BOSCH
GERMANY

Technical Instruction

Electronically Controlled Gasoline Injection System

Where the name BOSCH is used herein it denotes the firm of Robert Bosch or its successor, now called Robert Bosch GmbH, Stuttgart, Germany or the products manufactured by them.

Contents

Fold-out circuit diagram at the end of this booklet.

The pictures in this publication were obtained from a Bosch audio-visual presentation.

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Electronically Controlled Gasoline Injection

I. The Problem

High traffic density – particularly at congested points in metropolitan areas – requires an extremely delicate adjustment of the amount of fuel according to the varying operating conditions of the engine from the economic point of view (fuel consumption) as well as from that of health (exhaust gases) and smooth traffic flow (engine performance). This problem was solved by Bosch by an electronically controlled manifold gasoline injection system. It offers the following advantages:

Higher specific engine output
Higher torque at lower speeds and consequently improved flexibility and transition characteristics
Lower specific fuel consumption
Cleaner exhaust gases
Small space requirements
A mechanical drive is unnecessary.

II. Construction of the System

The fold-out diagram at the end of the booklet as well as Fig. 1 show a view of the most important components of the system.

1. Fuel Section

The fuel system consists of the following units: electrically driven fuel pump, fuel filter, header tank (not always included), pressure regulator, injection valves (1 for each cylinder), cold-start valve and a relay for energizing the pump.

2. Control Section

The "brain" of the system is the electronic control unit, the interior of which is shown on the title page. This small computer, built up on a printed circuit board contains about 250 components with about 30 transistors and nearly 40 diodes.

Additional instruments are: distributor with trigger contacts (not to be confused with the breaker points), intake manifold pressure sensor, temperature sensor, thermoswitch or thermo-time switch, auxiliary air valve, pressure switch, throttle valve switch and a relay for the power supply to the control unit.

These instruments have a specific function (sometimes several). Their interaction results in a correctly metered amount of fuel at the right moment for each working cycle in each engine cylinder.

Fig. 1. Most important components of the system (battery and ignition switch already in the vehicle).

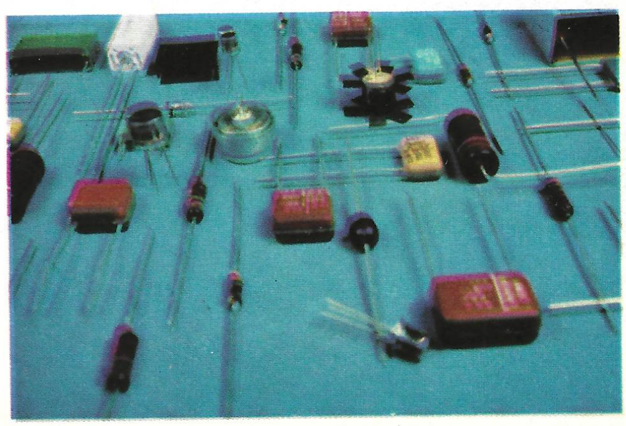

Fig. 2 Semiconductor components of control unit.

III. Mechanism of Operation

1. Fuel-Air Ratio

Every combustion process requires air – or more precisely: oxygen from the air. Theoretically air requirement is the amount of air just needed for complete combustion of a fuel expressed as the stoichiometric air/fuel ratio. With gasoline this is 14:1.

If the fuel component in the ratio is higher, the fuel is not utilized enough. Furthermore, the amount of unburnt harmful contaminants in the exhaust gas is higher. If the amount of fuel is smaller, compared to the amount of air, the power drops and the slower combustion causes the engine temperature to rise.

Exact fuel metering, i.e. maintaining the theoretical ratio under the various operating conditions is thus the function of the electronically controlled gasoline injection system.

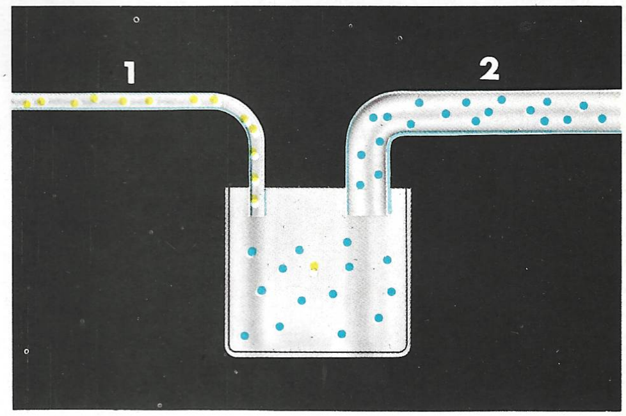

Fig. 3. Theoretical fuel-air ratio.

1 Fuel
2 Air

2. Operating Principle

The Bosch system represents a fuel injection system controlled by the intake manifold pressure and the engine speed, with an injection into the intake manifold directly in front of the intake valves of the engine. The amount of fuel to be supplied by the injectors is a function of the flow cross-section, the injection pressure and the duration of injection. The flow cross-section is design-determined and provisions are made for a constant injection pressure, as will be shown later. The principle consists in controlling the opening time of the injectors. This is done by supplying the control unit with data which the unit converts into pulses. These pulses are relayed to the injectors and determine the moment when gasoline is injected and the duration of injection.

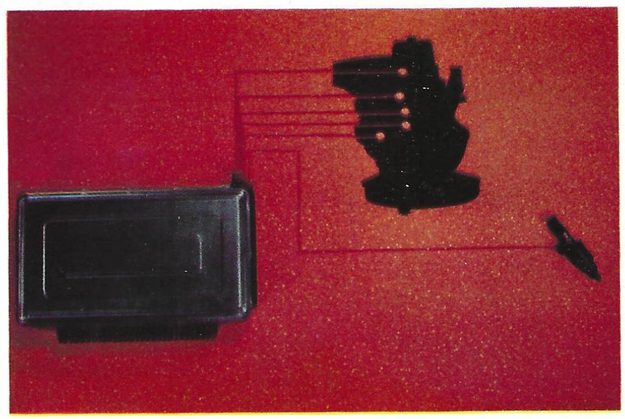

Fig. 4. The control unit receives numerous data which it converts into pulses for the injectors.

3. Fuel System

In the fuel system, fuel is drawn from the tank via a filter by an electrically driven fuel pump and forced into the distributor line and its branches to the injectors. At the end of the pressure line the pressure regulator is located; it maintains the pressure at 2 kgf/cm^2 (28 psig), and through it excess fuel returns to the tank. Therefore, we can speak of a fuel circuit.

As a result, all injectors are fed with a constant pressure of 2 kgf/cm^2 (28 psig).

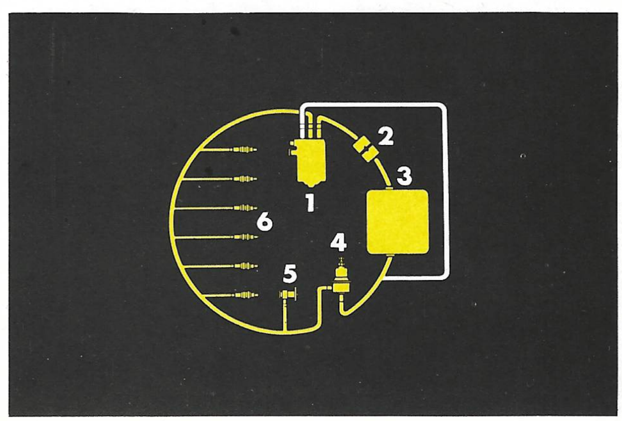

Fig. 5. Fuel system (cycle).

