

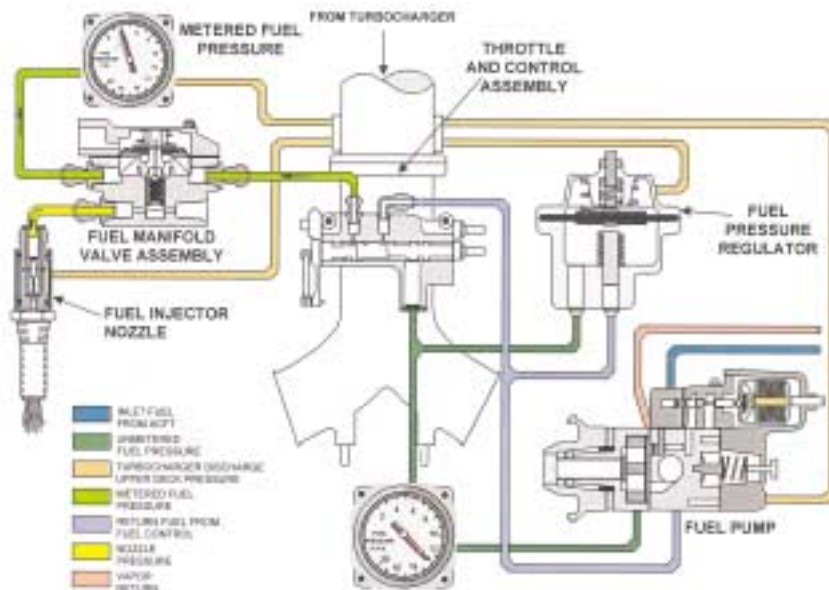
# AIRCRAFT Maintenance<sup>®</sup> TECHNOLOGY

Reprinted with permission from *Aircraft Maintenance Technology*, November 1998

## RECIPE TECHNOLOGY

# Continuous Flow Fuel Injection Systems

By Randy Knuteson



Typical Turbo-Charged Fuel System Schematic (With Regulator)

**C**ontinental Motors calls it their “Continuous Flow Fuel Injection System.” Some technicians refer to it in less dignified terms, replete with colorful expletives. The proclivity of human nature has always been to focus on the negative. But regardless of an occasional negative encounter, the positive attributes of these systems are easy to identify. You need not look far to appreciate the commendable features of the TCM Fuel Injection System.

For many years, the factory has pointed to “simplicity” as being the “single-most significant feature” of their systems. Some would agree. Others would strongly disagree. The

goal of this article is to provide some information to clear up any misunderstandings that may have landed you in the “disagree” camp.

### GENERAL OPERATION

As the name suggests, this system provides for a “continuous” (un-interrupted) flow of fuel to the intake port of each cylinder. To reach the cylinder, fuel follows a circuitous path from the engine-driven pump, through a metering device (controller), then to a manifold valve that serves to evenly distribute an equal flow through the lines and finally to the injection nozzles.

The TCM System varies greatly from its

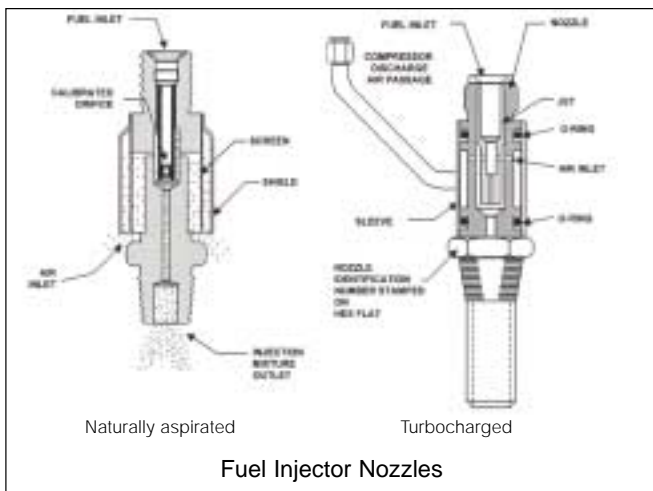
Lycoming counterpart, the Bendix Fuel Servo. Perhaps most noticeable is the absence of a venturi to schedule fuel flow proportionate to air flow. The Bendix system regulates fuel flow by means of a delta pressure across an air diaphragm. Comparatively, the Continental System has no way to sense airflow. It does not compensate for altitude or density changes, nor does it correct for MAP unless turbocharged.

