Harold T. Glenn's Volkswagen Type 3 / Type 4 Fuel Injection Guide

Compiled and condensed by Aaron Clow from

Glenn's diesel and gasoline fuel-injection manual

Henry Regnery Company – Chicago

Visit "Just Another Type 3 Site" at
http://www.tiserves.com/VW/
vw_variant71@yahoo.com

Mercedes-Benz, Porsche, Renault, Saab, Volkswagen, and Volvo are using a Bosch electronic fuel-injection system in which an electronic-control unit changes electric impulses, from various sensors in the engine, into control signals for regulating solenoid-actuated fuel injectors, which discharge varying amounts of fuel into the manifold, just in front of the intake valve. The control signals influence the opening times of the injectors and, thereby, the amount of fuel injected.

The air-fuel mixture is modified according to the conditions under which the engine is running: ambient air and coolant temperatures and engine load and speed. This information is "computerized" in the control unit and returned to the injectors in the form of control impulses.

PARTS OF THE SYSTEM

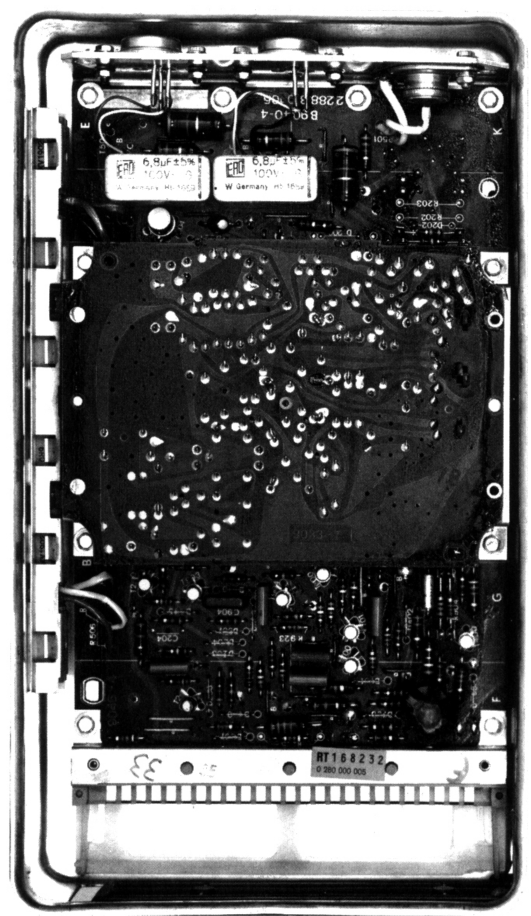
The system is made up of the following units: a fuel filter, electric fuel pump, pressure regulator, fuel injectors, cold-start valve, inlet duct, throttle-valve switch, auxiliary air regulator, temperature sensors (induction air and coolant or oil), pressure sensor (for pressure in the inlet duct), triggering contacts in the ignition distributor, and an electronic control unit.

THEORY OF OPERATION

Fuel is drawn by the electric fuel pump from the tank via and through the filter. From here it passes into the fuel pressure line. The pressure regulator, connected to the end of the pressure line, limits the fuel pressure to 28 psi. From the pressure regulator, excess fuel is sent back to the tank through the return line. The electro-magnetic fuel injectors are connected to the pressure line by means of fuel distributor pipes.

The duration of injection (fuel quantity) is governed basically by two factors: by speed and load conditions of the engine. Engine speed is relayed to the control unit by two contacts in the distributor. The load condition is determined by measuring the absolute pressure in the inlet manifold, which is converted into an electrical impulse. This is relayed to the control unit by the pressure sensor, which is connected to the common inlet duct by a hose.

The control unit processes this information and signals the injectors to open for a longer or shorter period of time. The control unit thus allows a varying amount of fuel to be passed through the electrically operated injectors, depending on the engine load and speed. In addition to the "basic quantity" of fuel, an accurately metered amount of fuel is injected when starting at low ambient air temperatures, during engine warm-up, during acceleration, and at full load. The cold-start valve injects additional fuel into the common inlet duct for as long as the starter is operated.



This is the control box with the cover taken off to show the components needed to regulate the Bosch electronic fuel-injection system. There are over 250 transistors as well as many other electronic components in this "brain" of the fuel-injection system.