1 Pump
2 Filter
3 Tank
4 Pressure regulator
5 Cold-start valve
6 Injection valves

Electrically driven fuel pump

The fuel pump consists of a permanent magnet series-wound motor assembled with a rotary roller pump with connections for suction, pressure and return lines. The pump is installed near the tank and switched on by a relay which is energized by the control unit. It is the so-called "wet" pump design meaning that fuel is also present in the electrical part. There is no danger of explosion because the pump housing never contains an inflammable mixture.

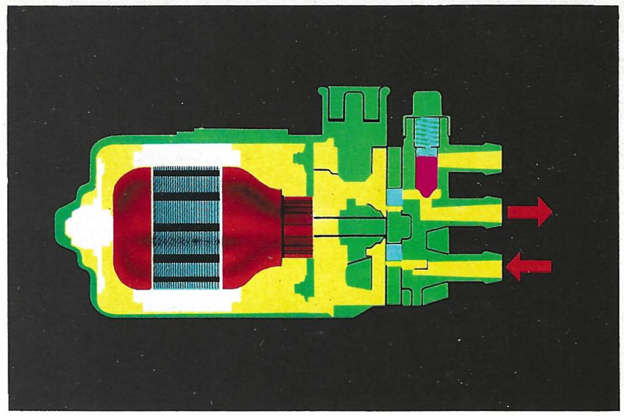

Fig. 6. Schematic diagram of the "wet" pump.

The rotary roller pump operates in such a way that the inserted rollers, resting closely in their guides, are forced against the wall of the rotary roller housing by centrifugal force. The pump delivers about 80 ltr/h (20 gal/h) which is considerably more than is consumed. The resulting fuel circuit prevents overheating of the fuel and thus the formation of vapor locks.

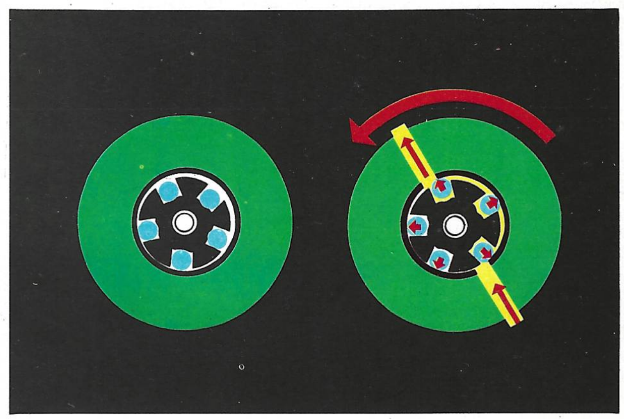

Fig. 7. Pumping effect of the rollers.

When the ignition is switched on, the pump only runs for about one second. Only when the engine has been started will the electronic control unit reactivate the pump by the relay. This safety circuit – called flooding protection – prevents flooding of the respective cylinder in the event of a damaged injector.

Another safeguard consists of a control piston (check valve) in the pump which closes the pressure line in the rest position so that the supply pressure is maintained in the fuel circuit.

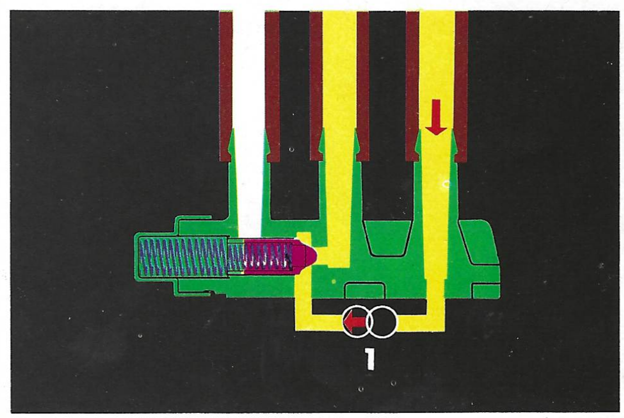

Fig. 8. Reserve pressure control.
1 Pump

Should the pressure regulator be inoperative because of a pinched line, excess pressure is prevented by opening of the relief valve, so that the fuel can flow back to the tank through the return connection on the pump.

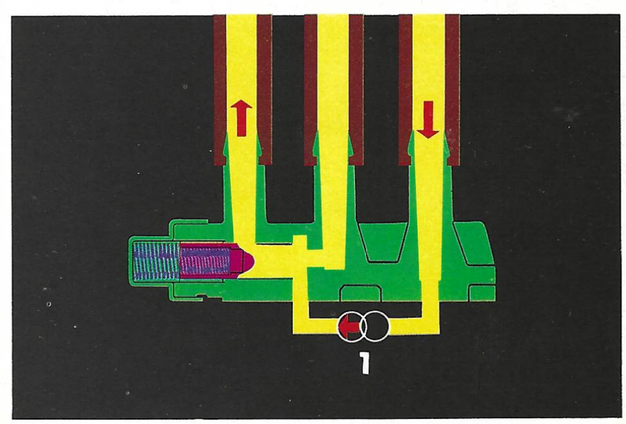

Fig. 9. Excess pressure prevention.
1 Pump

Header tank

When needed, a header tank is installed in the line between pump and pressure regulator. It is used to prevent loud pressure vibrations from being transmitted to the line and possibly from there to the body. The fuel is drawn through chamber (A) of the header tank and forced through chamber (B) into the ring line.

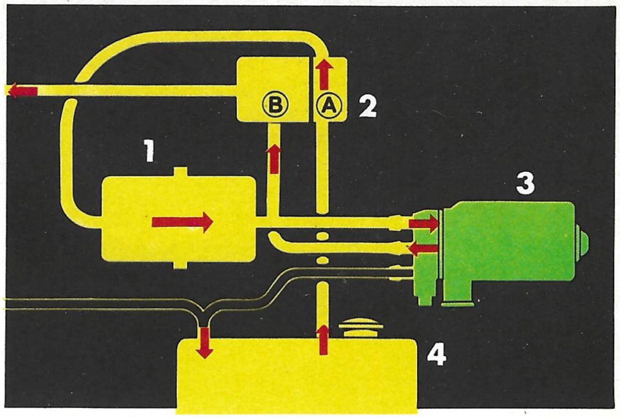

Fig. 10. Fuel flow in the header tank.

1 Filter
2 Header tank
3 Pump
4 Tank

Fuel filter

The filter serves to clean the fuel in order to prevent damage to the injectors and the pressure regulator. An arrow on the filter housing indicates the flow direction.

Pressure regulator

The adjustable pressure regulator is located at the pressure line behind the injectors and is provided with an inlet and return fitting. If the pressure rises beyond the set value of 2 kgf/cm^2 (28 psig), the fuel presses on the spring-loaded diaphragm. The diaphragm is connected to a valve plate which is lifted from its seat. This opens the return and the gasoline can flow back into the tank. The constant pressure of 2 kgf/cm^2 is maintained by an appropriate spring tension.