### FUEL PUMPS

The only continuously moving part of this system is a positive displacement rotary vane pump. Pump output and pressure will vary in accordance with engine rpms. At all rpm settings, these pumps are capable of producing fuel pressures well in excess of demand. Surplus fuel is internally re-circulated through the pump, and vapors are purged from the pump by means of the centrifuge action of the pump’s “swirl chamber.” These vapors exit through the vapor return on the top of the pump, and are routed to the fuel tank or header tank of the airframe.

TCM installed an adjustable orifice in their pumps to maintain adequate pressures at lower rpms. TCM provides a good analogy when they compare this orifice to “placing one’s thumb over the end of a garden hose to increase pressure.” Once set, this adjustable orifice becomes fixed during actual operation.

All TCM pumps rely on a “by-pass valve” which serves to purge vapors from the lines when the boost pump is engaged prior to engine start up. Also, in the unlikely event of a sheared fuel pump shaft, this by-pass enables the boost pump to provide enough fuel for the plane to maintain 75 percent power.



## METERING UNITS

Metering units remain relatively problem-free besides an occasional leaking “O” ring or an ICO problem due to scored valve faces (again, the result of fuel-borne contamination). Sometimes, “lean” conditions caused by induction leaks, are mistakenly blamed on this unit. Induction leaks usually reveal themselves in higher MAPs at lower rpms. Rich conditions on 360-style throttle bodies can often be traced to a

leaking throttle shaft “O” ring that allows fuel to seep past the throttle bushing and into the induction.

## MANIFOLDS

TCM manifolds are calibrated in conjunction with the nozzles making them a “married” system. Herein lies an ongoing problem. Well-meaning mechanics occasionally swap nozzles engine to engine. If little or no consideration is given to the letter designation on the wrenching flats of the nozzle, or to the “M” or “P” stamped on the manifold data tag, this action could result in a split in mixture levers and fuel flow indications.

## NOZZLES

Plugged or even partially plugged nozzles are notorious for creating rich and rough running engines. If these symptoms occur, look here first. Plugged jets create back pressures that route that nozzle’s fuel to the other cylinders, creating a rich indication, and are often the cause for in-flight roughness. Nozzles with plugged air-bleeds will allow the engine to suck excessive fuel from the lines, causing the flow divider to respond erratically. A simple “bottle test” may isolate the problem at the nozzle and save you pulling other components. Look for indications of fuel staining, loose shrouds, or dirty screens. Immerse nozzles in an ultrasonic cleaner if they require cleaning.

## JETS

TCM no longer sells jets for these nozzles. This poses a problem. Between overhaul, these jets may experience a slight fluid erosion of the brass, resulting in an enlarged jet diameter. In the past, shops would insert new jets into the existing nozzle bodies in order to properly set up the manifold since nozzles and manifolds are a “matched” set.

According to Kelly Aerospace Power Systems these jets can once again be procured. Kelly Aerospace Power Systems began manufacturing FAA-PMA replacement jets. Nozzle bodies, shrouds, and screens are also available. This should result in substantial savings since the only alternative is to purchase entire nozzle assemblies from the TCM factory.

