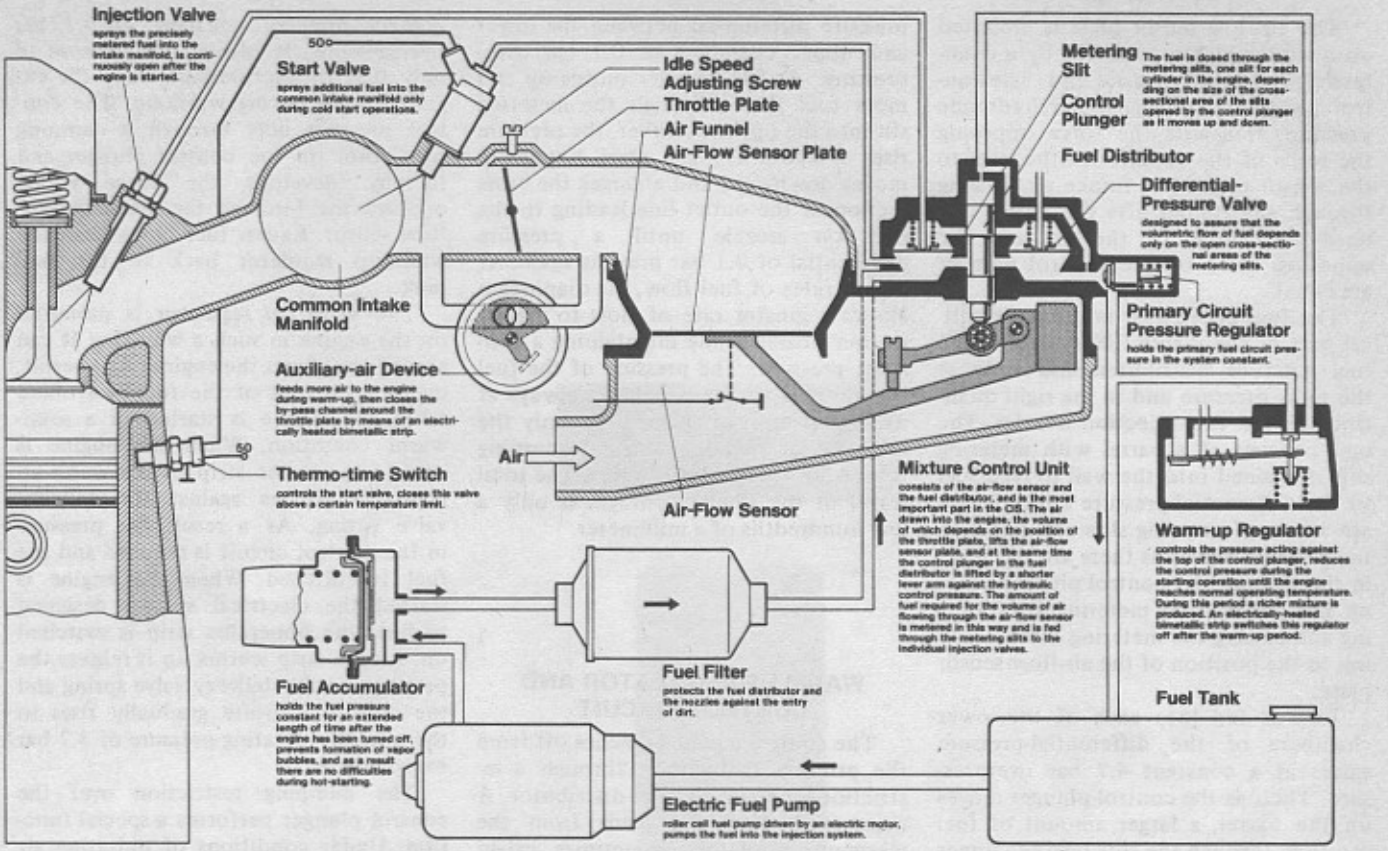


Study this schematic drawing of the Continuous Injection System, read the text, and you should be able to understand how fuel injection works.