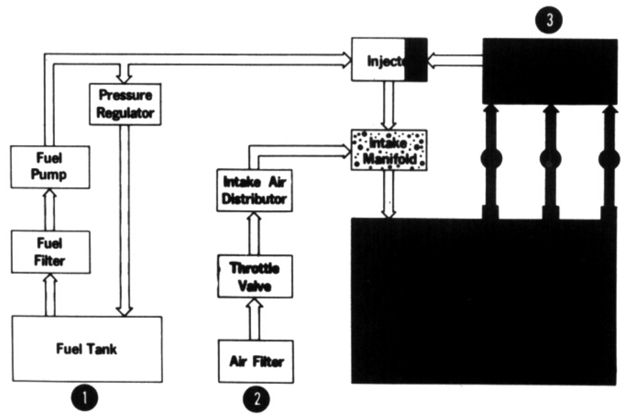
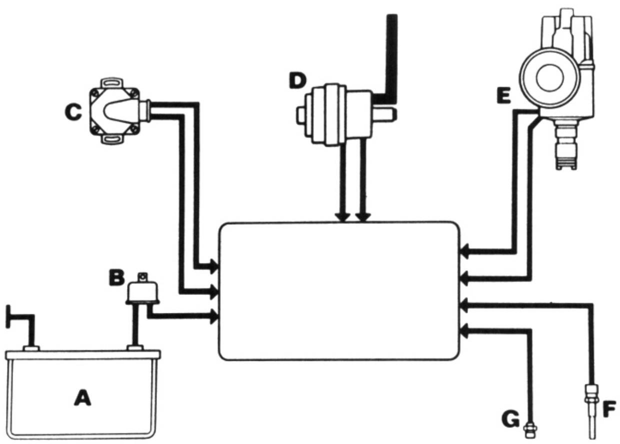


Diagram to show the inter-relationships that exist between the various control units of the electronic fuel-injection system used on Volkswagen engines. The fuel system (1) supplies a pressurized flow of fuel, with the excess diverted back to the gas tank. The air intake system (2) is controlled according to engine needs. The control system (3) monitors engine load, speed, and temperature to insure injection of the exact amount of fuel required by the engine.

During warm-up, the control unit receives information from the temperature sensor in the coolant and/or lubricating oil circuit, consequently permitting the injectors to remain open a little longer. But, if the engine is to operate properly with the increased flow of fuel, more air is required. This is obtained through an auxiliary air regulator, which closes gradually as engine temperature rises.

The electronic control unit receives impulses from the throttle valve switch for additional fuel during acceleration. When the accelerator pedal is depressed, impulses are released from the throttle switch to the control unit, which then gives "orders" to the injectors to inject a number of times between the regular injections. If the accelerator pedal is depressed quickly, the duration of injection will be longer than the regular injection time.

The throttle-valve switch has another function. When the accelerator pedal is eased up on deceleration on most models, a contact set in the throttle-valve switch is actuated. It emits an impulse to the control unit, which shuts off all fuel injections as long as engine speed exceeds 1,700 rpm. If the speed drops to approximately 1,000 rpm, the fuel supply is switched on again so that a smooth changeover to idling operation is assured. In some 1971-72 models a bypass (overrun) valve adds air to the intake duct to lean the mixture while the fuel injectors continue in operation during this operating mode.



Schematic diagram to show how the control signals are sent to the electronic control box in the VW fuel-injection system. The battery (A) supplies current to the relay (B). The throttle valve switch (C) indicates whether the vehicle is aclerating or decelerating. The pressure sensor (D) informs the control unit about engine load. The trigger contacts in the distributor (E) measure engine speed. Temperature sensors (G & F) control mixture enrichment. All of this information is used to determine the length of time that fuel is injected through each nozzle—varying from 0.002-0.010 of a second.

CONTROL UNIT

The control unit processes the information from the various sensors and determines the opening interval for the injectors, if and for how long the cold-start valve should remain open, and when the fuel pump should start operating. The cold-start valve and fuel pump are operated by control relays.

