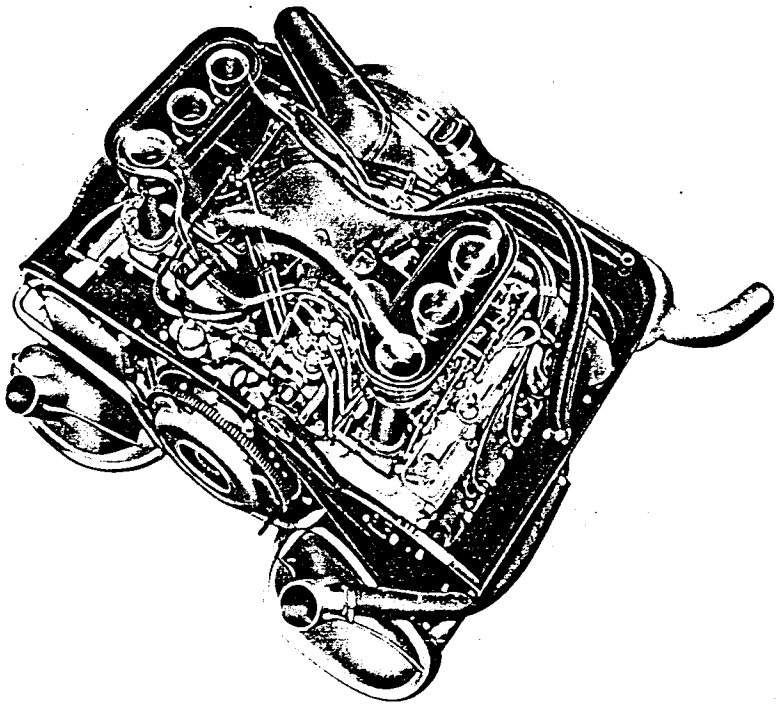


Mechanical Fuel Injection

by Leslie F. Rice

The wonderful sound of a well-tuned early 911S flat six with mechanical fuel injection is magical. This is because the pressure of practical necessity caused the "House of Porsche" to use pure racing technology to create what is basically a racing engine for the street.

The MFI installation first appeared on the 225hp 906 race car which ran in the World Manufacturer's Championship in 1966. The little 2.0 liter engine raced successfully, and was later installed in the 911R of 1968. This was followed by the production version for the 1969 911S. The 2.0 liter 1969 911S developed 170 (DIN) hp with the new MFI (10 hp more than the carburetted version), and worked very well as a "street" engine. Further refinements came quickly as the 2.0 progressed to the 2.2, 2.4, and eventually the well-rounded 2.7RS.

The mating of the MFI to the 911S was not just for the horsepower increase, but also to comply with exhaust emissions laws that were becoming difficult to meet with carburetors. For emission compliance, fuel injection offered advantages by its basic nature. It had a closed, non-vented fuel supply, instead of the carburetors' open float-bowl vents. Also, adjustments for fuel delivery could be made quickly without disassembling the MFI pump, whereas the carbs required removing the whole top of each carburetor to re-set the float level.

Beside these major differences, the fuel injection pump offered automatic cold-start enrichment of the fuel mixture and subsequent leaning as the engine warmed up. The MFI pump adjusted fuel mixture for barometric conditions (weather changes and mountain driving) as well as a total fuel delivery shut-off when coasting or going downhill. The MFI

pump also has a governor-controlled "space cam" tailored specifically for each type engine (T, E, S, and RS) that controls fuel delivery depending on RPM, throttle position, barometric pressure and warm-up temperature.

The basic MFI pump is one of the most reliable mechanical devices ever built, and the cost reflects this technology. Compared to the carburetion system it replaced, the Bosch MFI in the early 911S rarely needs adjusting, runs reliably for hundreds of thousands of miles, delivers superior engine power, and uses less fuel.

How good is MFI? You need only to drive a good car with a properly set up MFI to learn to love the race-car acceleration and response; and throttle feel so precise you learn to throttle-steer without even consciously thinking about it.

Until smog and fuel mileage requirements mandated computer systems, the MFI was the simplest, most efficient and *the best*. In many ways, the MFI is *still* the best because it has the highest pressure injection (except for the direct cylinder injection used in Diesels). MFI nozzles "blow off" at 225 - 250 PSI! Fuel squirting from a nozzle at this pressure is atomized to a *very* fine mist. This significantly increases the surface area of the fuel which, in turn, aids combustion considerably.