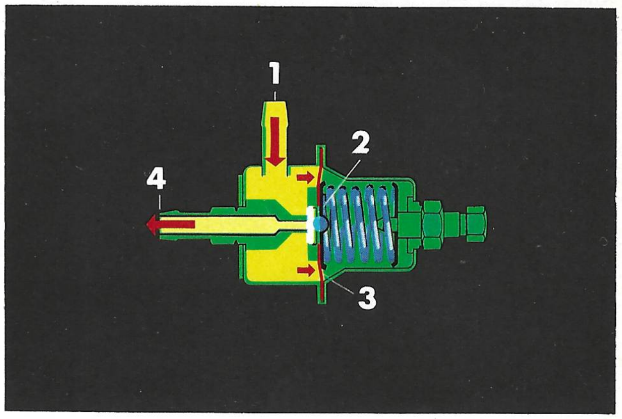

Fig. 11. Cross-section of pressure regulator.

1 Pressure connection
2 Valve head
3 Diaphragm
4 Return

Cold-start valve

The cold-start valve (12 V) is installed on the intake manifold and injects additional fuel during cold starting so that the engine starts more easily. This valve is also opened by an electrical signal and the fuel is injected in an atomized state by a turbulence nozzle.

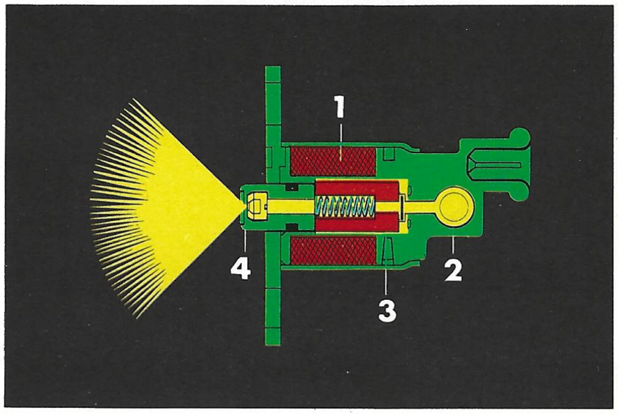

Fig. 12. Cross-section of the cold-start valve.

1 Solenoid coil
2 Fuel inlet
3 Plunger
4 Turbulence nozzle

Injection valve

To each engine cylinder an injector has been assigned in the intake manifold which is actuated electromagnetically once in every working cycle and which sprays fuel directly onto the cylinder intake valve.

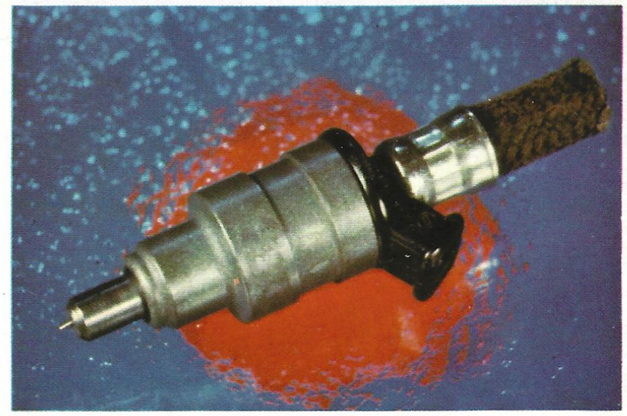

Fig. 13. Injector

Each injector is equipped with a field coil designed for a voltage of 3 V. The housing cover is equipped with a connecting hose for the fuel supply. At the other end is a nozzle body in which a nozzle valve moves; this valve is connected to the plunger. The end of the nozzle valve is equipped with a valve seat and a valve pintle which atomizes the gasoline.

Electrical pulses transmitted by the control unit build up a magnetic field in the winding. This attracts the plunger and lifts the nozzle valve from the body seat. This clears the way for the pressurized fuel. The stroke of the plunger amounts to about 0.15 mm and its response time is about 1/1000 sec. Depending on the amount of required fuel, the opening period of the injector amounts to 2/1000 – 10/1000 sec.

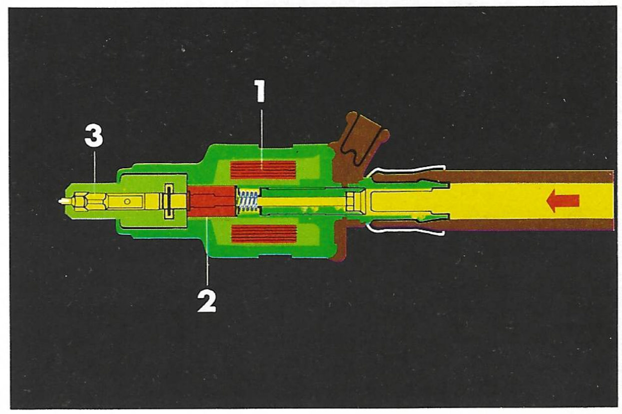

Fig. 14. Cross-section of an injector.

1 Solenoid coil
2 Plunger
3 Nozzle valve

To retain other contaminants (installation, repairs) a filter is installed in the fuel line to the valve.

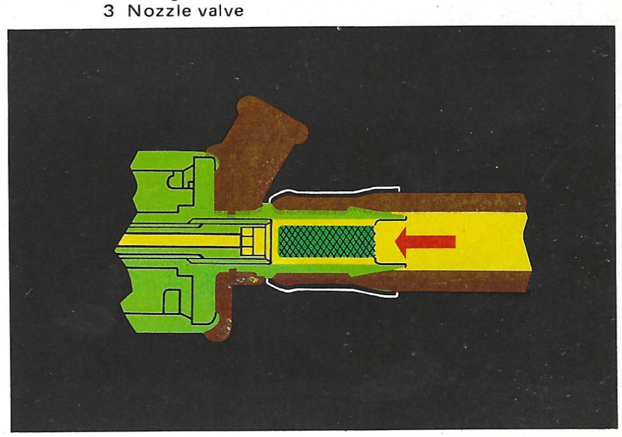

Fig. 15. Filter in the injector.

The injectors are mounted in rubber for noise control and sealing and thus are also insulated against high temperatures.

To keep the number of electronic components at a minimum, the electronic control unit controls the injectors in two groups of 2 valves each (for four-cylinder engines) or 3 valves (for six-cylinder engines). The valves of one group belong to 2 or 3 cylinders in the firing sequence. They are connected in parallel and thus inject simultaneously. Only two cylinders receive the fuel on the intake stroke; in the other cylinders, the fuel is stored and aspirated into the cylinder during the next intake stroke.

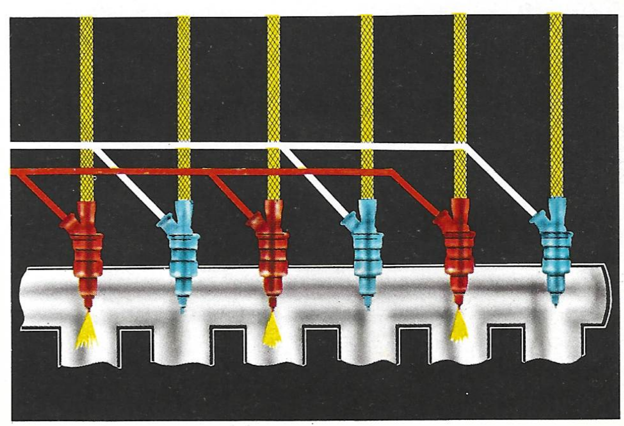

Fig. 16. Injector groups. Three valves each spray simultaneously (six-cylinder engine).

4. Injection Timing

Fig. 17. Distributor (arrow indicates position of trigger contacts).

Ignition distributor

The distributor is equipped with the usual breaker points as well as with the standard centrifugal and vacuum advance. In addition, two nonadjustable trigger contacts, which are spaced 180° apart, have been provided in the lower part of the housing. A single-lobe cam on the distributor shaft alternately closes the trigger contacts whereby the control unit receives signals for start of injection and data on the engine speed.