Fuel Injection Basics

THE CONTINUOUS INJECTION SYSTEM

BY JOHN G. RETTIE

Last month we covered the basic theory behind fuel injection systems. Simply put, a system consists of a fuel pump that pumps the fuel, under pressure, to a metering unit that distributes the fuel in the correct amount to each cylinder. There are several different types of metering units available. VWs use either an electronically controlled unit or a mechanically controlled unit. We are going to look in more detail at the Bosch CIS (Continuous Injection System or K-Jetronic) mechanically controlled fuel injection as used on the Rabbit and Scirocco, as well as on many other cars including Porsches.

The system is basically straightforward and if you study the schematic drawing of the various components and read the detailed description you should be able to understand the workings of the system better than that of a carburetor.

MIXTURE CONTROL UNIT

As mentioned before, this is the heart of the system, the mechanical brain. It consists of an air-flow sensor and a fuel disbributor. The air-flow sensor works on the suspended body principle. A round disc (the air-flow sensor plate) rises in a conical air funnel until its weight and the force of the air flow against the bottom of the disc are in equilibrium. If the volume of air drawn into the engine increases, the rate of air flow increases through the funnel of the air-flow sensor. As a result, the flow force increases and the air-flow sensor plate is forced further up. The position of the air-flow sensor plate therefore represents a measure of the quantity of fuel required as it is in direct proportion to the quantity of air drawn into the engine.

The air-flow sensor plate is mounted on a lever which is balanced by a counterweight at the opposite end. The control plunger operating under hydraulic pressure, transmits the force opposing the force of the air through the lever to the sensor plate. The intake air flowing through the funnel lifts the lever plate until the force of the air and the opposing force of the control plunger are equal.

The fuel distributor is the most critical part of the whole CIS system as the fuel must be distributed uniformly at the right pressure and in the right quantities to the fuel injection nozzles. The unit consists of a barrel with metering slits machined into the wall to feed fuel to the differential-pressure valves. There are as many metering slits and differential-pressure valves as there are cylinders in the engine. The control plunger slides up and down in the metering slot, opening and closing the metering slits according to the position of the air-flow sensor plate.

Fuel is fed into each of the lower chambers of the differential-pressure valves at a constant 4.7 bar overpressure. Then as the control plunger moves up the barrel, a larger amount of fuel can flow through the slits into the upper chamber in proportion to the required fuel flow. There is a diaphragm between the two chambers controlled by a spring that maintains a constant pressure differential between the lower and upper chambers of 0.1 bar overpressure. As the plunger moves up and more fuel flows through the metering slit into the upper chamber, the pressure rises temporarily. The steel diaphragm moves downward and enlarges the cross section of the outlet line leading to the injection nozzle until a pressure differential of 0.1 bar prevails again. At higher rates of fuel flow, the diaphragm allows a greater rate of flow to the injection nozzle while maintaining a constant pressure. The pressure of the fuel in the lines to the nozzles is always at 3.3 bar overpressure and it is only the quantity of fuel that differs according to the position of the plunger. The total travel of the steel diaphragm is only a few hundredths of a millimeter.

