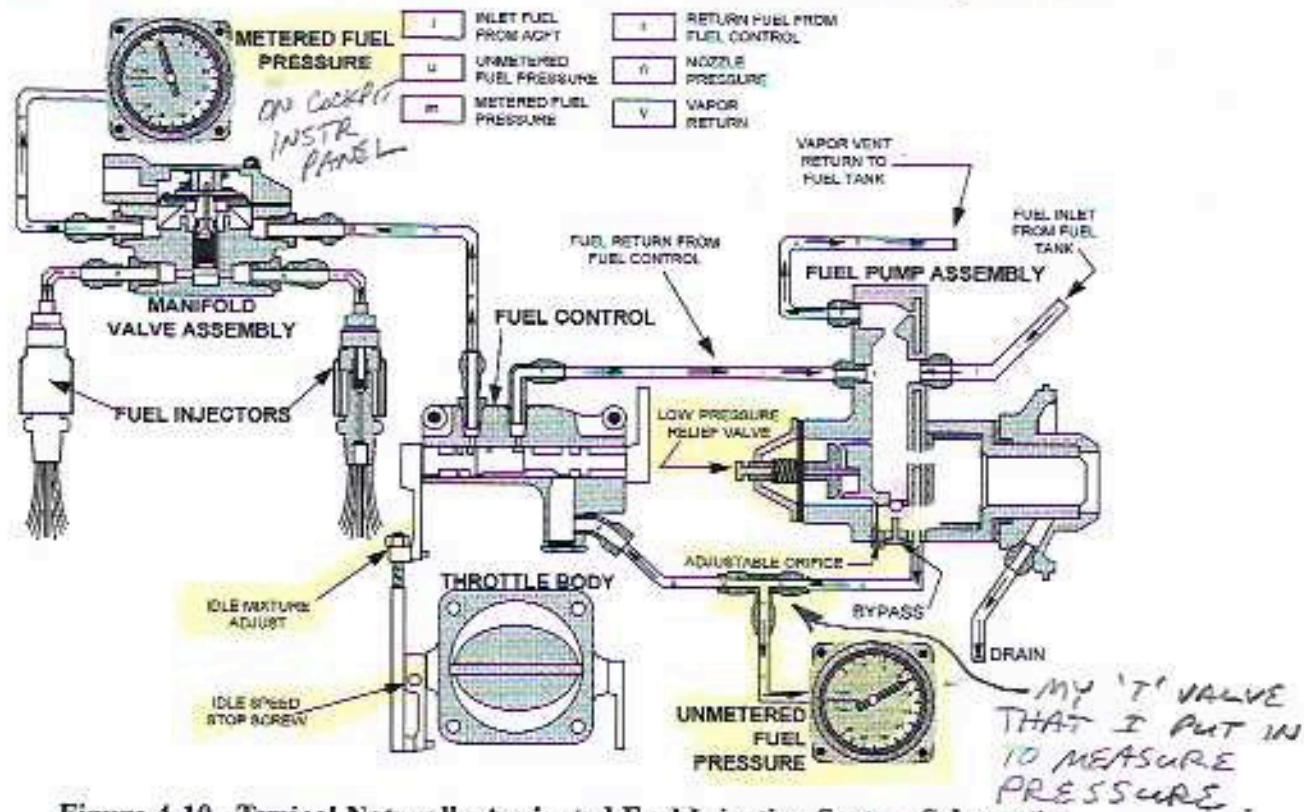


Figure 4-10. Typical Naturally Aspirated Fuel Injection System Schematic.

FUEL INJECTION SYSTEM COMPONENT DETAILED DESCRIPTION

Fuel Pump - Fuel enters the fuel pump at the swirl well of the vapor separator. Here, vapor is separated by a swirling motion so that only liquid fuel is fed to the pump. The vapor is drawn from the top center of the swirl well by a small pressure-jet of fuel and is fed into the vapor return line. This line carries the vapor back to the fuel tank. There are no moving parts in the vapor separator, and the only restrictive passage is used in connection with vapor removal. Thus, there is no restriction of main fuel flow.

Ignoring the effect of altitude or ambient air conditions for the moment, the use of a positive displacement, engine-driven pump means that changes in engine speed affect total pump flow proportionally. The fuel pump provides greater capacity than is required by the engine. Thus, a recirculation path is provided.

By arranging a calibrated adjustable orifice and relief valve in this path, the pump delivery pressure is maintained proportional to engine speed. These provisions assure proper pump pressure and delivery for all engine operating speeds.

A check valve is provided so that aircraft boost pump pressure to the system can by-pass the engine driven fuel pump during engine priming and starting. This feature also aids in the suppression of vapor formation during high ambient temperature conditions. The check valve permits the use of the aircraft auxiliary fuel boost pump should the engine driven fuel pump fail.

Air Throttle and Fuel Control Unit - The function of this assembly is to control engine air intake and to set the metered fuel pressure for proper fuel/air ratio. The air throttle is mounted at the air manifold inlet. The throttle valve controls the flow of air to the engine as positioned by the cockpit throttle control lever.

Fuel enters the fuel control unit through a strainer and passes to the metering valve. The rotary metering valve has a cam shaped edge across the fuel delivery port. The position of the cam at the port controls fuel flow to the fuel manifold valve and fuel nozzles. The fuel mixture is controlled by the manual mixture control lever in the cockpit that is connected to the fuel control unit mixture control valve.

NOTE...FUNCTION OF THE THROTTLE, MOUNTING OF THE FUEL CONTROL UNIT AND LINKAGE CONNECTION BETWEEN THE THROTTLE AND FUEL CONTROL UNIT ARE THE SAME ON THE VARIOUS IO-520 SANDCAST SERIES ENGINE MODELS. HOWEVER, THE THROTTLE BODIES USED ON THE DIFFERENT ENGINE MODELS ARE PHYSICALLY DIFFERENT.