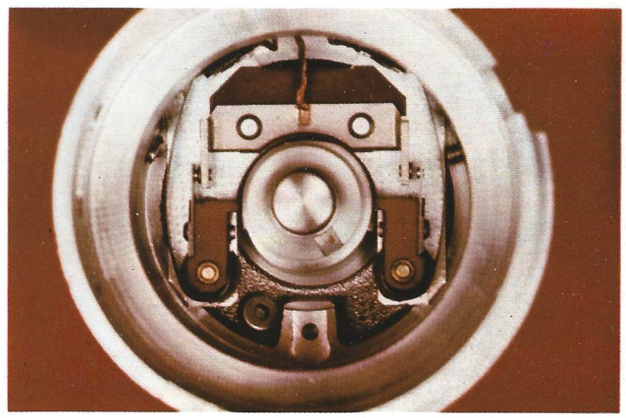

Fig. 18. Arrangement of trigger contacts.

Timing diagram

This diagram shows the time sequence of the inlet valve opening, start of injection and ignition for a six-cylinder engine.
Bottom: Data (in degrees) on the crank shaft position (°KW).
Left: The firing sequence of the cylinder (Zyl.) in Groups I and II.
The blue area indicates the open phase of the intake valve or the intake stroke.
The start of injection for each set of three cylinders is shown in yellow.
The red flash is the ignition firing.

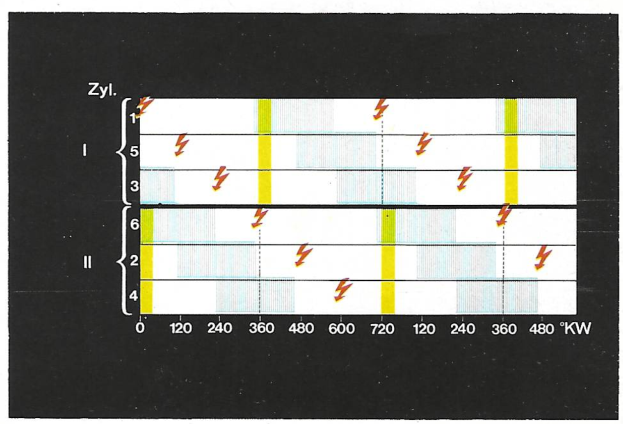

Fig. 19. Timing diagram.

5. Control of Injected Fuel Quantity

The correct fuel quantity is determined by control of the length of opening time of the injectors. The main control data for the electronic control unit are the intake manifold pressure and the engine speed but other data such as the engine and ambient temperatures also determine the operating conditions. All of these factors for metering the correct amount of fuel are fed into the control unit which converts these data into electrical pulses of shorter or longer duration. The pulse duration then determines the length of the opening time of the injectors and thus the amount of fuel injected.

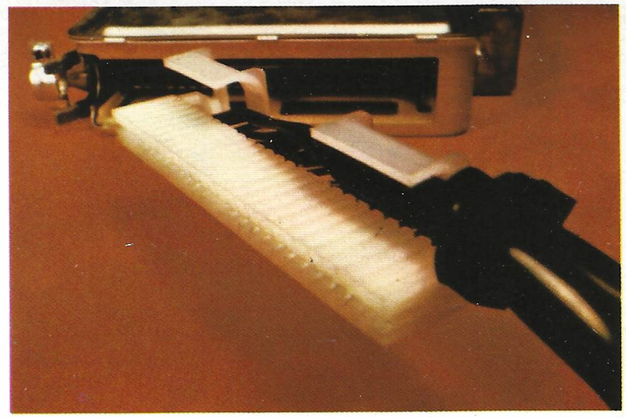

Fig. 21. 25-pole plug at control unit.

Electronic control unit

The heart of the system is the control unit. A 25-pole plug connects it to the data sensors which are mounted or connected to various points of the engine.

It is true that the unit is connected to the battery, but it is designed so that voltage variations during driving cannot impair its function.

When the ignition is switched on, the injection system also becomes ready for operation via a relay. The current consumption at full load is about 5 A (at 12 V).

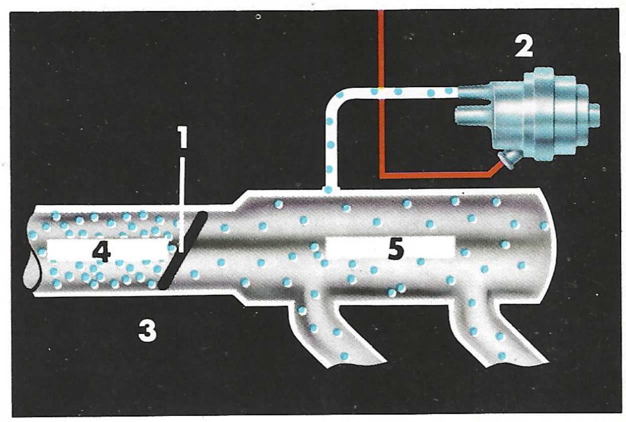

Fig. 22. Pressure ratio in the intake manifold and connection of pressure sensor.

1 Throttle valve
2 Pressure sensor
3 Intake manifold
4 Atm. pressure
5 Underpressure

Pressure sensors

In the intake manifold, ambient atmospheric pressure prevails in front of the throttle valve, while behind the throttle there is an underpressure which changes continuously depending on the throttle position. This underpressure is now used as a parameter to determine the most important information – the engine load.

The pressure sensor transmits data on the intake manifold pressure. Therefore, we also speak of an "intake manifold pressure sensor". It is connected by a hose to the intake manifold.

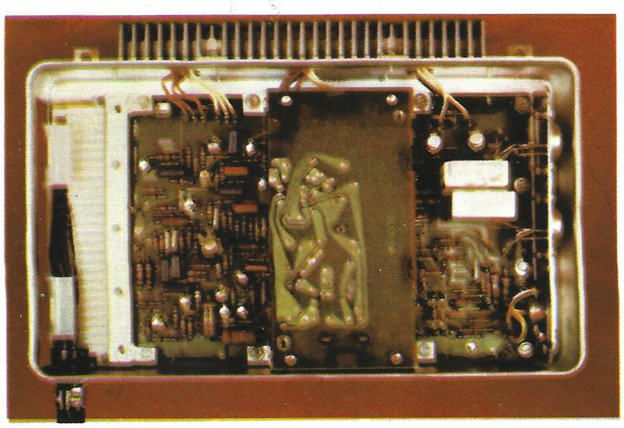

Fig. 20. Electronic control unit.

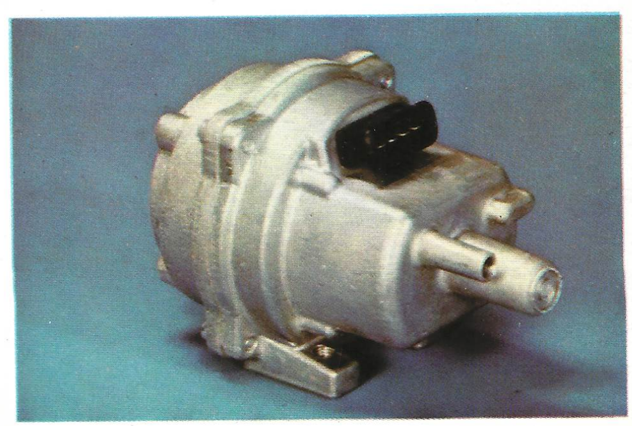

Fig. 23. Pressure sensor.