Unfortunately, there's also a downside. First, MFI replacement parts can be incredibly expensive. Second, it's been 25 years since the last MFI appeared on a production Porsche (though there were the limited-production 1974 3-liter RS and 1984 3-liter 911SC/RS). As a result, the MFI system has become rare. These days there are few people qualified to work on it, and even fewer who are willing to learn.

That's where this article comes in. The system is actually pretty simple to understand and not really that hard to work on. With a little patience and a thorough familiarization with the basics, your 911S MFI engine need not take a back seat to anything else on the road.

The typical MFI system either runs well or hardly runs at all. Thus, when problems arise, don't go off half-cocked and blame the fuel injection system until everything else has been checked. This is what we mean by "the basics."

Back in the early '70s, the dealers received a maintenance aid in the form of a check list. This check list was to be given to all the mechanics that worked on 911s. The list was entitled "**The Ten Demandments.**" It was meant to be a sharp reminder that many perfectly good MFI parts were being replaced because the basics were ignored.

The list said:

CHECK...THINK...REPAIR

CHECK - IN SEQUENCE:

1. Air Cleaner and Element
2. Compression Loss
3. Spark Plugs and Connectors
4. Dwell Angle
5. Ignition Timing
6. Fuel Pressure and Flow
7. Injection Nozzles
8. Injection Timing
9. Throttle Correlation
10. Exhaust Emissions
    a. at part load
    b. at idle

NEVER DEVIATE FROM THIS SEQUENCE

Please note that checks on the MFI are in the latter half of the list, indicating that the factory considered fuel injection problems the least

likely source of poor running. This little reminder list saved much embarrassment and many dollars. There is a never-ending lesson to be learned: Always start with the basics! Be sure you check the "Ten Demandments" before you do anything else (Do them now!).
With the above in mind, I'll run through a basic check and adjustment of the MFI. Here we go!

Checking and Adjusting the MFI System

Publications

There are several publications that will help you to become familiar with the system:

1. **Porsche Factory Manual P/N 4532.21. "Mechanical Fuel Injection: Check, Measure, Adjust."**

*(Ed. - The Registry has reprints of this manual available free to **Registry members only**. If you'd like one, please send an SASE to the Registry PO Box. The envelope must be big enough to hold twenty-eight 8½X11" pages (laid flat, not folded), and must have about $3.00 postage on it (and your address, of course). **Please note**: With the information below, Lee's diagram (see the Photo Gallery) and any of the other manuals below, the above manual is probably not necessary for good results. We're happy to supply it to you, but please don't overtax us with frivolous requests if you really don't need it.)*

2. **Your 911S Owner's Manual.** These have great descriptions and cut-away photos of the entire system.

3. **The Factory Workshop Manual** for your model year.

4. **The HAYNES manual** found in almost every auto supply store.

Tools Needed

Standard tool box with metric sockets, and 2 each of 6mm, 7mm, and 8mm hand wrenches.

Vacuum tester with hoses, T-fittings and clamps (necessary if your car has a vacuum box on the distributor).

Air flow synchronizer (Uni-syn or other).

Long skinny common screwdriver - approx. 24".

Specialty MFI pump tools for idle and main rack adjustments (These are available from most Porsche dealers and many after-market catalogs).

MFI High Pressure Pump

A serious problem with the MFI pump is usually observed as a sudden drastic change of running, e.g., suddenly very rich, blowing lots of black smoke and terrible running.

Occasionally, the internal mechanical parts can wear out to the breaking point. One prime example of this is a broken spring on the governor flyweight, which will cause the pump to run very rich - usually beyond the point of being able to run at all. If this spring breaks, you will also hear a loud knocking sound as the loose flyweight bangs against the pump housing. This can destroy the pump, so a complete rebuild and re-calibration of the MFI pump is in order.