Fuel-borne contaminants can wreak havoc in any fuel system and often are the cause for the poor performance of many an aircraft engine. It may seem that the TCM fuel system is more susceptible than other systems. We’ll leave that judgment to the experts. Suffice it to say, regular maintenance is in order. Keep the finger strainer in the brass metering unit free of debris and clean the injection nozzles at regular intervals (some suggest every 100 hours). Close attention should also be given to leaking fuel lines, seals, fittings, diaphragms, and reference lines. Any of these can be the cause for erratic fuel indications.

## SETTING UP THE SYSTEM

### Is “Fine-Tuning” Required?

Some shops make the erroneous assumption that a freshly overhauled fuel system need only to be bolted to the engine and flown away. They say “after all, wasn’t the system overhauled and calibrated to factory specs?” Yes — however, variations in induction systems, supply systems, and operating environments mandate a final “tweaking” of the installed components. Still, some tenaciously hold to the mind set that “it should be set up for my airplane out of the box.”

For this reason, many Repair Stations have difficulty persuading technicians to use calibrated hand-held gauges while setting up their Continental systems on the airframe. While TCM strongly recommends the usage of externally plumbed gauges, some technicians still consider this procedure nothing more than a mere suggestion. Failure to follow this “suggestion” often results in lackluster performance, frustration, and dissatisfied customers. Always use these gauges if you expect to appreciate the system’s full-performance capabilities. Teledyne’s Service Information Directive 97-3 provides clear instructions for final adjustments once fuel components are installed on the airplane.

## BEFORE ADJUSTING

Verify the accuracy of the following gauges

before making adjustments to the fuel system: Tach, MAP, Fuel Flow, Oil Temp, Oil Press, CHT, EGT. Don’t rely solely on the ship’s gauges when setting pressures and flows. Rectify any discrepancy if found. Errant gauge readings, if significant, can result in annealed rings, com-



**Turbocharged engines reference upper-deck pressure to the injection nozzles. Always replace o-rings and packings when cleaning or replacing these nozzles.**

## THROTTLE/CONTROL ASSEMBLY (METERING UNIT)

The pump feeds fuel under pressure to the controller. The controller’s chief purpose is to meter this fuel proportionate to the air being ingested at the cylinder. Depending on the configuration of the unit, this is accomplished by adjusting either a linkage rod or a fuel adjustment screw. Either adjustment serves to change the position of a cam-faced valve in relation to a metering jet, enabling the unit to schedule adequate fuel on demand.

## MANIFOLD/LINES/NOZZLES

The primary task of the manifold valve is to provide an even distribution of fuel to each cylinder. It serves a dual purpose by providing a secondary idle cut off (ICO) when mixtures are pulled. The resulting decrease in fuel pressure allows its plunger to seat, disrupting fuel flow to the nozzles.

## IDENTIFYING POTENTIAL PROBLEMS

Many TCM fuel system failures can be attributed to contaminants that have entered the system. These contaminants range from shaved “O” rings to fuel bladder material. “Foreign objects” always seem to migrate to the worst possible spots.

## FUEL PUMP

In the fuel pump, debris lodged under the seat of the relief valve results in a loss of pump pressure. This loss of pressure is especially apparent below 1,500 rpm and may require boost pressure to keep the engine running at idle. If contaminants obstruct the adjustable orifice, the opposite occurs — an increase in output pressure at higher RPMs (above 1700 rpm). Contaminants can also hinder the free-floating movement of the variable metering rod connected to the aneroid in turbocharged applications. And, any small obstructions lodged in the vapor ejector may result in a rich and rough running engine due to the excess fuel (and vapors) now being pumped into the metering unit. This rich characteristic can also occur if the vapor return check valve is installed backwards.



***This is a typical 470 and 520 mixture style adjustment. It requires a 3/8 wrench with a clockwise rotation to enrich the mixture.***

pression loss, and cylinder detonation. Tee in the calibrated gauges. Pressurize the system with the boost pump and inspect for leaks. Chock the wheels, set the brakes. Finally, before attempting any adjustments, allow CHTs and oil temps to reach their normal operating values as spelled out in the POH.

