WR engine fuel injection system by Jim Howard

The WR engine uses Bosch K-JET CIS fuel injection. CIS is a continuous and purely mechanical injection system. This means that all the injectors spray fuel all the time the engine is running.
This may sound extremely wasteful as most of the time fuel must be being sprayed onto shut valves, but when you actually think about how well the fuel is atomised, and how long each valve is actually open and shut for at say 2000rpm it's not so bad. A cloud of vaporized fuel will just wait behind the shut inlet valve to be drawn in on the next intake stroke
The system is made up of several components:-

Fuel Pump
The fuel pump can deliver much more fuel than the injection system requires. A large percentage of the fuel delivered by the pump goes through the fuel distributor and back to the tank. This ensures that there is sufficient reserve in case of sudden opening of the throttle.
There is a one way valve on the output of the pump to stop fuel draining back into the tank after shutdown.
Pumps wear out, draw more current, become noisy, and eventually fail to deliver the necessary fuel flow. A particular weakness on the Ur quattro is the inline connector for the fuel pump supply. This connector can be found beneath the rear seat near to the battery and looks like an inline fuse, it should be checked for condition regularly on any quattro. A good modification to this circuit is to fit an auxiliary relay to relieve the current drawn through that connector and associated wiring, which was only just up to the job 20 odd years ago. A diagram for this can be found on my homepage
There is a specific test for the delivery rate of the pump/filter see the fuel filter section below.

Fuel Accumulator

The fuel accumulator consists of a metal can with a diaphragm and a spring inside. Fuel enters the can on top of the diaphragm and the fuel pressure compresses the spring under the diaphragm.
The purpose of the fuel accumulator is to smooth out any pressure pulses from the pump and to hold fuel pressure in the system for a period to aid hot starting and help to prevent vapour lock in the injector fuel lines.
You can test for a split diaphragm on a WR accumulator by removing a small screw in the opposite end of the can from the fuel lines. If fuel leaks out, the diaphragm is split. The operation of the accumulator can be tested with a fuel pressure gauge at the fuel distributor. The residual pressure in the system must be at least 2.6 bar (38psi) 10 minutes after the engine has been run up to temperature and shut down.

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Fuel Filter

There is a large cylindrical fuel filter fitted to the WR which is situated under the floor on the opposite side of the car from the fuel pump.
If you have no record of your fuel filter being changed, it should be renewed.
Fuel filters absorb moisture from the fuel and this can cause the innards to swell up and block the passage of fuel.
If you fuel pump is noisy or fails the delivery test below, the first thing to do is replace the filter and re-test.

The fuel system delivery rate can be measured by removing one of the fuel lines which is open to system pressure (i found the line to the Cold Start Injector to be easiest) and putting the end into a measuring bottle. The pump should deliver at least 900ml 30 seconds. If it doesn't, replace the filter and re-test. A pass does not guarantee a good filter, as a swollen filter element can take more than 30 seconds to start to restrict flow.

Fuel distributor

The fuel distributor (sometimes referred to as metering head) is the round black thing which all the fuel lines from the injectors go to.
It has several 'parts'.

The system pressure regulator is built into the metering head on the WR. It consists a plunger pushing on a spring. Shims can be added / removed from the plunger to adjust system pressure. System pressure values and adjustment procedure can be found on Phil Payne's site.www.isham-research.co.uk/quattro

The Control plunger is what actually controls the delivery rate fo fuel to the injectors. It consists of a precision made plunder inside and equally precision made barrel. The barrel has 6 slits around it's circumference - one for each outlet of the fuel distributor (remember that the WR fuel distributor is a six outlet unit with one outlet banked off, to supply fuel to 5 injectors). The plunger moves up and down inside the barrel to control the amount of the slits which are exposed to fuel flow. If more of the slit is exposed to the flow of fuel, then more fuel can flow through it to the injector. The movement of the plunger is controlled directly by mechanical linkage to the air metering flap.
The control plunger movement is also influenced by the control pressure - this is fuel at a known pressure metered onto the top of the plunger to resist it's upward movement. This means that the amount of plunger movement can be varied for a given air flap movement. This variable contro pressure provides mixture control for cold running and full throttle operation and is controlled by the Control Pressure Regulator.