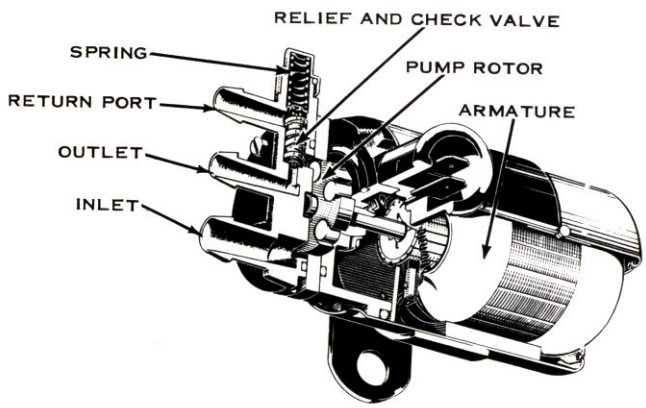
The main relay has a diode in the control circuit to prevent the injection system from being engaged and damaged if the battery connections are accidentally reversed.

FUEL FILTER

The fuel filter is mounted in the suction line between the tank and fuel pump on most models. It is a paper type, which must be replaced every 12,000 miles.

ELECTRIC FUEL PUMP

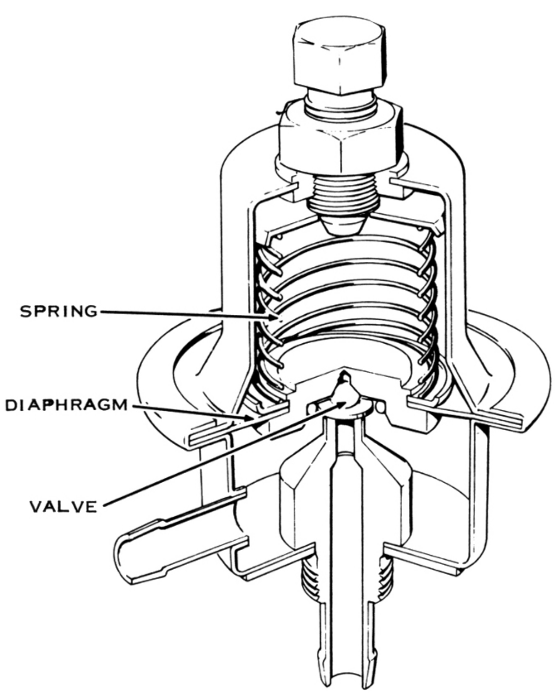
The electric fuel pump is mounted at the front end of the fuel tank. The pump and motor are enclosed and cannot be repaired. The fuel circulates inside the motor so that the rotor and



Sectioned view of the electronic fuel pump, with the relief and check valves at the left side.

The pump is provided with a combined relief and check {one-way) valve, which also serves as a vent if the pump has drawn in air. When the pump starts to operate and there is air in it, the air is forced into the overflow line via the column in the piston, which is not large enough to allow all the fuel to pass. When the air is forced out, the piston is forced back towards the seat to seal the port, while the outlet channel opens. When the pump shuts off and the pressure drops, the piston is pressed forward and closes the outlet chan-nel. Should the pressure exceed 64 psi, the spring would be compressed and the piston would open to release fuel into the return line as a safety measure.

The pump operates initially for 1-2 seconds when the ignition switch is turned ON and then shuts off. This is to prevent the engine from being filled with gasoline by a leaking cold-start valve or injector. The pump then works only when the starter motor is engaged or when the engine is running.



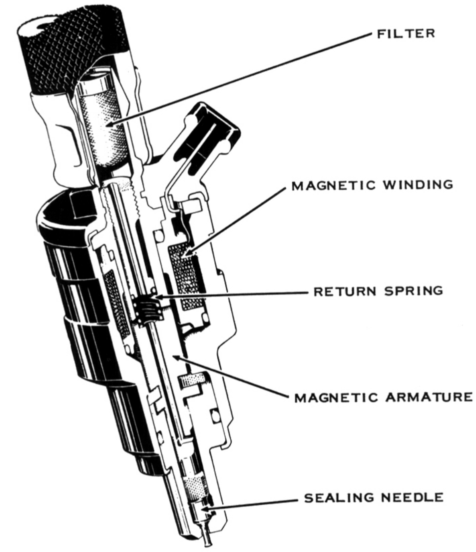
Sectioned view of the fuel pressure regulator, with the ad-justing screw at the top.

FUEL PRESSURE REGULATOR

The fuel pressure regulator is a mechanical device which regulates the pressure in the fuel lines to 28 psi. When the pressure is lower, the valve closes. When the pressure exceeds 28 psi, the valve opens and releases excess fuel into the return line to the tank. This valve is adjustable.