If you determine that your MFI pump *absolutely* needs to be rebuilt, send it to:

Pacific Fuel Injection, Inc.
153 Utah Street
South San Francisco, CA 94080
415-588-8880

However, do this only as a last resort. Major problems are relatively rare. The most common MFI pump problem is simple loss of warm air from the left (driver's side) heat exchanger to the MFI thermostat housing. This causes the pump to remain in the full cold-rich position. Black smoke and poor running will be evident. Eventually, cylinder, piston ring and piston

wear will occur. CHECK for warm air flow exiting from the thermostat housing on the MFI pump. If you don't detect any, you can *carefully* remove the fragile warm air paper/metal hose from the thermostat housing and, while the engine is running, use a propane torch to sparingly apply heat to the inlet of the thermostat. When doing this, please remember that an open flame and gasoline are a dangerous combination - act accordingly. If the engine rpm gradually increases *or* decreases within 30 seconds, there is a problem.

Check the left heat exchanger. Remove the clamp and hose and check for an obstruction and for the condition of the "U" tube that ducts hot air to the hose. With the hoses removed, look through them to insure they are clear of dents and debris. The hose from the engine sheet metal up to the thermostat is a double hose. The inner hose is metal/paper and ducts the hot air; the outer hose is a wrap for the inner hose, supplying not only protection but insulation. This means that looking at the outside hose will NOT reveal the important inside hose's condition. If these checks do not resolve excessive richness, the problem is likely a defective thermostat. Be sure all this is OK before you procede.

Air Flow System

With a fully warm engine and the thermostat positively warm and working, the MFI system is ready for evaluation and adjustment.

The air flow system consists of dual three-barrel metal or plastic air stacks, and dual three-barrel throttle-bodies with their throttle control rods, idle air by-pass adjustment screws, and vacuum ports to retard ignition at idle.

These assemblies deteriorate from two main factors: wear of the throttle shaft bushings and accumulation of both fuel-gum and carbon in the idle air-correction channels and vacuum passages.

The throttle shafts wear out the bushings from the strong "burp-back" air flow caused by the long-duration S camshafts. You can actually see and hear the valve overlap take place as the engine runs at idle.

During the intake stroke, the intake valve is open and a little pressure from the exhaust stroke "burps" up into the throttle, pushing against the closed throttle plate (at idle) and forces the throttle shaft to wear against the stop bolt and bushing. As the bushing wears, the throttle plate also wears a ring groove into the throttle bore.

Just as fast as the throttle plate is pushed up from the exhaust, it is instantly sucked down by the piston pulling air into the cylinder for the next cycle. This causes the throttle plate shaft to wear the other side of the bushing. When the throttle bushings wear, they also cause the ball-and-socket joints on the linkage rods to wear. The racket from tired 911 throttle bodies can sound like a Diesel!

With worn throttle shafts, bushings, plates, and linkages, and plugged-up idle air-correction passages and vacuum tubes, the whole system is beyond the range of adjustment. This is why it is difficult or impossible to simply "tune" a worn system. If your system is this badly worn, it must be fixed before you go any farther.

To really check thoroughly, it's best to remove the whole air flow system from the engine.

When you remove the air stack/throttle body assembly, go slow and count all the hardware as you remove it. Not nice to drop a washer or nut into an intake port!

Once you've removed the assembly, check for any slop in the throttle shafts and ball-and-socket joints in the linkage (there shouldn't be

any). Also check for wear where the throttle plate hits the inside of the throttle body.

If all seems OK, solvent clean the whole assembly *very* thoroughly, paying special attention to the vacuum passages (see below) and the six air-correction channels. Carbon deposits can be pretty unyielding, so, if too badly clogged for mere solvent, use a #41 drill bit to clean out the air-correction channels (remove the air screws first). Also check the screws themselves to be sure they're straight. When you're sure everything is squeaky clean, put it all back together and reinstall the air flow system on the engine using new gaskets. Count the hardware again as you put it on.

On the other hand, if you do find significant wear, the air flow system can be rebuilt. This is not the factory recommended method, as they would have you buy new ones (with the old type bushings). However, there are specialty shops that completely overhaul the throttle-body assemblies with new, larger and stronger bushings that almost never wear out (better than new?). Besides repairing the bushings, they replace the throttle plates, linkage rods, ball-and-socket joints and throttle arms if necessary. Everything is re-finished as factory new. *Additionally,* some shops then put the rebuilt units on a flow bench and set all the linkage and throttle-stop adjustments described below - all you do is put them back on the engine and go!