Fuel distributor (continued)

The fuel distributor also contains pressure drop regulators (one for each outlet). These pressure regulators ensure a constant pressure drop at the slits in the control plunger barrel, allowing better control of fuel flow and even flow at each outlet. The ability of the fuel distributor to equally deliver fuel to each injector can be tested - details of the test are here.

Control Pressure Regulator

The control pressure regulator (CPR) is the rectangular unit which sits on the left hand side of the engine block. It has 2 fuel lines, a vacuum line and an electrical connection to it.
The purpose of the Control pressure regulator is to vary the control pressure acting on the top of the control plunger to vary the mixture. There always needs to be some control pressure to dampen the movement of the air metering flap and the control plunger, and to encourage both back to their rest positions.
The CPR contains a bi-metal leaf spring and a vacuum diapragm both actuating a fuel pressure valve.
When the engine is cold, the bi-metal spring pushes on the pressure valve and reduces the fuel flow to the top of the control plunger, this allows more control plunger movement for a given air flow and therefore a richer mixture. The bi-metal spring is heated, both electrically and by heat from the engine block. When heated the bi-metal spring bends away allowing more fuel pressure to the top of the control plunger and therefore a leaner mixture.
The fuel pressure delivered by the CPR also depends on the level of vacuum administered to it. The more vacuum that is applied, the more the control pressure rises. More vacuum = leaner mixture.
When the engine is cold, the thermo-pneumatic valve is open. This allows inlet manifold vacuum levels to act directly on the CPR. When you partially open the throttle on a cold engine, the vacuum level at the inlet manifold, and therefore the CPR, will drop, resulting in a richer mixture.
When the engine has armed up, there’s no need for this extra enrichment at partial throttle and the thermo-pneumatic valve closes.
The control pressure test is on Phil Payne’s site with the system pressure test.

Fuel Injectors

The fuel injectors used in the CIS system are purely mechanical. The injector is basically a valve which opens at a set pressure, and a fine nozzle for atomising the fuel. Once the fuel pressure at the injectors reaches a certain level, the injectors all open and spray fuel continuously until the pressure drops. Fuel injectors can be cleaned and tested with a special hand pump assembly. If you have no history of your fuel injectors being replaced, then replace them.

The fuel injectors are held in place by green O rings. These are easily available, cheap and they don't last very long. The O rings harden with the heat, leak air and can be extremely hard to remove if very hard. Again, if you have no history of them being replaced, replace them now, and then every couple of years.

Air metering Dome

The air metering dome is often referred to as the 'igloo'. Inside it is a cone shaped funnel with a round flat air metering flap moving up and down in the cone.
The flap is pushed up by air rushing though the cone. On the bottom of the flap is a two-part lever which acts directly on the control plunger. The more the flap is raised by the incoming air, the more the control plunger is moved, and more fuel is injected.
The mixture adjustment screw changes the relationship between the two halves of the lever and therefore changes the amount of control plunger movement for a given air flap movement - adjusting the base mixture. This affects the mixture throughout the rev range, but it is much more noticeable at idle.
At rest, the air flap must be at, or just below, the narrowest point of the cone. It should not be above that point or hard cold starting will occur. The rest position of the air flap can be adjusted by bending the spring clip under the flap.
The flap should be central in the cone and can be adjusted by loosening the central bolt.
On sudden opening of the throttle, lag in the system will allow momentary over-travel of the air metering flap, resulting in a momentary rich mixture - this is a desirable side effect.

Full throttle (WOT) enrichment

Wide Open Throttle or WOT enrichment is desirable for maximum power on a hot engine, to develop maximum power with no regard for economy, and to prevent detonation
.
The amount of vacuum applied to the CPR affects the mixture.