Fuel Control Unit - The fuel control body is made of SAE 88 Brass. The fuel metering shaft and mixture control shaft are made of stainless steel. The metering valve is located at one end and the mixture control valve is located at the other end of the control valve central bore. The valves ride in bushings and are sealed against leakage by o-rings. Loading springs force the valve ends against a fixed plug installed in the center of the central bore. This bronze plug has one passage that mates with the fuel return port and one passage that connects the mixture control valve chamber with the metering valve chamber. O-rings seal this plug in the central bore. Each valve includes a groove which forms a fuel chamber. The contoured end face of the mixture control valve aligns with the passages in the metering plug to regulate the fuel flow from the fuel chamber. A control lever is installed on the mixture control valve shaft for connection to the cockpit mixture control. In the metering valve, a cam shaped cut is made on the outer part of the end face. A control lever on the metering valve shaft is connected to the air throttle valve shaft with linkage. The fuel return port in the control body connects to the return passage of the metering plug and alignment of the mixture control valve face with this passage determines the amount of fuel returned to the fuel pump. A removable plug at the fuel inlet port includes a filter screen to prevent admittance of foreign debris.

Fuel Manifold Valve - The fuel manifold valve body contains a fuel inlet, a diaphragm chamber and outlet ports for fuel lines to the individual nozzles. The spring loaded diaphragm carries a plunger in the central bore of the manifold body. The diaphragm is enclosed by a vented cover which retains the diaphragm loading spring. When the plunger is down in the body bore, fuel passages to the nozzles are closed off. The plunger is drilled for passage of fuel from the diaphragm chamber to its base and the valve within the plunger. As fuel flow increases pressure overcomes diaphragm spring tension causing the plunger to move to the open position and fuel flows from manifold valve outlets through fuel lines to the fuel nozzle assemblies.

Fuel Nozzle - The fuel discharge nozzle is located in the cylinder head. The nozzle outlet is screwed into the cylinder head tapped fuel nozzle hole. The nozzle body has a drilled central passage with a counterbore at each end. The lower end is the fuel outlet. The upper bore contains a removable jet for calibrating the nozzles. Near the top, radial holes connect the upper counterbore with the outside of the nozzle body for air admission. These holes enter the counterbore above the orifice and draw outside air through a cylindrical screen fitted over the nozzle body which keeps dirt and foreign material out of the interior of the nozzle. A press-fitted shield is mounted on the nozzle body and extends over the greater

part of the filter screen, leaving an opening near the bottom. This provides both mechanical protection and an air path.

Nozzles are calibrated in several ranges and all nozzles furnished for one engine are of the same range identified by a letter stamped on the hex of the nozzle body.

INDUCTION SYSTEM DESCRIPTION

BOTTOM VIEW OF ENGINE
WITH INDUCTION MANIFOLD
INSTALLED

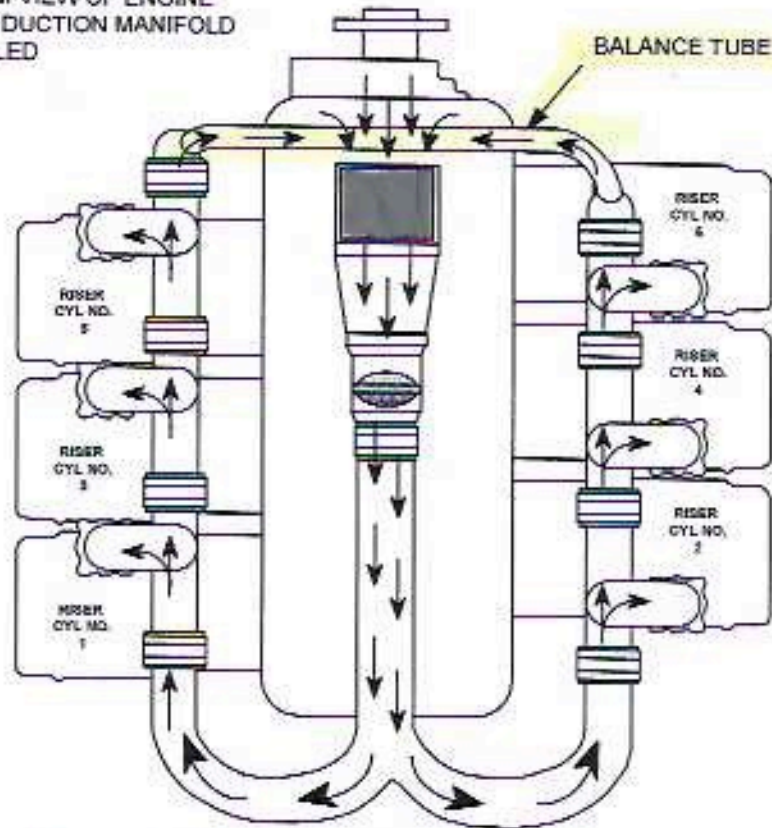


Figure 4-11. IO-550-B Updraft Runner Induction System.

Engine components through which intake air flows following the aircraft air inlet filter/alternate air door are: throttle assembly, manifold, induction tubes and cylinder intake ports. Air flows through these components in the order they are listed.

Refer to the airplane manufacturer's Airplane Flight Manual (AFM) for alternate air door operations.

The intake manifold is an air distribution system mounted below the engine cylinders. It consists of two runners and a balance tube. It serves to carry induction air to the individual cylinder intake ports.

The cylinder intake ports are cast into the cylinder head assembly. Air from the manifold is carried into the intake ports, mixed with fuel from the injector nozzles where it enters the cylinder as a combustible mixture when the intake valve opens.