INJECTORS

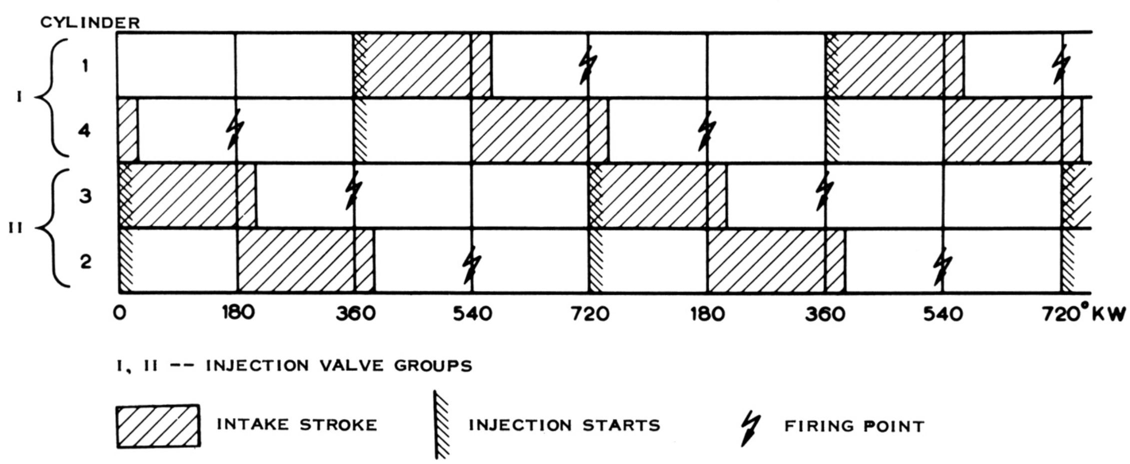
Fuel is injected into the intake ports of the cylinder head by four or six injectors, one for each port. The injectors are mounted in holders on the cylinder head. The injectors are actuated in groups of two. Injectors 1 and 3 inject at the same time, while 2 and 4 inject together. This means that injectors 1 and 4 inject when their respective intake valves are open, but that injectors 2 and 3 inject when their respective intake valves are closed. In this case, fuel is stored in the port until the intake valve opens.



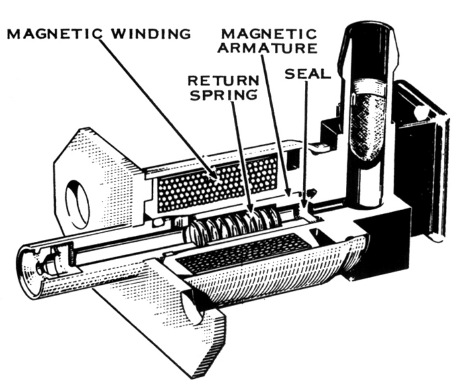
Sectioned view of the injector unit.

The injector consists of a housing containing a sealing needle, coil, and return spring. When the coil winding is not in the circuit, the return spring forces the sealing needle against a seat, and this shuts off the supply of fuel.

When the coil winding receives current from the control unit, it attracts the rear section of the sealing needle, which is shaped as a magnetic armature, and this lifts the needle about 0.15mm (0.006") from the seat to allow fuel to pass. Since the needle and opening in the valve are accurately calibrated and the fuel pressure is constant, only the valve-opening interval (2-10 milliseconds ~ 0.002-0.010 seconds) determines the amount of fuel that is injected.



Two fuel injectors operate at the same time to keep the system as simple as possible. On the VW engine, which is diagramed above, the nozzles of cylinders 1 and 3 inject fuel past the open intake valves, while the nozzles of cylinders 2 and 4 inject into the intake ports while the intake valve is closed. In this case, the fuel is "stored" in the port until the intake valve opens.