More vacuum = leaner mixture, less vacuum = richer mixture.
The CPR applies no further enrichment for boost pressure, the internal diaphragm is maxed out at atmospheric pressure. Extra fuelling to account for boost is controlled by extra movement of the air metering flap.

When the engine is hot, the thremo-pneumatic valve is shut and only vacuum is allowed to pass to the CPR and this vacuum is held there irrespective of drops in manifold vacuum by the one way valve.

When the WOT switch is activated, the two-way valve is opened, bypassing the one way valve. This allows the high vacuum level held at the CPR to escape and match the inlet manifold vacuum. At WOT the inlet manifold vacuum level will be atmospheric, or positive boost pressure. This pressure will disperse the vacuum held on the CPR and richen the mixture. Less vacuum = richer mixture.

The two-way valve is at the WOT position at rest. When the ignition is turned on, voltage is applied to the valve via the normally closed WOT switch. When the WOT switch is acted upon by the throttle linkage it breaks the circuit and the two-way valve switches over to the WOT position.

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CPR vacuum hose circuit

On the following 4 pages are diagrams of the CPR vacuum hose circuit and a description of each mode of operation.

It is absolutely essential that all the components are working correctly and that there are no vacuum leaks. Otherwise you will have a car which struggles to get below the 4% CO MOT requirement, while at the same time also struggles to deliver the necessary fuel at WOT to prevent detonation.

The CPR vacuum hose circuit should be overhauled if you are not absolutely ceratin of it's correct operation / condition.
To do this:-

Remove all the small diameter vacuum hoses in the circuit.

Individually test each component for correct operation and lack of vacuum / pressure leaks with a MityVac or similar.

Test the one way valve to make sure that only vacuum can pass in one direction (MityVac connected at black end of valve) and only pressure can pass at the other end (MityVac applying pressure at the blue end).

Test the thermo-pneumatic valve by submerging only the metal part in hot water. As the water heats, the thermo-pneumatic valve should snap shut.
Check that you can pass vacuum or pressure in both directions with the valve cold, and no vacuum or pressure with the valve shut.