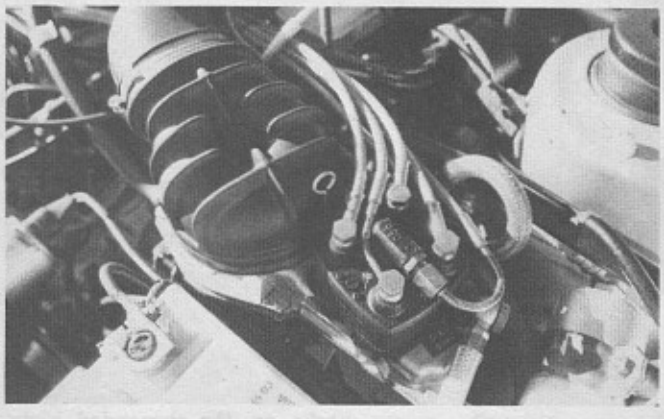
WARM-UP REGULATOR AND CONTROL CIRCUIT

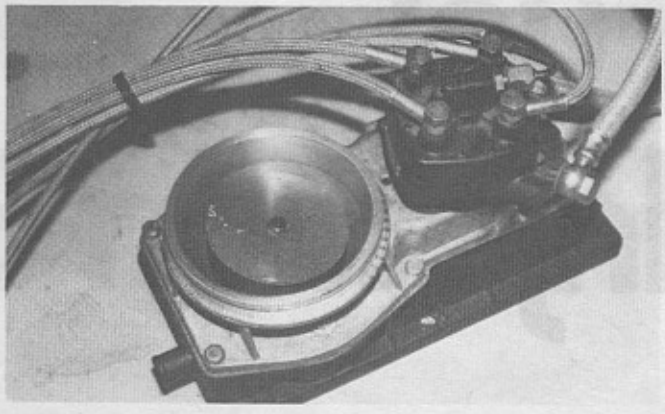
The control circuit branches off from the primary fuel circuit through a restriction bore in the fuel distributor. A connection line also leads from the warm-up regulator (sometimes called the control pressure regulator) to the top of the fuel distributor above the control plunger. At normal operating temperatures the regulator holds the control pressure constant at 3.7 bar overpressure. It lowers the pressure to only 0.5 bar overpressure when the engine is cold during warm-up. The control pressure acts through a damping restriction on the control plunger and thereby develops the force which opposes the force of the air in the air-flow sensor. Excess fuel flows from the warm-up regulator back to the fuel tank.

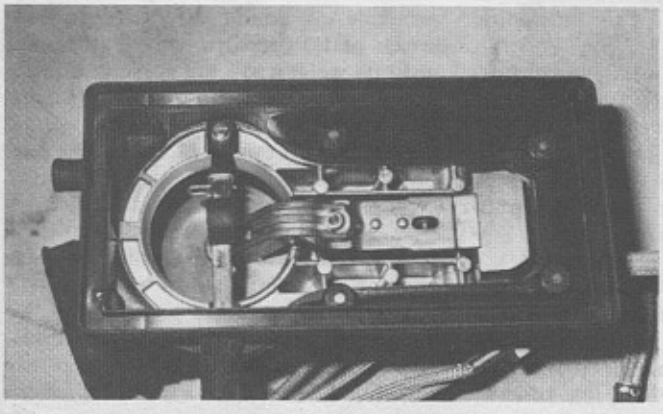
The warm-up regulator is mounted on the engine in such a way that it can absorb heat from the engine. As a result, over enrichment of the fuel is avoided when the engine is started in a semi-warm condition. When the engine is cold, a bimetallic strip in the warm-up regulator presses against the delivery valve spring. As a result the pressure in the control circuit is reduced and the fuel is enriched. When the engine is started the electrical system designed to heat the bimetallic strip is switched on. As the strip warms up it relaxes the pressure on the delivery valve spring and the control pressure gradually rises to the normal operating pressure of 3.7 bar overpressure.

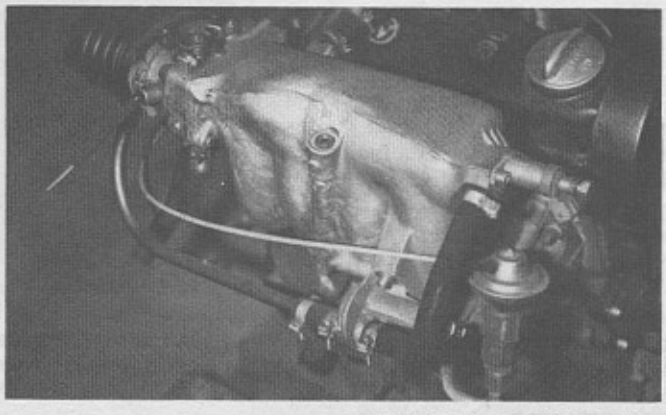
The damping restriction over the control plunger performs a special function. Under conditions of pulsating air flow that occur, for example at low engine speed and high load, the restriction creates a damping on the air-flow sensor plate.