The pressure sensor contains an inductive data transmitter (transformer) connected to an electronic time switch in the control unit. The pressure sensor also contains two evacuated aneroids which move the plunger in the magnetic circuit of the transformer and thus change its inductance.

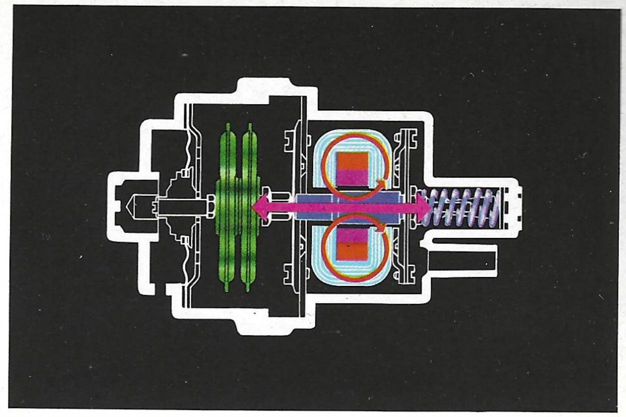

Fig. 24. Cross-section of the pressure sensor.

With a closed throttle, the absolute intake manifold pressure is low, the aneroids are expanded and move the plunger out of the magnetic circuit. The inductance is low, so that the pulse is short and consequently the injectors release only a small amount of fuel.

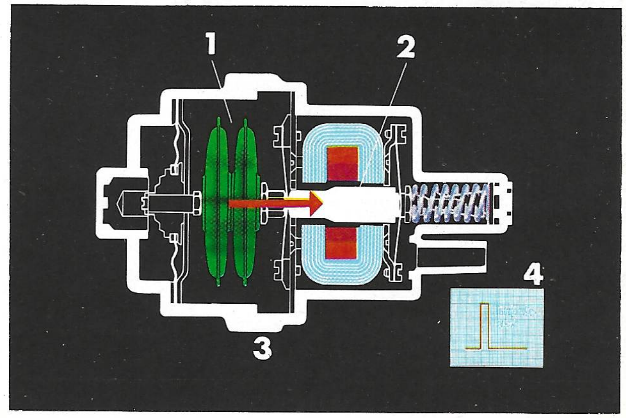

Fig. 25. Intake manifold pressure, inductance and pulse duration with closed throttle.

1 low pressure
2 low inductance
3 short valve opening period
small amount of fuel
4 pulse duration

Inversely, with an open throttle, the absolute intake manifold pressure is high, the aneroids are compressed, the plunger is deep in the magnetic circuit, the inductance is high, the opening pulse is long, and a large amount of injected fuel results.

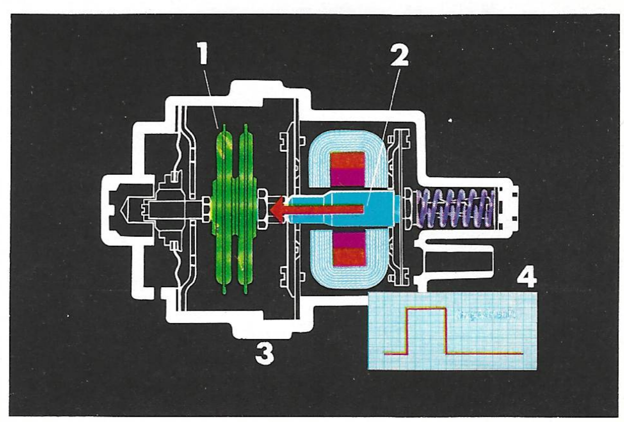

Fig. 26. Intake manifold pressure, inductance and pulse duration with open throttle.

1 high pressure
2 high inductance
3 long valve opening period
large amount of fuel
4 pulse duration

Since the pressure sensor measures the absolute pressure in the intake manifold, all influences on the pressure caused e.g. by altitude, weather conditions or the condition of the air filter, are taken into consideration.

Basically we should keep in mind that the start of injection is activated by the trigger contacts in the distributor, while the end of injection — and thus the amount of injected fuel — is determined by the pressure sensor via the electronic time switch in the control unit.

Correction factors

In addition to the main control as a function of the intake manifold pressure and the engine speed, the following correction factors have to be considered to obtain correct engine performance: cold-start enrichment, warm-up enrichment, full-load enrichment, acceleration (temporary) enrichment, fuel cut-off during engine braking. This requires additional components in the system.

Temperature sensors

The temperature sensors consist of a metal body shaped like a hexagonal screw in which a so-called NTC resistor has been installed. NTC stands for "negative temperature coefficient" and means that these resistors considerably reduce their ohmic resistance with increasing temperature.

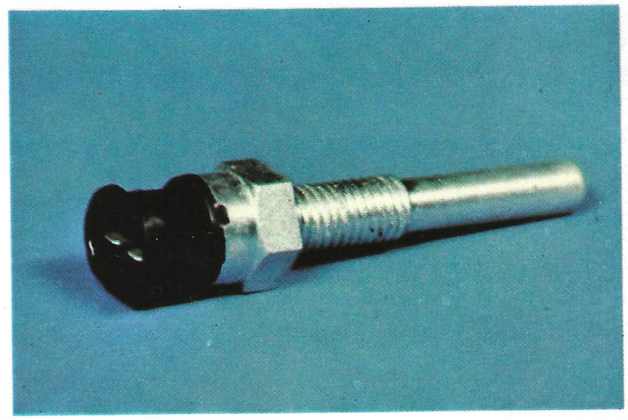

Fig. 27. Temperature sensor.

The temperature sensors supply the control unit with temperature data which are important for different purposes. To this end, they measure the temperature of the coolant in water-cooled engines and of the cylinder head in air-cooled engines.

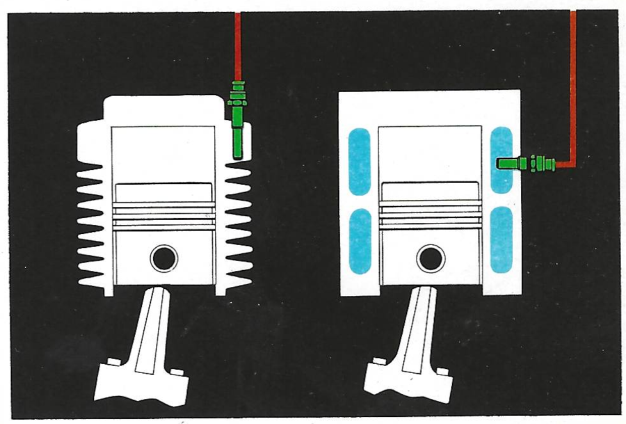

Fig. 28. Installation of temperature sensors in the engine.

In some systems the intake air temperature is also used as input data so that the air density in the cylinder can be taken into consideration (cold air = much air = much fuel, warm air = little air = little fuel). In this case, an additional temperature sensor is installed in the intake manifold.