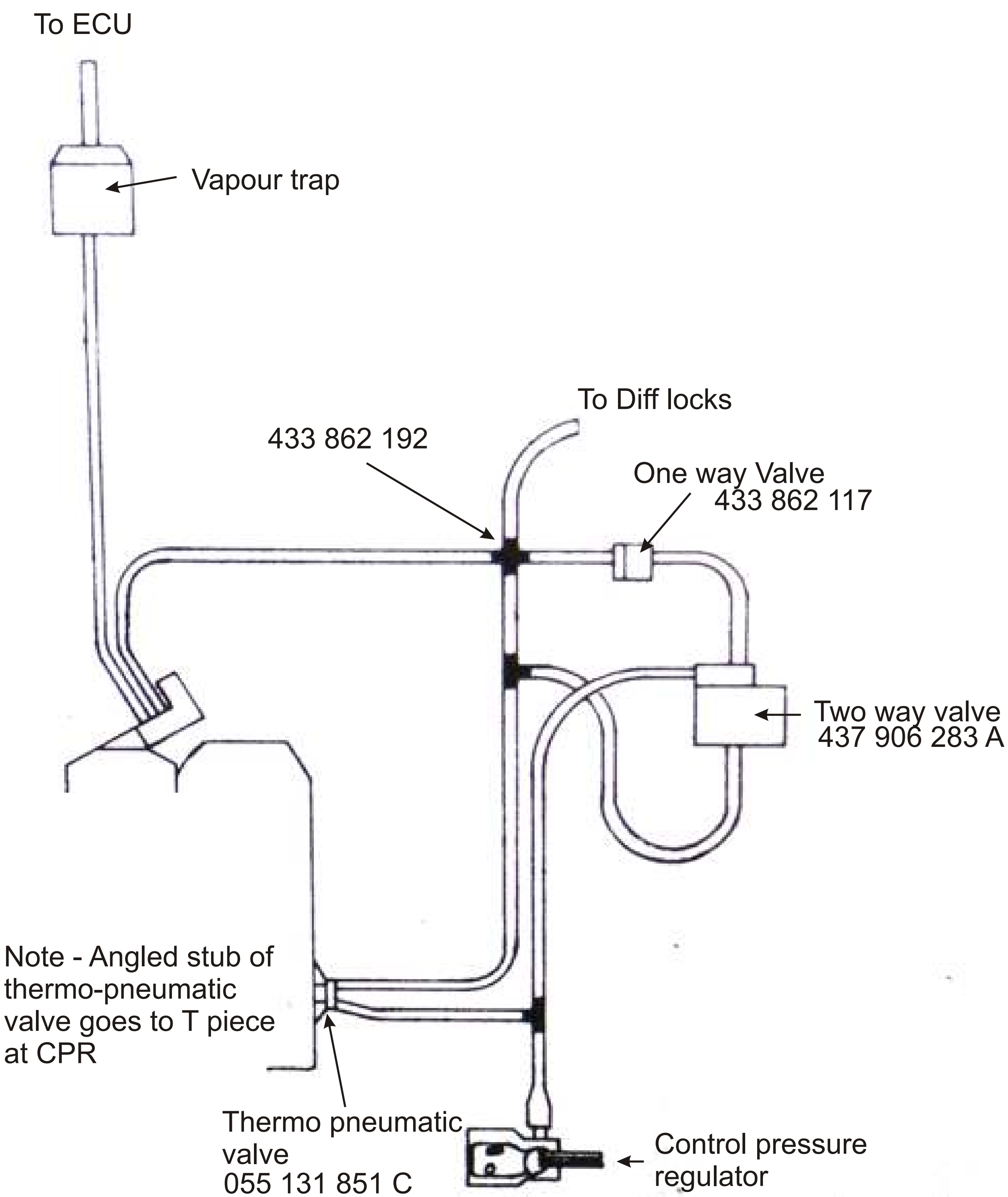
Test the two way valve by switching on the ignition. With the valves electrical connection still made, apply vacuum & pressure to the bottom vacuum connection - vacuum & pressure should hold.
Now apply vacuum and pressure to the top vacuum connection. If you block off the side connection, the vacuum & pressure should hold.
Now activate the WOT switch (or if the WOT switch operation has already been tested, you can just switch off the ignition). Apply vacuum & pressure to the top vacuum connection- vacuum & pressure should hold.
Now apply vaccum & pressure to the bottom connection. If you block off the side connection vacuum & pressure should hold.

Test the CPR by applying vacuum to it, check that it holds vacuum and watch the control pressure rise (on a fuel pressure gauge) as the vacuum level is increased. This test is best done in conjunction with the standard control pressure test.

Fit new vacuum hose & clips.