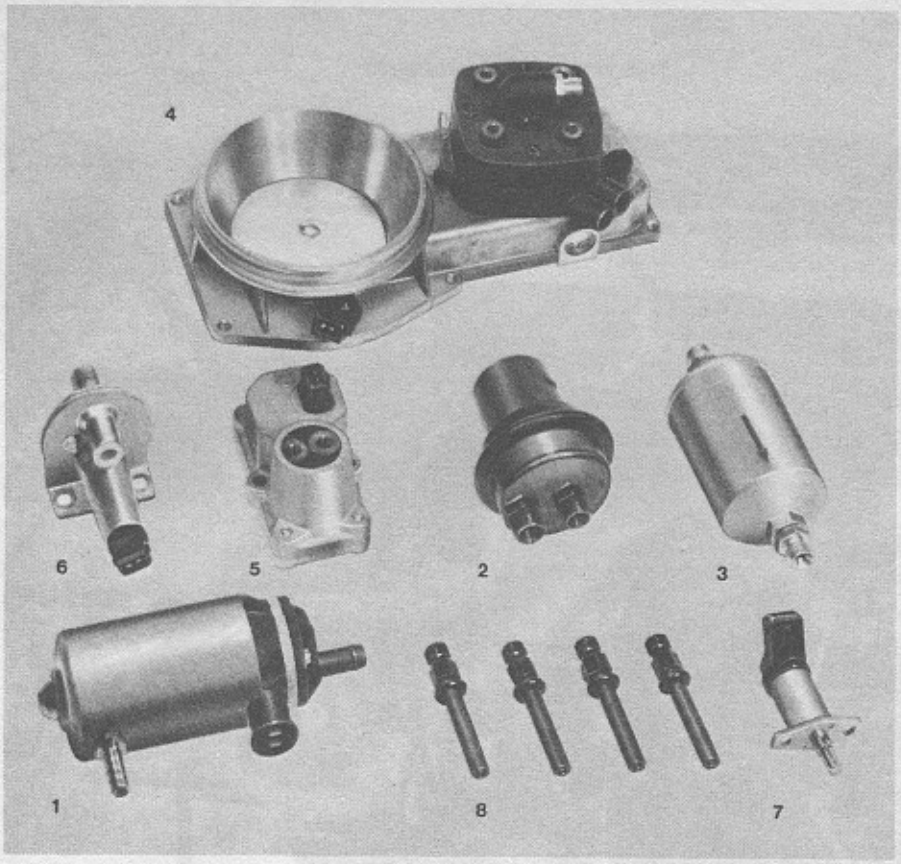
BELOW LEFT, the mixture control unit is the mechanical brain of the Bosch CIS. The unit sits on top of the air cleaner. BELOW RIGHT, with the air conducting duct removed, the funnel and the air-flow sensor plate are clearly visible. The fuel distributor is the black box to the right of the funnel complete with fuel lines that lead to the injection nozzles. BOTTOM LEFT, a view underneath the air-flow sensor shows the lever and counterweight that controls the plunger. BOTTOM RIGHT, the auxiliary air-device is located behind the common intake manifold.



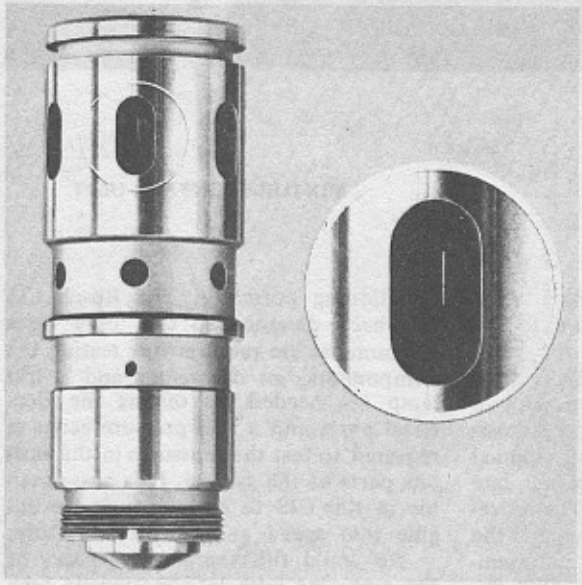








Bosch components for the CIS: 1. electric fuel pump; 2. fuel accumulator; 3. fuel filter; 4. mixture control unit; 5. warm-up regulator; 6. auxiliary air device; 7. start valve; 8. injection nozzles.



LEFT, barrel with metering slits, about actual size, with enlargement of one slit.

PRIMARY FUEL SUPPLY

This is the part of the system that feeds fuel into the primary circuit of the fuel distributor. It consists of a fuel pump, fuel accumulator, fuel filter and a primary circuit pressure regulator. The fuel pump is a roller cell pump driven by a permanent-magnet electric motor. It delivers several times the quantity of fuel actually required so the excess fuel is diverted off at the primary circuit pressure regulator and flows back under no pressure to the fuel tank.