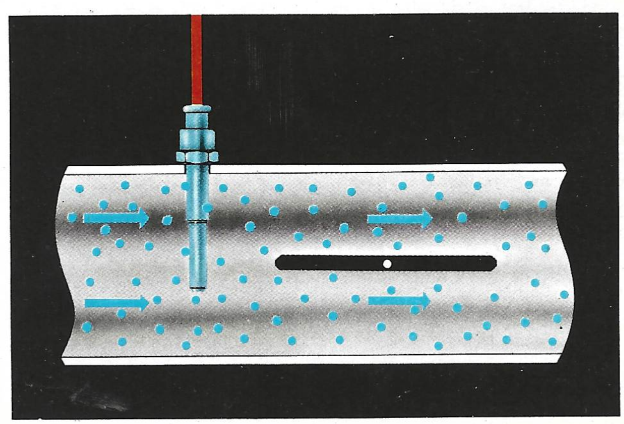

Fig. 29. Installation of temperature sensor in the intake manifold.

Cold-start enrichment (thermoswitch, thermo-time switch)

In a cold engine some fuel condenses on the cold cylinder walls so that too little fuel is available compared to the aspirated amount of air. Therefore additional fuel must be supplied to the cylinder in this operating state and we say that the mixture must be enriched. This is done by the cold-start valve (see p. 6).

The pulse for this valve is not supplied by the control unit but is generated when the starting switch is activated by the closed thermoswitch or thermo-time switch. Above a certain temperature level the cold-start valve does not operate at all; however, below this level it stays open during the entire starting process. (In some systems, the injectors receive a longer pulse during this time, the so-called start lift.)

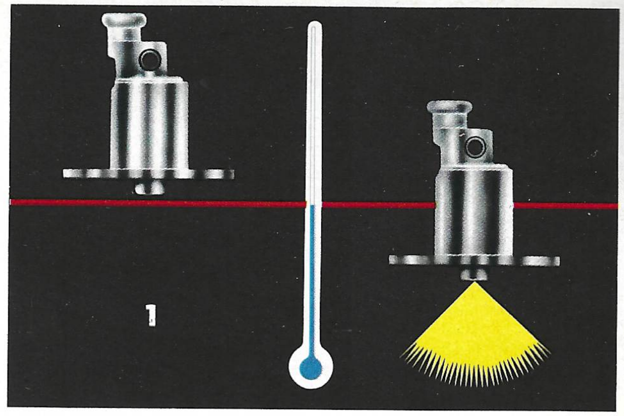

Fig. 30. Temperature dependence of the cold-start valve.
1 Temperature

Consequently, the thermoswitch closes or opens the circuit of the cold-start valve depending on the temperature.

In place of the thermoswitch, a thermo-time switch may also be installed; it also closes the circuit of the cold-start valve as a function of temperature but opens it again after a certain time.

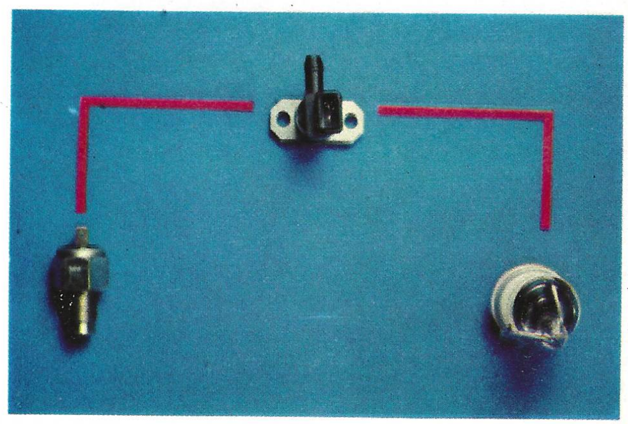

Fig. 31. Electrical circuit for starting switch, thermo(time) switch and cold-start valve.

Warm-up enrichment (auxiliary air valve and pressure sensor: increased amount; temperature sensor: enrichment)

After the cold start, the engine would immediately stall with the small amount of fuel normally supplied by the idling system. The frictional resistances caused by thickened oil are too great.

To guarantee acceptable idling, even with a closed throttle, the engine receives more air and more fuel during the warm-up period. With a cold engine the increased amount of air is supplied by the wide-open auxiliary air valve. The pressure sensor immediately responds to this pressure change in the intake manifold and when there is more air, it also supplies more fuel. The data from the temperature sensor causes more fuel to be injected; as a result, the mixture is enriched during this phase.

As the engine temperature rises, however, this additional air is no longer needed and the auxiliary air valve closes. The pressure and temperature sensors transmit the respective data to the control unit and less fuel is injected.

The operating mechanism of the auxiliary air valve is that a thermostat in its interior displaces a piston with a metering edge as a function of temperature. When the temperature rises, the air flow cross-section is continuously reduced and at about 70° C (158° F) closed entirely.

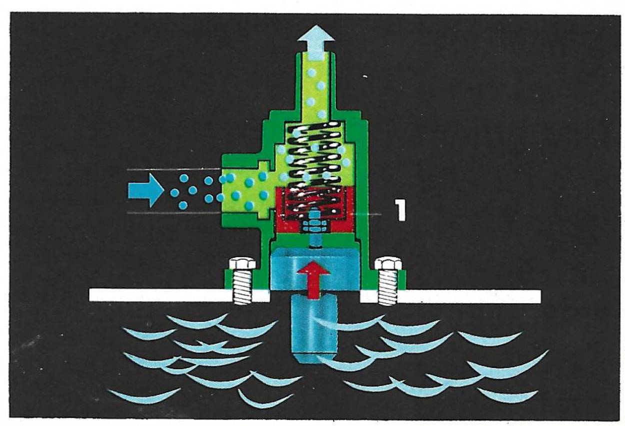

Fig. 32. Cross-section of auxiliary air valve.
1 Piston

Full-load enrichment (pressure switch)

To obtain maximum performance, the mixture must also be enriched at full load. This information is supplied by the pressure switch, respectively the diaphragm component of the pressure sensor. The control unit computes the information into longer pulses for the injection duration.

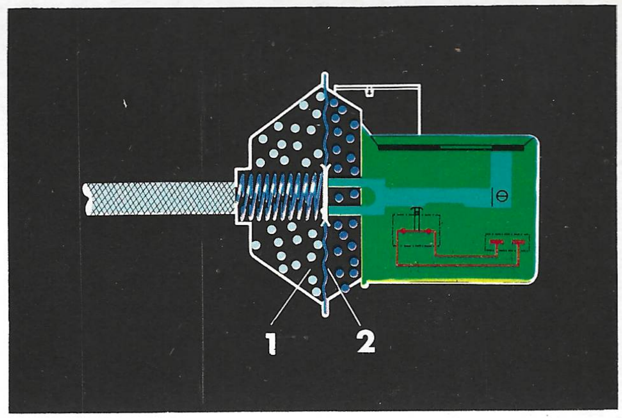

Fig. 33. Cross-section of pressure switch
1 Intake manifold pressure 2 Atm.pressure

In some systems a separate pressure switch serves as the data transmitter for full-load enrichment. It is connected to the intake manifold by a hose. A built-in diaphragm prestressed by a coil spring and exposed on one side to the atmospheric pressure and on the other to the intake manifold pressure, actuates a snap switch which transmits the comparison values between the atmospheric pressure and the pressure in the intake manifold to the control unit in the form of an electrical signal.