WR engine fuel injection system

CPR vacuum hose layout



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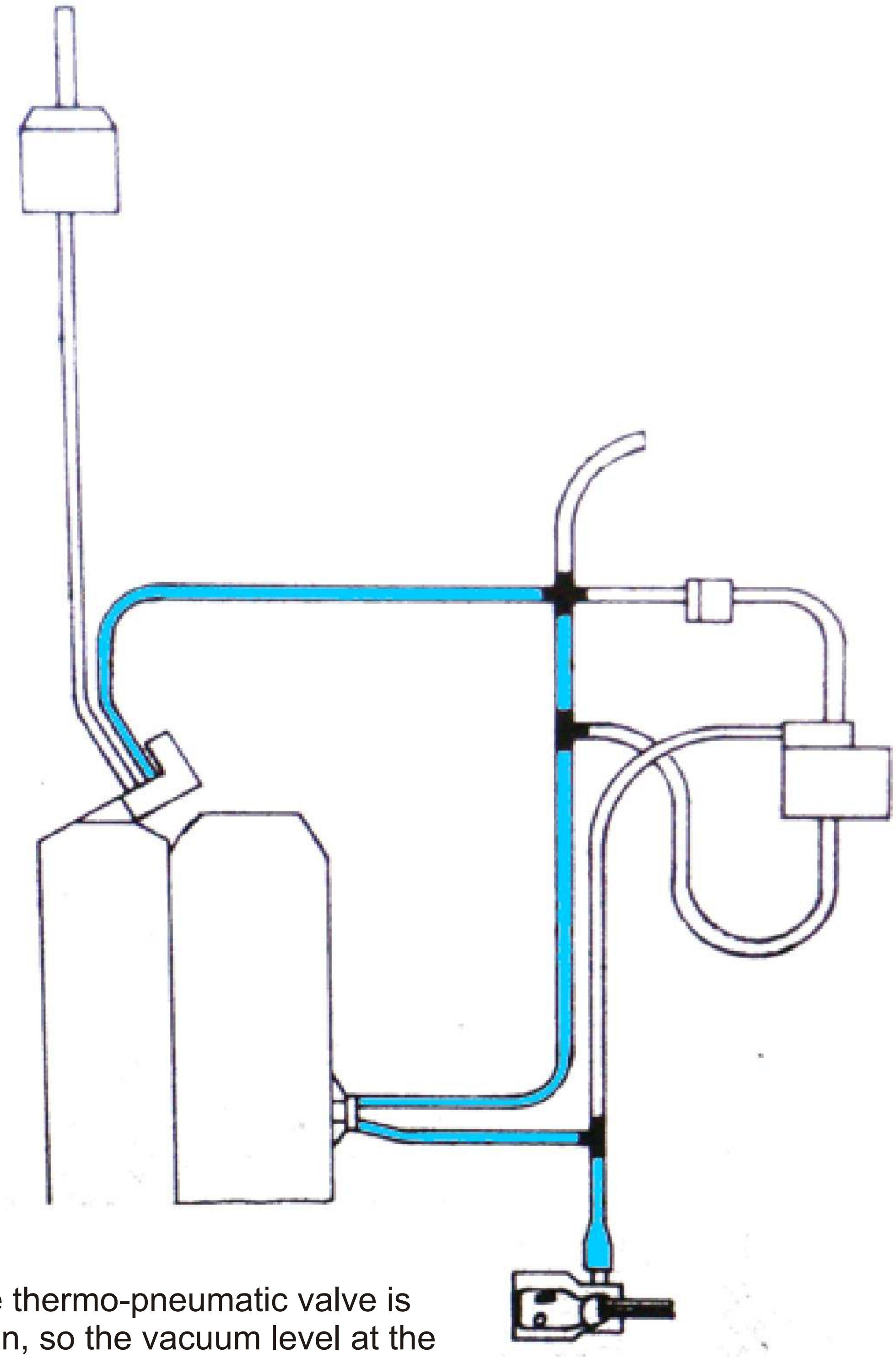
CPR vacuum hose layout

Cold Engine operation



The thermo-pneumatic valve is
open, so the vacuum level at the
CPR follows that of the inlet manifold.
Enrichment will happen as soon as the throttle is partially opened and the inlet manifold vacuum drops.