A "good ol' standby" shop that does this rebuilding service is:

Eurometrix
PO Box 1361
Campbell, CA 95008
408-296-1533

(Ed. - We recently heard a rumor that Eurometrix no longer rebuilds S throttle-bodies. A quick phone call debunked this. Fortunately, the rumor is completely false. Eurometrix is still available to work their magic. Check V6#4. I had my throttle-bodies rebuilt by Eurometrix and am still completely satisfied and quite enthusiastic about the results. My S runs great!)

So, if your budget doesn't allow new units, there is still hope as these throttles can be repaired. The re-work does take about a day to do, but having done it on my very tired 2.2 911S and then driving it daily and time-trialing it for years, I can state that it works.

Injection Pump Control Rod

If your throttle-bodies are not worn enough to warrant a complete rebuild, the next thing to check is the injection pump control rod. This is the short rod connected to the side of the MFI pump (#3 on my diagram).

It is an adjustable metal rod with a ball-socket and lock-nut on each end. These rods have a L/H thread on one end and a R/H thread on the other end. The idea is that for any adjustment you need only loosen the nuts on each end and turn the rod. Rotating the rod one way lengthens it, the other way shortens it. Nice idea. It rarely works that way.

This rod's required setting is **extremely** critical: **114mm ± 0.2mm**, measured from center-to-center of the ball socket openings. In my experience, the majority of MFI air-flow problems are due to a mis-adjustment of **this connecting rod alone**, so be sure it's right! What makes this adjustment even more fun is that the sockets on each end of the rod face in opposite directions.

Remove the rod from the MFI pump arm and the cross shaft by *gently* prying each socket away from the lever arm ball with a wide-blade screwdriver. Measure the rod length and adjust if necessary. Check for even alignment of the

ball sockets so that the rod rotates between the pump arm and the cross shaft slightly without any binding. Once you are sure this critical 114mm setting is exact, **paint a yellow mark** on the locking nuts to be sure it is never disturbed again. With this setting made, there is some latitude that can be allowed with the rest of the rod linkage system, but first:

Distributor

Now that the injection pump control rod is set accurately and the air flow system is in good shape, check the idle speed. The air flow system can normally be adjusted to a smooth idle of 900 to 1000 rpm. If this cannot be met, recheck the TEN DEMANDMENTS, paying special attention to #5: Ignition Timing.

This does not mean simply checking the timing with a strobe light. The distributor must be healthy or nothing else will work. If in doubt, the distributor advance curve should be checked for smooth movement from full retard to full advance. Fix any problems here before proceeding to anything else.

Special instructions for 2.4 and later cars or any other engines with vacuum boxes on the distributor: Vacuum is critical for these engines as even a healthy engine can barely generate enough vacuum (250-300 mm) to retard the vacuum box to its specified timing of *negative* 5°. Check the vacuum box to be absolutely sure it works properly and holds vacuum - not even slow leaks are acceptable. Is there vacuum at the brass tube coming from #1 & #4 throttle? If not, the tube is likely plugged with carbon deposits, common after high miles. Here are a few hints on how to clean it:

#1 and #4 throttles have a tiny brass tube that supplies vacuum via a 2.5mm hose to a T fitting, and then to the distributor vacuum box. Are the hoses in good condition? Will they hold a vacuum? If not, replace with a 2.5mm silicone vacuum hose. Is the T fitting cracked? This can (and does) happen, so check it.

The distributor vacuum source is taken from the rearmost air stacks (#1 & #4). If these are plugged or partially obstructed, they must be cleaned by removing the throttle stack assembly from the engine, and reaming these internal passages (four total for the two air stacks) with a 4" long #41 drill bit. Turn the bit slowly and carefully by hand - the carbon should be easily removed. Finish by solvent-cleaning the vacuum passages (and the entire assembly), then blowing dry with compressed air. When you reassemble the air control system on the engine you should now have good vacuum all the way to the distributor.

Throttle Linkages

The following assumes that you decided your throttle bodies were not so bad they needed to be rebuilt.

OK, our air flow system is spotlessly clean inside and out, and installed with fresh gaskets. The throttle control rod is correctly set, and the distributor is working fine. Now, and only now, can we adjust the rest.

First, turn the air-correction screws in to their fully closed position, then back them out exactly 2½ turns open.