### CAUTIONARY NOTES

Be sure to limit the duration of full rated power run-ups, and cowl the engine to direct prop-blast across the cooling fins of the cylinders. Carefully monitor CHT readings during all ground runs. Allow the engine to stabilize for 10 to 15 seconds, and take your readings, but always hold high rpm runs to a minimum especially with newly installed cylinders. Never exceed 420°F CHT or 210°F oil temps. Failure to take these precautions could dramatically shorten the life of your cylinders. After full powered runs, it is also imperative that the engine be allowed to run at 800 to 1000 rpm for a few minutes. This practice allows the engine temperatures to stabilize prior to engine shut down.

### SETTING PUMP PRESSURES

Don't be alarmed if it takes several

attempts to set pump pressures. Both low- and high-end settings tend to chase each other. Fine-tuning these pressures requires a little patience.

When adjusting the pump idle pressure it is important to recognize that the fuel system's idle mixture is established by the combination of the pump idle pressure and metering unit mixture setting. A high idle pump pressure setting will require a lean metering unit mixture setting in order to maintain the OE's specified mixture rise.

Conversely, a low idle pressure setting will require a rich metering unit mixture setting in order to maintain the same mixture rise. The metering unit mixture setting establishes a bias in the fuel system that affects fuel flow over the entire range of throttle operation. However, the authority of the fuel pump's idle control setting progressively decays as the engine speed increases. By 1,500 rpm the idle pump pressure setting has little affect of the fuel system's mixture control.

With these relationships in view, its difficult to be emphatic about where the pump idle pressure should be set, at the upper or lower end of the limit. The predominant school of thought is that setting the idle pump pressure to the lower limit is preferred as it yields a rich part-throttle mixture condition. Rich mixtures may lead to cool heads at taxi and idle setting but may also lead to stumbling on acceleration, increased rates of valve seat deposits, fowled spark plugs, back firing and afterburning. Rich mixtures are also know to have a detrimental affect on the cylinder's ability to hold a sufficient oil film. End gases from an overly rich combustion event may "wash" oil from the cylinder walls during the power stroke.

When setting the pump idle pressure consideration should be given to the home field elevation for the aircraft, the condition of the

### SOME ANOMALIES TO CONSIDER

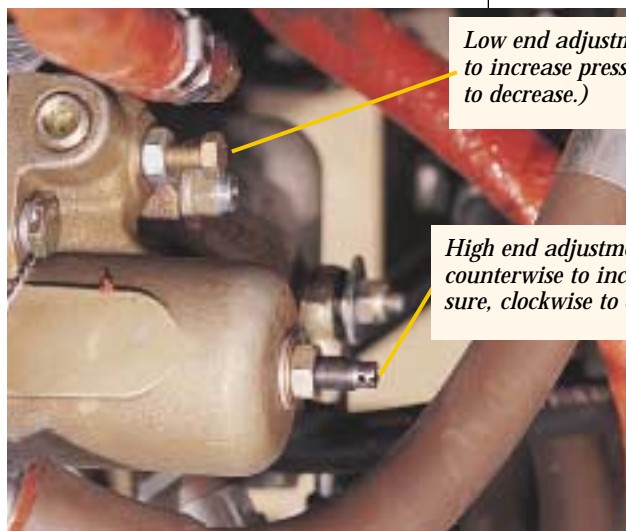
This system's inability to sense changes in air density and temperature creates a challenge when dealing with aftermarket intercooler installations. The denser air coming from the intercooler requires more fuel to keep the fuel/air ratios in the cooler burning ranges required by the engine. The easiest way to tell if fuel flow is adjusted correctly is to set full rich on takeoff and climb and check the TIT. If adjusted correctly (TSIO-360,470,and 520 engines) the temperature on a calibrated TIT system would read in the high 1300's to low 1400 degrees fahrenheit.