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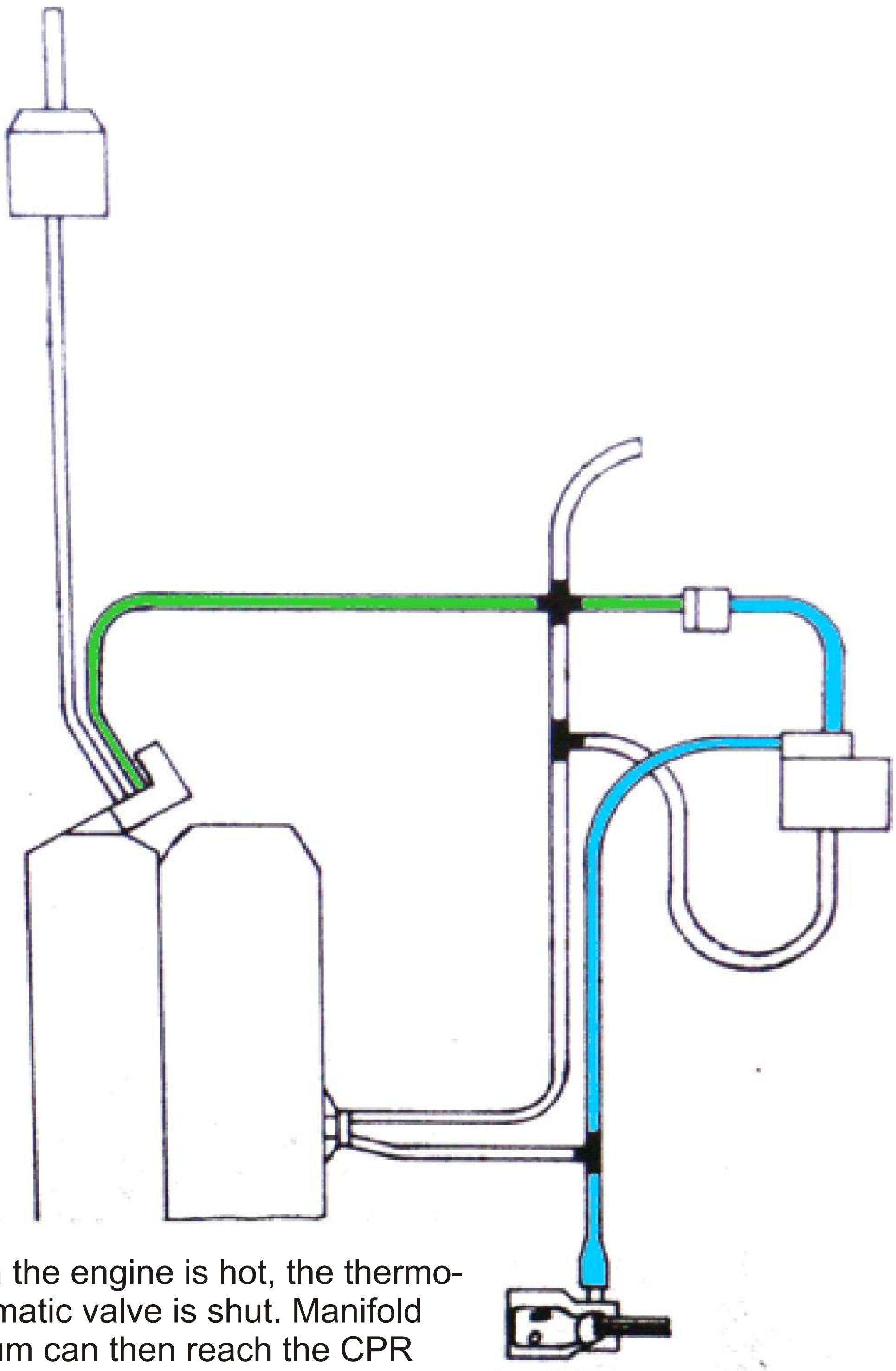
CPR vacuum hose layout

Hot Engine operation



When the engine is hot, the thermo-pneumatic valve is shut. Manifold vacuum can then reach the CPR via the 2 valves. Because of the one way valve, only vacuum can pass - not boost pressure. Maximum attained manifold vacuum is then held on the CPR (resulting in a leaner mixture) all the time until the WOT switch is activated.