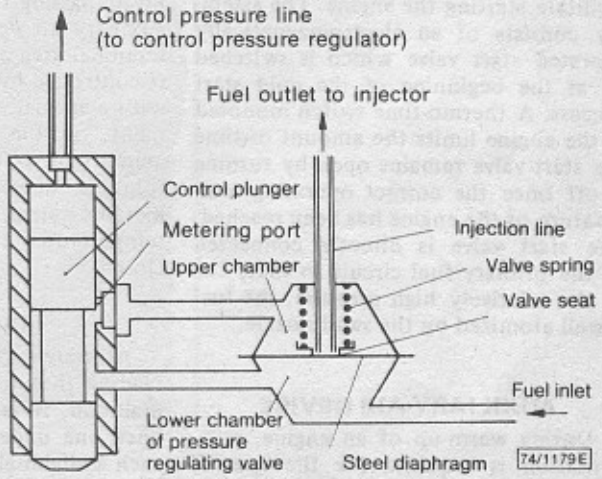
The fuel accumulator fulfills three functions: 1. Damping the pulsations from the fuel pump; 2. Delaying the build-up of pressure in the primary fuel circuit when the engine is started—this ensures that the control plunger is in the zero position; and, 3. Retention of pressure in the system after the engine has been turned off.

The primary circuit pressure regulator holds the pressure in the primary circuit at a constant 4.7 bar overpressure. It is a plunger type regulator fitted in the fuel distributor and allows excess fuel to flow back to the fuel tank under no pressure. This regulator also serves another important function. When the engine is turned off, the primary circuit regulator lets the pressure in the system fall rapidly to the opening pressure of the injection nozzles. It then holds the pressure at this level by means of a rubber valve seat. As a result of the rapid drop in pressure, "running on" or "dieseling" of the engine is prevented as the injection nozzles will not operate at the lower pressure.

The fuel accumulator also holds the fuel pressure constant for a considerable length of time after the engine has been turned off, preventing the formation of vapor locks which would make it difficult to restart the engine when still hot.