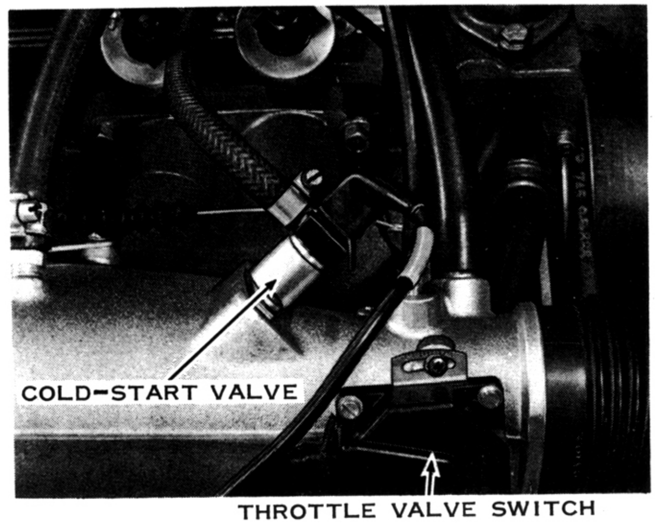
Sectioned view of the cold-start valve used on a Volvo engine.

COLD-START VALVE

The cold-start valve, which is mounted in the inlet duct behind the air throttle, provides the engine with extra fuel during cold starting. The injection time is governed by the control unit which, in turn, receives information from the coolant or oil temperature sensors. At — 4 ° F and colder, the cold-start valve provides extra fuel for 10 seconds. At 130°F the cold-start valve stops delivering fuel during starting.

The cold-start valve operates only when the cranking motor is running. When the engine is running and the cranking motor has been shut off before the injection interval (governed by the control unit) is completed, the cold-start valve also ceases to inject fuel.

The cold-start valve consists of a housing in which a coil winding and an armature, together with a return spring and seal, are placed. When the winding is not in the circuit, the seal is pressed against the inlet of the armature which, in turn, is actuated by the return spring. This keeps the cold-start valve closed. When the coil winding is fed current from the control unit via the control relay, the armature is forced down, and fuel passes through the cold-start valve and into the inlet duct.

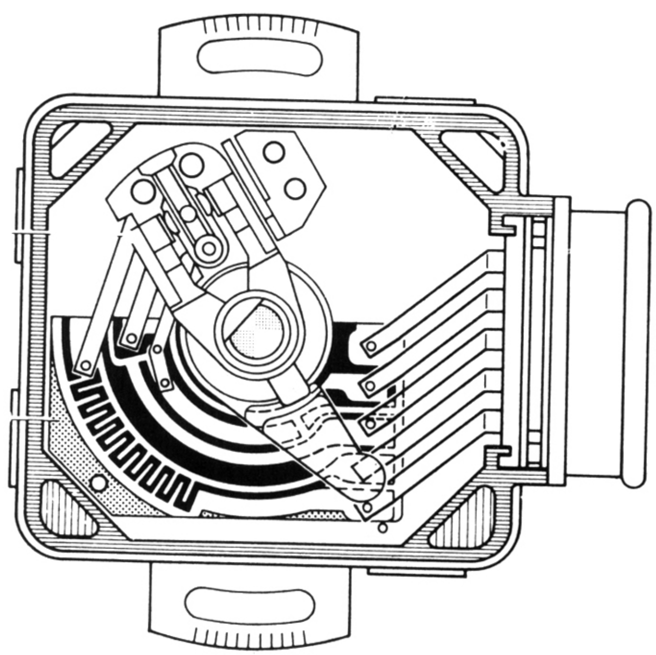


The cold-start valve discharges a spray of fuel into the intake manifold when a fuel-injected engine is started.

THROTTLE-VALVE SWITCH

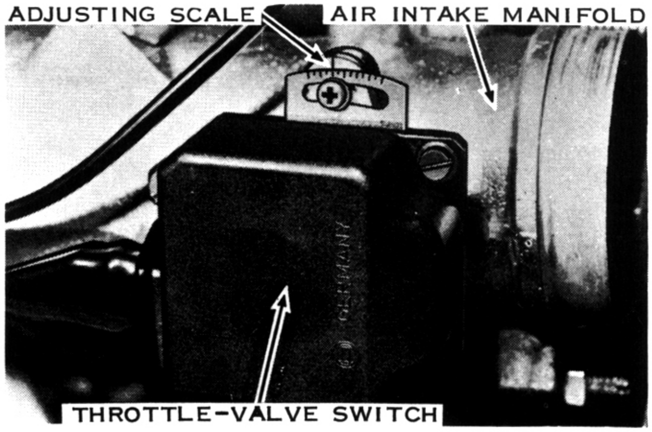
The throttle-valve switch is mounted on the inlet duct and is connected to the throttle shaft. The throttle-valve switch has two functions: one, it sends impulses to the control unit to increase the fuel supply during acceleration; two, it sends impulses to the control unit to shut off the fuel supply during deceleration on most models.