Next, adjust the throttle stops. Remove all the throttle linkages. One at a time, loosen each throttle bolt locking nut. If these are tight, use Liquid Wrench or the equivalent to loosen. Lightly push the throttle plate toward the fully closed position. Turn the throttle stop bolt to allow the throttle plate to close completely. When you get to the point where you have almost removed the bolt, the throttle plate will stick shut. Now screw the throttle stop bolt back in to the point where the throttle plate no longer sticks shut. This is actually rather critical - the fit is very precise, and if the

throttle plate is closed down too far, it can become stuck solid as the changes in engine temperature cause the clearances to change. Go slow and get it just right. When you've got the throttle stop bolt set to just keep the throttle plate from sticking, screw the throttle stop bolt another ¾ turn in the direction that opens the throttle plate. Check for a free fit by pushing lightly toward the stop. If all is OK, secure with the locking nut. Repeat for the remaining five throttles.

At this point, the engine should start and run, though the idle will probably be slow. Run the engine until warm (oil temp 180°+). Shut it off, wait 15 min. for heat expansion, then re-start the engine.

Check each throttle with your air flow synchronizer. Find the throttle with the lowest air flow and adjust the throttle stop bolt to allow more air through that throttle plate. **Important:** Never adjust any throttle plate towards closing it farther. Again taking your time, adjust all six throttles up to identical air flow. Idle speed should now be close to spec. Remember that any weak point in the engine, like a poor spark plug or plug connector, will affect this adjustment.

Next, with the engine still running, adjust and reinstall the four throttle valve connecting rods (#5 in the diagram) to just keep the throttle arms on the stop bolts without changing the idle rpm.

Left and right throttle valve push rods (#4 in the diagram) should be adjusted to 149.5 mm and reinstalled. This adjustment may not be possible, just get them as close to this length as you can, and be sure they are equal.

Now with all the rods connected and the engine at idle, check the idle mixture. Since you've already done the "Ten Demandments" (you have done them, right?), the pump setting should be close, so this will only be for fine tuning. What you're trying to do now is correlate the pump setting with the new throttle settings.

If the idle speed is low (which is the norm), you must determine if the engine needs more air or more fuel to achieve correct idle. Here's the easy way to find out.

Remove the injection pump control rod (#3 in the diagram) at the cross shaft end *only* (#2 in the diagram). Leave the other end attached to the injection pump. Check to be absolutely sure the throttles are still on their idle stop positions, then push the pump rod very slightly open. This will inject a little more fuel into the engine with only idle air available.

Does the engine speed up? Pump is set too lean.

Does the engine slow down, puffing a little black smoke? Pump is set too rich.

At perfect adjustment, pushing lightly on the pump rod will cause the engine rpm to initially increase a little, then rapidly decrease.

The MFI pump is adjusted for basic rich/lean at 1000+ rpm with the main enrichment. The idle speed is adjusted with the idle enrichment and is only effective at or below 1000 rpm.

Fine-tuning the idle speed can be accomplished by evenly turning all six air correction screws very slightly (like 1/16 turn), then rechecking with your synchronizer to be sure they're still all the same.

Re-check all linkages to be lightly tight and secured with the lock nuts. Use Bosch ignition grease in the ball sockets - it works as well as anything else.

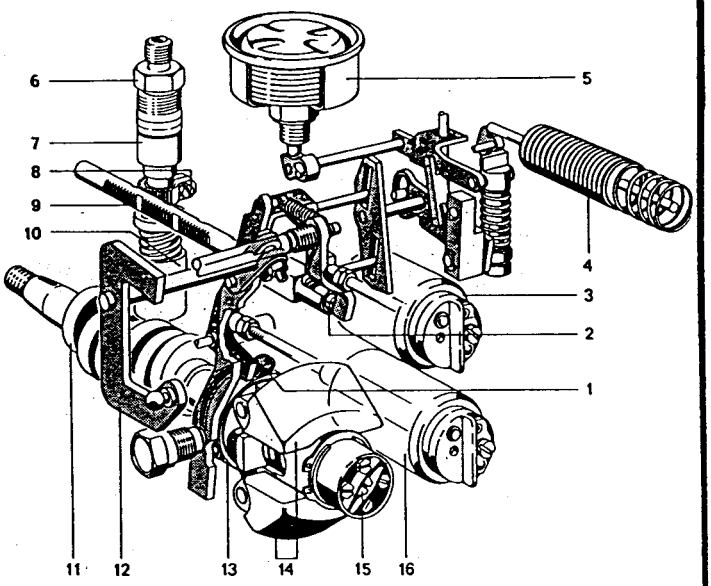
Last, check to be sure that when the throttle pedal is all the way down, the MFI pump is also at full throttle. Adjustments for this are at the transmission bell crank and at the throttle pedal itself. Also, check to be sure that both the upper and lower bellcrank bushings are in good shape. Probably should have mentioned