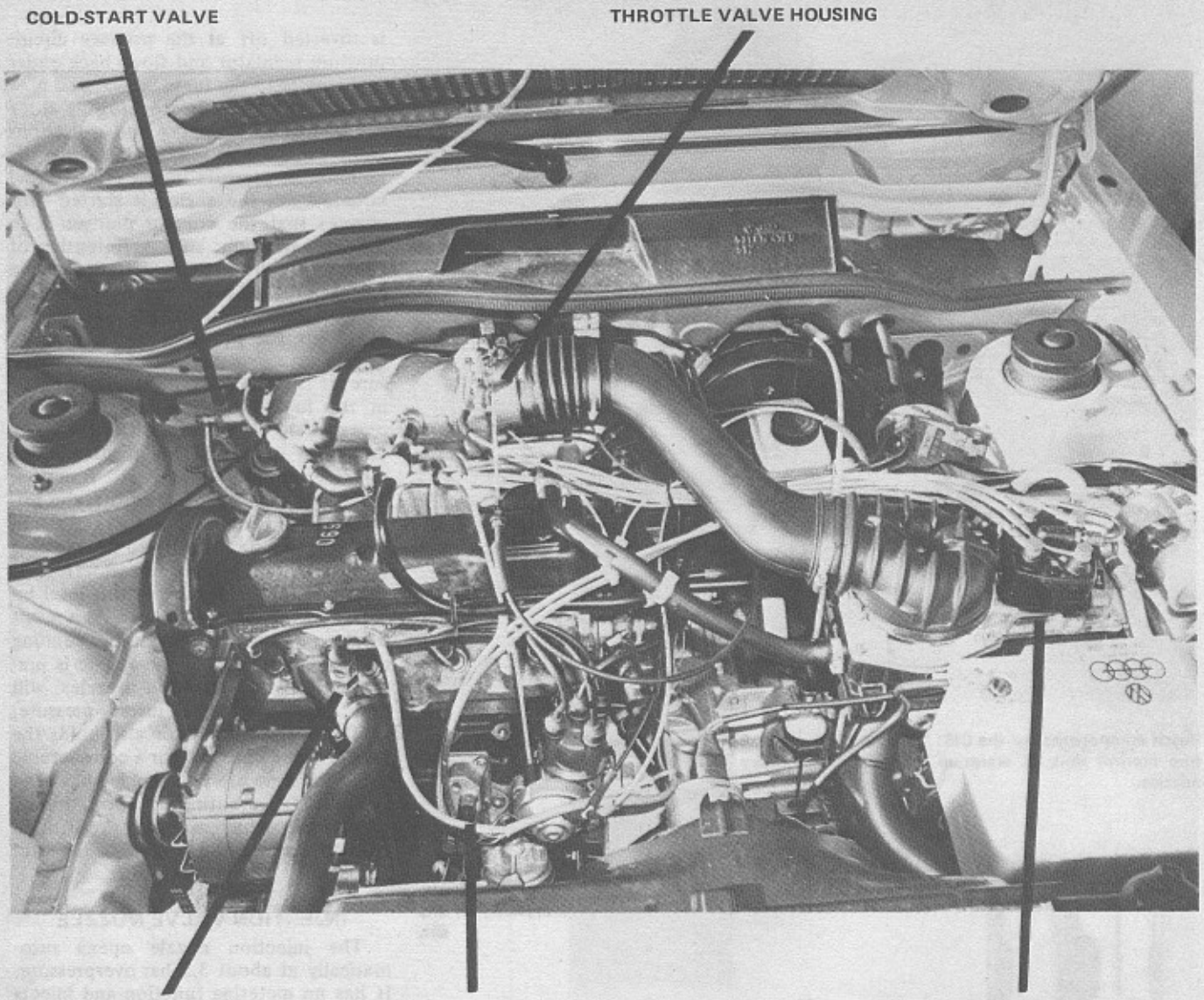
INJECTION VALVE NOZZLE

The injection nozzle opens automatically at about 3.3 bar overpressure. It has no metering function and injects the fuel into the cylinder constantly at different rates of flow determined by the fuel distributor. The nozzle is pressed into the cylinder head and is supported on a specially shaped rubber shoulder. The fuel is finely atomized even at a low rate of fuel flow.



RIGHT, schematic layout of the fuel distributor's metering unit.

Bosch CIS components as used on a Scirocco engine.



START VALVE

During cold starts an additional amount of fuel is sprayed directly into the common intake manifold to help facilitate starting the engine. The assembly consists of an electromagnetically operated start valve which is switched on at the beginning of the cold start process. A thermo-time switch mounted in the engine limits the amount of time the start valve remains open by turning it off once the correct operating temperature of the engine has been reached. The start valve is directly connected to the primary fuel circuit so that, due to the relatively high pressure, the fuel is well atomized by the swirl nozzle.

AUXILIARY-AIR DEVICE

During warm-up of an engine, compensation is required for the loss of power due to the greater friction in the engine. This is done by feeding a larger volume of the air-fuel mixture to the engine than corresponds to the position of the throttle plate. This is done by by-passing the throttle plate with an auxiliary air device in which the cross-sectional area of an auxiliary air channel is controlled by a pivoted blocking plate with a specially shaped hole. The movement of the plate, and hence the amount of extra air entering the manifold, is dependent on a heated bimetallic strip. At normal operating temperatures this extra air channel is closed.

MAINTENANCE

Although it might appear at first reading that the CIS is complicated to maintain, it is actually straightforward once one understands the functions of each individual part of the system and the requirements to keep those parts functioning correctly. The Bosch CIS has been designed so that only three instruments are required for testing the components, an ohmmeter and a test lamp are needed for testing the electrical parts and a fuel pressure gauge is required to test the pressures in the various parts of the system. It is also possible in this CIS to easily adjust the engine idle speed and the idle mixture.

We could fill several more pages of the magazine with information on how to troubleshoot the CIS, but the Robert Bentley service manual has more than 20 pages on just that and we can highly recommend it to anybody who wants to maintain the fuel injection system on their car. ●

Bibliography

Bosch Technical Instruction manual on Fuel Injection: Continuous Injection System (CIS)
Robert Bentley Service Manual: Rabbit/Scirocco.