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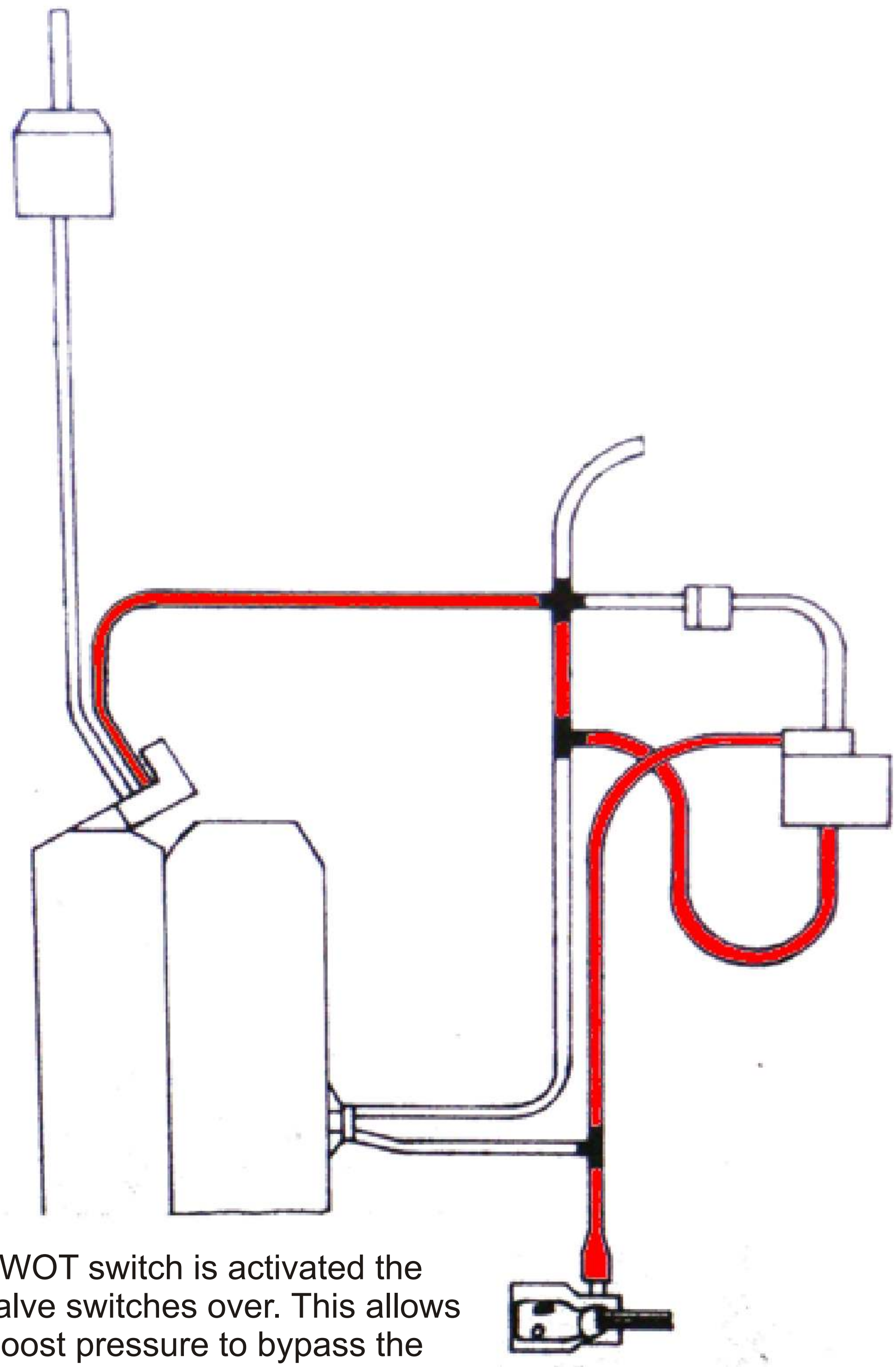
CPR vacuum hose layout

Wide Open Throttle (WOT) operation



When the WOT switch is activated the two way valve switches over. This allows manifold boost pressure to bypass the one way valve and disperse the vacuum previously held on the CPR. The lack of vacuum at the CPR results in a richer mixture - full throttle enrichment.

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