this earlier as the upper is almost impossible to check without removing the air stacks. Hope you read the whole article before you started.

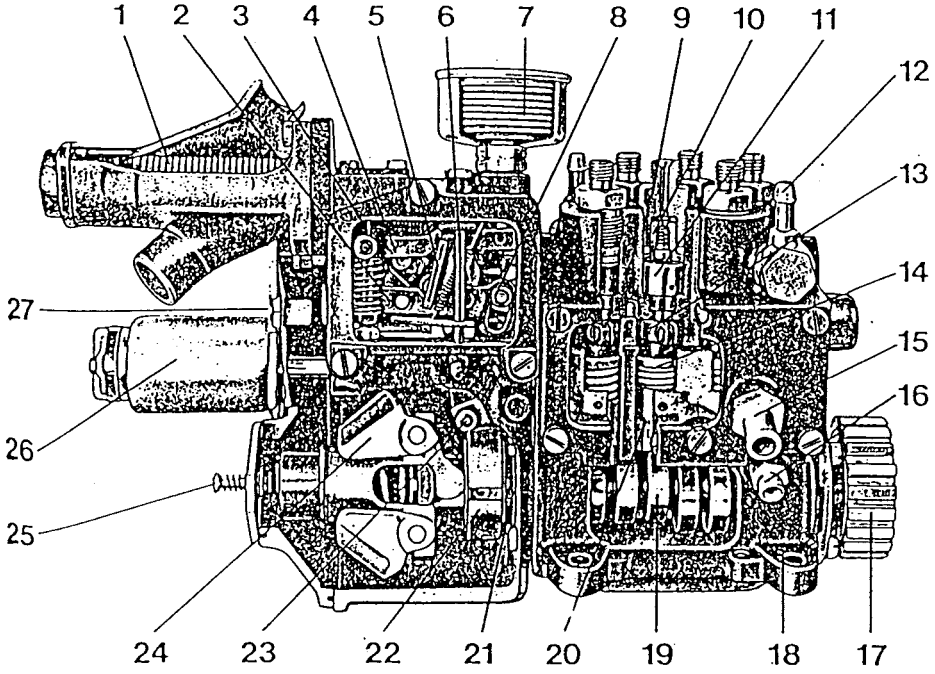
Drive the car for a few days so all the parts will have a chance to settle after the heat cycles have made their small changes. At this point, an engine analyzer will help you dial in the final CO adjustments.

The MFI system benefits from regular preventative maintenance (like cleaning and replacing the grease in the ball-and-socket joints regularly), and should run well for a long time. The reward is exceptional performance that can be compared to the best racing cars. Porsche did all the hard work. All you have to do is keep it clean and mind the small things before they become problems.