Another after-market change that requires attention when dealing with the fuel system is the "Merlin" wastegate system for the TSIO-360. This engine, more so than others (due to fixed wastegates from the factory), is very sensitive to upper deck pressure adjustments for proper fuel flow when the turbo is in operation. Careful attention to installation instructions and set-up procedures will help to head off cylinder problems in the future.

baffles, the specific engine model being serviced, general engine health, and the operational habits of the operator. Evaluating these factors will help determine at what point within the allowable idle pressure range the pump's idle pressure should be set.

When setting up the top end of naturally aspirated systems, be sure to fly the airplane, rather than rely on ground runs. Most naturally aspirated engines will not achieve redline rpm in static runs at any field elevation, but will do so on takeoff roll as air gets moving through the prop — it's just a fixed-pitched prop until the engine turns up to on-speed governor rpm. Make certain the governor is adjusted to redline rpm also. Use a tach checker, as most older mechanical tachs seem to deviate as much as 100 rpm. Remember, this system is rpm dependent and will require actual redline rpm and full rich mixture (regardless of altitude) to check redline/takeoff fuel flow. Turbo systems can be tuned by using static runs but pay close attention to those temps.

Turbo-charged engines that incorporate a pressure regulator require this unit to be deactivated when setting pump pressures. Remove the center hose to the regulator and cap the fitting. Also plug the detached hose. TCM recommends setting these systems so full power metered fuel pressure and fuel flow are "5 percent higher than the maximum specified limit." Upon successfully setting pump pressures, plumb the pressure regulator back into the system. Pressure regulators, (sometimes referred to as pressure controllers), serve to "regulate" or limit full power fuel pressures without compromising maximum fuel pressures at lower rpms.



***Low end adjustment. (Turn clockwise to increase pressure, counterclockwise to decrease.)***

***High end adjustment. (Turn counterwise to increase pressure, clockwise to decrease.)***

***Typical turbocharged fuel pump w/aneroid adjustment (high-end fuel pressure) and relief-valve adjustment for low-end pressures.***



## ADJUSTING THE THROTTLE/CONTROL ASSEMBLY

The pilot's sole control over the fuel system lies in the throttle and control (metering unit) assemblies. The metering-unit houses both the mixture and the main metering valves. Adjustments to these units are rather straightforward. Idle speed is increased by a clockwise rotation of the adjustment screw and conversely, a CCW

**360s and some 520s incorporate a mixture boss. Adjustments are made with a straight bladed screwdriver or allen wrench. Turning it counter-clockwise (out), enriches the mixture.**

rotation decreases idle speed. Mixture set up is accomplished by adjusting the length of a linkage rod joining the throttle plate to the metering valve. Once set, this arrangement then schedules fuel in relation to airflow. A 3/8 in. elastic stop nut serves to make this adjustment. A C/W rotation of this nut enriches the mixture and turning it, CCW leans the mixture. Mixture adjustments made to the GTSIO system on the Cessna 421 are the exact opposite and are an exception to this rule. Throttle bodies that include an appendage like Seneca's 360 system requires the usage of a straight-bladed screwdriver or allen wrench to adjust mixtures. On these control assemblies, a C/W rotation leans the mixture. When leaning to ICO, an rpm increase of 25 to 50 rpm (75rpm+ at 5,000 ft. field elevations) should

be observed on the tach. A reading in excess of 50 rpm indicates an overly rich setting whereas, no increase in rpm reveals a lean condition. Between mixture adjustments advance the throttle to approximately 1,500 rpm for a short period of time to clear the engine in order to prevent it from loading up and giving false rich indications.

## MANIFOLD VALVE ASSEMBLY

The next component in line is the manifold valve. It sits astride the backbone of the engine and, as mentioned earlier, serves several practical purposes. Although there are no field adjustments that can be made to this simple device, a few suggestions may help when faced with the grim task of troubleshooting.