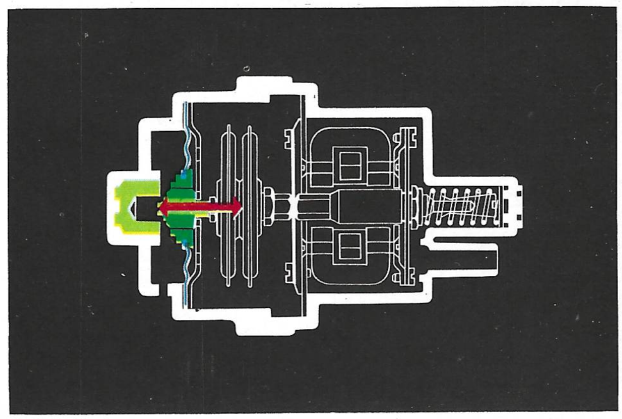

Fig. 34. Pressure switch combined with pressure sensor.

In other systems, the diaphragm system of the pressure switch has been coupled with the moveable plunger of the pressure sensor described earlier.

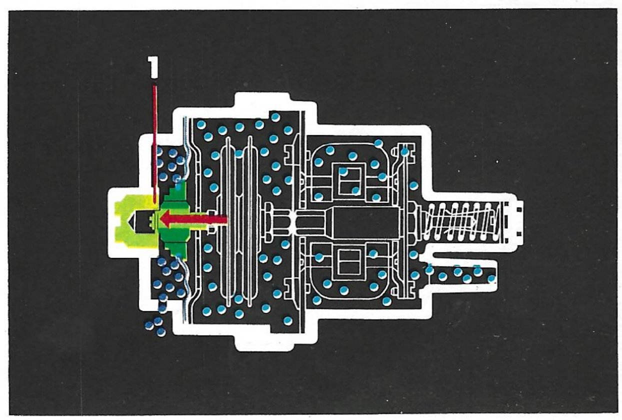

Fig. 35. Full-load stop in pressure switch (part).
1 Full-load stop

With a fully open throttle, i.e. nearly equal pressure on both sides of the diaphragm, the diaphragm disk rests on the full-load stop and causes the plunger of the pressure sensor to be pushed farther into the magnetic circuit (longer pulse at the injector = much fuel).

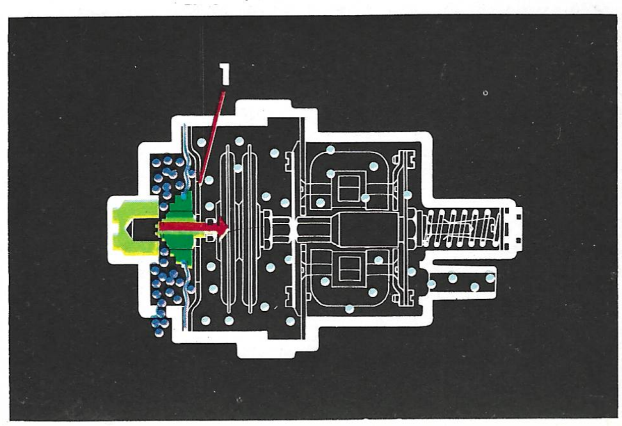

Fig..36. Partial-load stop in pressure switch (part).
1 Partial-load stop

With a pressure difference of more than 4 in Hg, i.e. in partial load operation, the diaphragm rests on the opposite "partial load stop" and the pressure sensor then operates only through the aneroids (no enrichment).

Fuel cut-off during engine braking (throttle valve switch)

When the engine is driven by the rolling vehicle on a downgrade or during deceleration, the throttle is closed. If the engine speed is above about 1800 rev/min no fuel is injected at all (fuel cut-off). The necessary data are fed to the control unit by the trigger contacts in the distributor (engine speed) and the throttle valve switch (throttle valve closed). This switch is actuated directly by the throttle shaft. A pair of contacts triggers the fuel cut-off process.

So that the engine continues to run during idling i.e. with a closed throttle, the fuel supply starts again at about 1200 rev/min (fuel cut-in). When the driver accelerates, the fuel feed is reestablished immediately.

With the aid of a graduated scale the throttle switch can be adjusted so that the contact opens even with a 1° throttle opening. How delicate this adjustment is, is demonstrated by the fact that one scale division represents only 2 degrees.

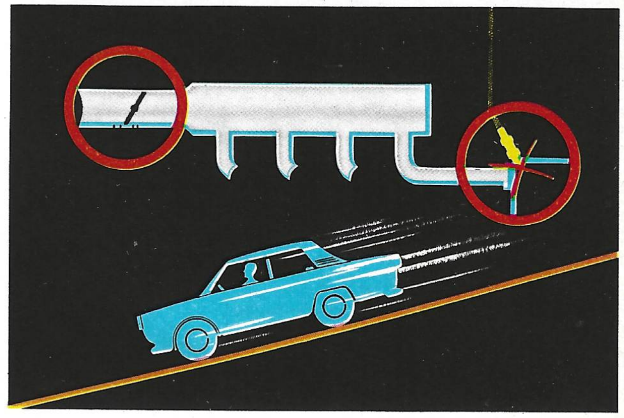

Fig. 37. Fuel cut-off during engine braking.

Acceleration (temporary) enrichment

The injection engine with an intake manifold control also requires a fuel mixture enrichment during acceleration as it is supplied, e.g. in a carburetor engine by the accelerator pump. During acceleration, i.e. a throttle movement in the "open" direction, the auxiliary device in the throttle valve switch provides for additional injection pulses by the control unit.

This device consists basically of two comb-like contact tracks and a drag switch. During acceleration the contact slides over the tracks; the drag switch is closed so that additional injection pulses are transmitted to the injectors. If the accelerator is released (throttle movement in "closed" direction), the switch opens and the injectors receive no additional pulses.

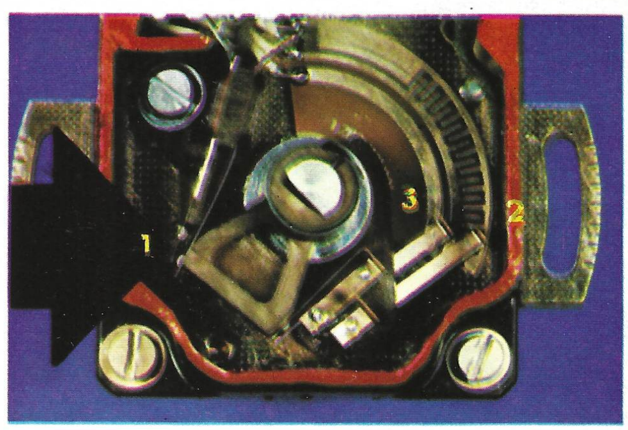

Fig. 38. Throttle valve switch open; arrow indicates the contacts for fuel cut-off; switch and contact tracks on the right.

1 Fuel cut-off contacts
2 Graduated scale
3 Drag switch

IV. Instructions for Operation and Checking

The system requires no special maintenance although for operation the following points must be observed:

1. Control Unit

In spite of its relative ruggedness, the control unit could be damaged by careless handling. Therefore, the following rules apply:
Never operate the car without battery.
Do not operate the system while it is connected to a battery charger.
Do not connect or disconnect the 25-pole plug while the ignition is switched on.

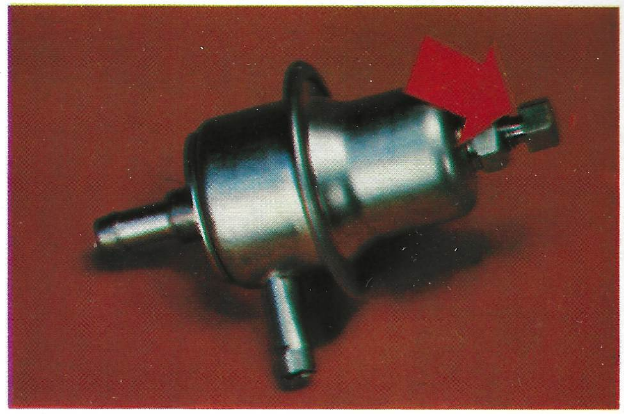

Fig. 39. Set screw on the pressure regulator.