God Speed,
Lee Rice

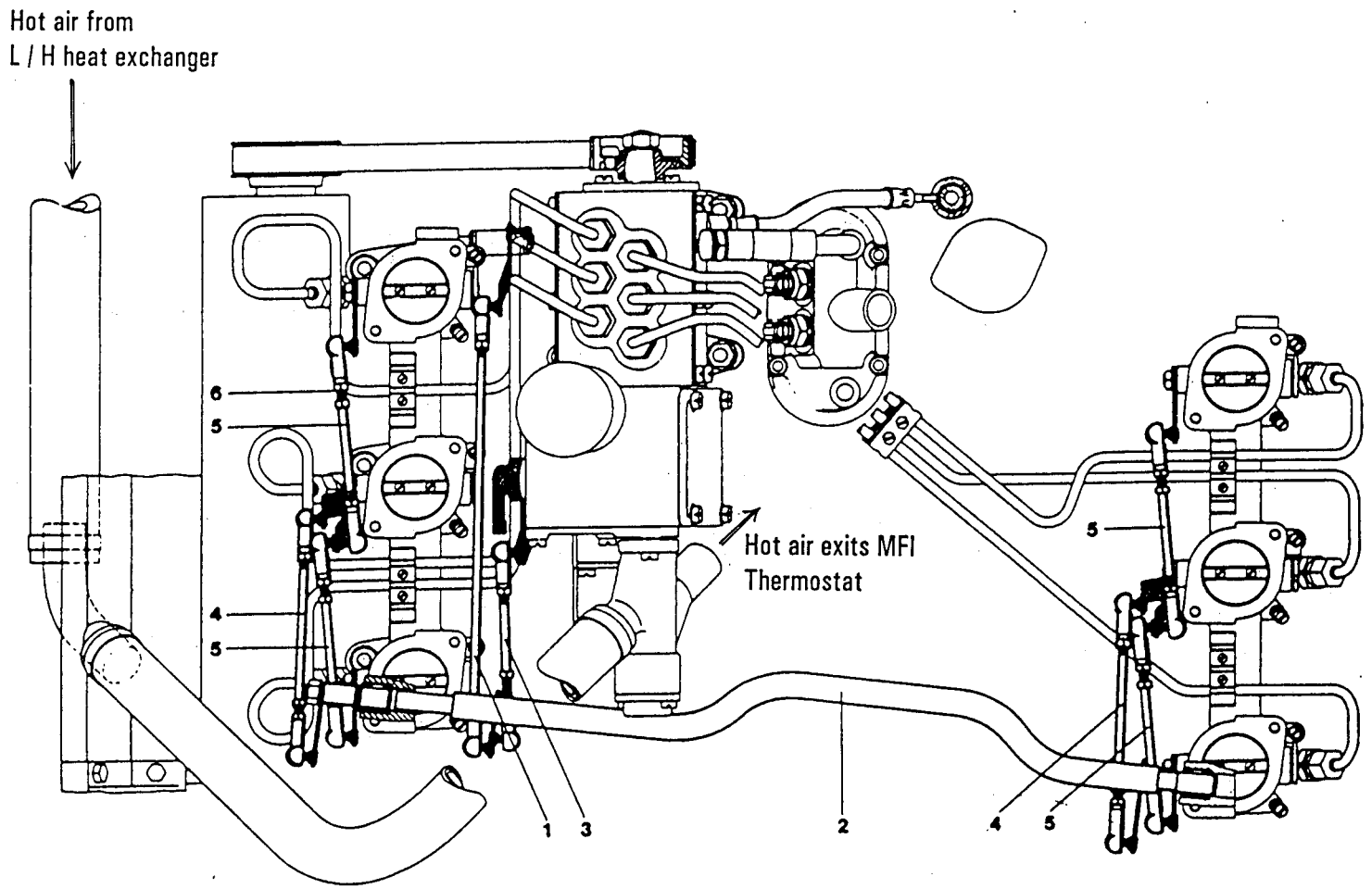


1 *Cam roller*
2 *Control rack head*
3 *Enrichment solenoid*
4 *Thermostat*
5 *Barometric cell*
6 *Non-return valve*
7 *Plunger unit*
8 *Toothed segment*
9 *Control rack*
10 *Roller tappet*
11 *Camshaft*
12 *Governor control lever*
13 *Cam*
14 *Centrifugal governor*
15 *Idle adjusting screw*
16 *Shut off solenoid*



1 Thermostat
2 Compensating lever
3 Thermostat connecting shell
4 Pivot
5 Connecting link
6 Guide stud
7 Barometric cell
8 Guide
9 Injector line fitting
10 Check valve
11 Plunger unit
12 Fuel inlet
13 Toothed segment
14 Plunger spring
15 Oil return to engine
16 Oil inlet from engine
17 Pump drive wheel
18 Support flange
19 Camshaft
20 Roller tappet
21 Contoured cam spring
22 Contoured cam
23 Sensor
24 Governor counterweight
25 Idle speed adjustment
26 Shut-off solenoid
27 Access to control rack head

Diagram for Lee Rice's MFI article



THROTTLE LINKAGES

1. Pull rod
2. Cross shaft
3. Injection pump control lever
4. Throttle valve push rod
5. Throttle valve connecting rods
6. Paint seal