If an engine continues to lope on at ICO, it can usually be attributed to either scored mixture valves in the metering unit or a manifold plunger that refuses to seat. Typically, if the engine runs on indefinitely, the problem can be attributed to scored mixture valves. However, if it continues to run for a short period, then the problem lies somewhere between the manifold valve and the cylinders. To further isolate the cause, remove the hose feeding the manifold valve at the metering unit outlet fitting. With the mixture valve against the ICO stop, engage the boost pump and look for any indication of fuel flow from this fitting. Be certain to capture any leaking fuel in a suitable container and use caution if the engine or exhaust is heat-soaked. Leakage in excess of 20 drops per minute at 10 psi of pressure is unacceptable. The metering unit should be sent in for repair. If you're still uncertain as to the cause, interrupt the hose feeding the manifold inlet and plumb a ball-valve between it and the metering unit. Then, with the engine running at idle speed, use the ball valve to manually cut off fuel flow to the divider. If the engine



**Paul Cramer of Kelly Aerospace is using a Porta Test unit manufactured by Aero Test, Inc. to set fuel pressures on a Cessna 340.**

continues to run, the problem most likely rests at the manifold valve. Other contributing causes of poor idle cut off may stem from a leaking primer system — plugged or partially plugged injection nozzles, allowing the engine to run on residual fuel pooled in the induction, or in the case of a turbo-charged engine, a leaking fuel pump aneroid seal that dumps fuel back into the upper-deck.

A fuel system that has been fine-tuned for a specific engine/airframe may require a periodic re-trimming. As the engine breaks in, and operating parameters change, and cockpit gauges lose their accuracy, it becomes necessary to perform a "check-up."

Continental encourages an "operational verification" any time an engine is installed, a 100 hr. or annual is performed, or whenever a fuel component is replaced or adjusted. This may seem "excessive," but it assures of a smooth running engine to TBO.

**RAY**

**Randy Knuteson is Director of Product Support for Kelly Aerospace Power Systems in Montgomery, AL.**

## AUTO-LEANING

Some mechanics remain mystified by the auto-leaning capabilities of the IO-550 fuel pumps installed in some Bonanzas and Barons. This pump has what appears to be an aneroid configured much like a typical TSIO-520. However, unlike the turboed 520 that is referenced to upper deck pressure, this application has an aneroid that senses changes in ambient pressures. Ambient pressures are routed to the aneroid through the drain fitting via a bolt hole channel in the pump body. High rpm pressures are set by means of a tapered needle (like those seen on naturally aspirated models) housed in a brass boss on the side of the pump. Field elevations and pressure altitudes are to be compensated for when adjusting the aneroid. Normally, this auto-leaning aneroid is factory set and requires no adjustment. A tenuous balance must be achieved when setting up these pumps especially if the aneroid requires adjustment. When properly set these pumps achieve the desired results. When misunderstood or haphazardly adjusted they may cause fuel flows to drop well out of acceptable limits. Needless to say, this pump continues to baffle a fair share of mechanics.

This ongoing confusion was the impetus for Raytheon issuing SB28-3052 in February of this year. This optional bulletin allows for the replacement of the auto-leaning pump with the manual leaning. Many pilots prefer the manual leaning capabilities as it puts the control back in their hands and eliminates the occurrence of improperly adjusted pumps. On twin applications both pumps must be replaced. It is advisable to specify which pumps are desired (by spec. #) when purchasing OH'd or factory new 550 engines.

**The 550 style pump incorporates three adjustments. The aneroid adjustment is factory preset to compensate for altitude changes. The brass boss on the side of the pump is an adjustable orifice that once set, determines high-end fuel pressures output. Turning it clockwise (in) increases pressure. The 5/16-inch bolt with 3/8 jamnut is the relief valve adjustment that determines low-end pump pressure. A clockwise movement increases pump pressure.**