2. Pressure regulator

Should it ever be necessary to readjust the specified pressure of 2 kgf/cm^2 (28 psig), it can be readjusted by the set screw.

3. Line Connections

Although the 25-pole plug guarantees correct connection to the control unit, ensure that the order line ends are correctly connected to the right units.

The harness with which all transmitters are connected to the control unit forms a separate circuit within the total electrical system of the vehicle.

Four connections — terminal 30 (power line), terminal 50 (starter solenoid), terminal 15 (ignition) and the ground connection or terminal 31 — form the connections with the vehicle electrical system.

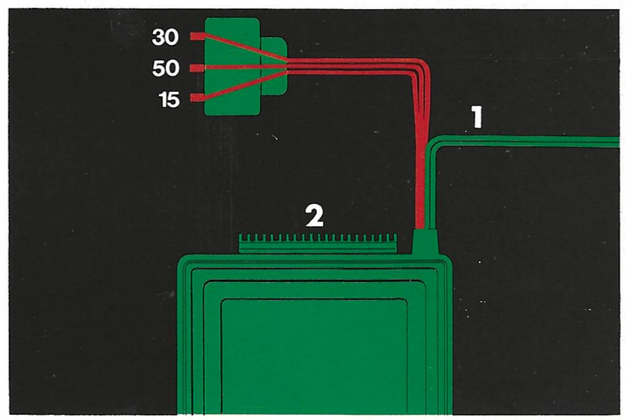

Fig. 40. Electrical connection of the unit with the vehicle system.

1 to the sensors
2 Electronic control unit

4. Checking

A Bosch tester developed together with the system allows all information transmitters and their connections to be checked.

The fuel system can also be checked for correct supply pressure as well as absence of leaks.

A check list adapted to the checking sequence of the tester permits checking and troubleshooting.

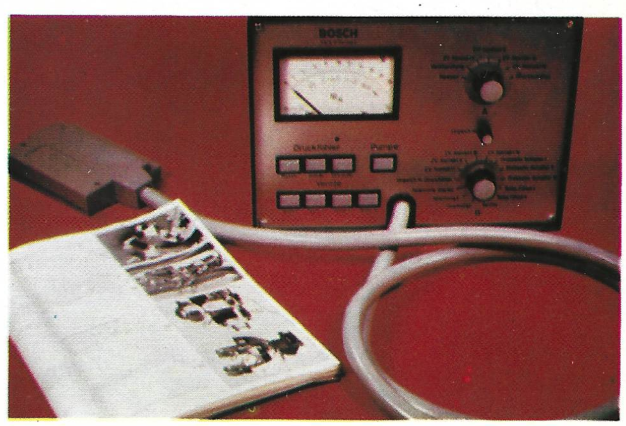

Fig. 41. Tester for checking the system. Testing is done according to a check list.

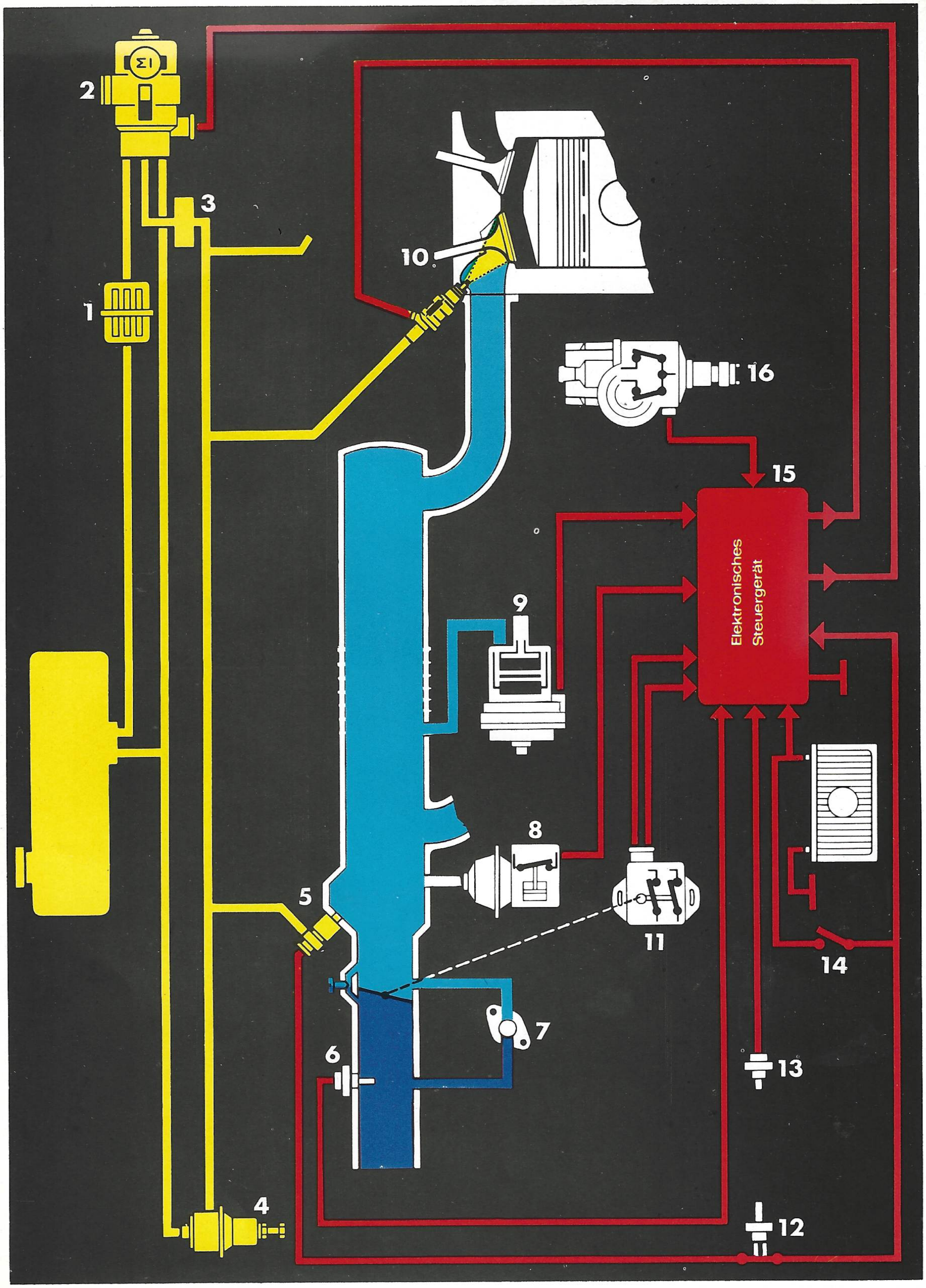

Fig. 42. Schematic diagram of system.

1 Filter
2 Pump
3 Header tank
4 Pressure regulator
5 Cold-start valve
6 Intake manifold temperature sensor
7 Auxiliary air valve
8 Pressure switch
9 Pressure sensor
10 Injection valve
11 Throttle valve
12 Thermoswitch
13 Temperature sensor
14 Ignition starting switch
15 Electronic control unit
16 Ignition distributor with trigger contacts

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