During acceleration, the contacts are forced together to cut in the circuits so that current can flow from one switch to the other. When the sliding contacts move over the zig-zag contacts, the control unit receives impulses. Depending upon the number of impulses and their rapidity, the control unit determines how much additional fuel should be injected (that is, how many additional injections will take place and how much the injection interval will be extended). Throttle reduction opens the contacts to prevent the control unit from receiving impulses for extra fuel.



The throttle valve switch used on the electronic fuel-injected engine is located at the throttle plate housing, is operated by the throttle linkage. It has a number of functions: (1) At idle, it interrupts fuel injection in connection with the rpm switch. (2) During acceleration, it triggers additional injection impulses to overcome the time lag in the response of the pressure sensor. (3) It triggers maximum fuel enrichment at WOT.

Easing up on the accelerator pedal fully on most models causes other contacts to come together, and this supplies information to the control unit that the air throttle valve is closed. If engine speed is higher than 1,700 rpm when the contacts are closed, the control unit shuts off all fuel injection until engine speed drops to about 1,000 rpm at which speed the fuel supply is switched on again to provide a smooth transition to idling speed. Fuel cutoff during deceleration is an effective emission-control device. On some 1971-72 engines the fuel continues to be injected and a bypass valve is added to lean the mixture during deceleration.



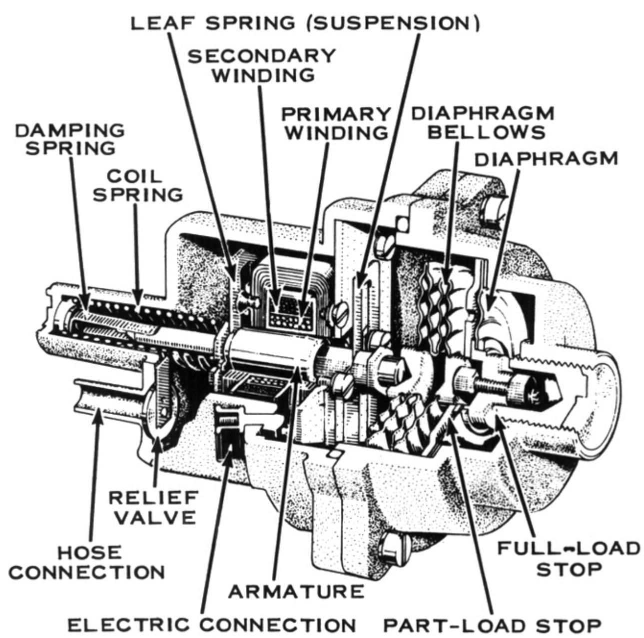
The throttle-valve switch is located on the air intake manifold and connected to the throttle shaft.

When the engine is cold, the speed limits are increased by 300 rpm. Naturally, fuel injection restarts immediately when the accelerator pedal is depressed and the contacts open before engine speed drops to 1,000 rpm.

PRESSURE SENSOR

The pressure senses the pressure in the inlet duct. These variations influence the armature in a transformer, this altering the transformer's inductance. Thus, the pressure sensor informs the control unit about the load on the engine. The pressure sensor is connected to the inlet duct by means of a hose. With the engine turned off, atmospheric pressure exists on both sides of the diaphragm, and the movable armature (which is suspended free between both leaf springs) is pressed against the full-load stop by a spring. Moreover, both of the deflated diaphragm bellows are pressed together since they are influenced by atmospheric pressure and, in this way, permit the armature to move itself farther to the right. With the armature at the extreme right (full-load stop), the pressure sensor informs the control unit that maximum possible fuel should now be injected.

When the engine starts and the vacuum from the intake manifold influences the left-hand side of the diaphragm, atmospheric pressure forces the diaphragm over to the part-load stop. At the same tune, the diaphragm bellows expands since they are influenced by the vacuum inside of the pressure sensor so that they move the armature slightly to the left. Depending upon the pressure in the inlet duct (engine load), the armature adjusts itself to different positions. At full-throttle, the pressure in the inlet duct drops almost to atmospheric, at which point the armature takes up the same position as when the engine started.



Sectioned view of the pressure sensor.

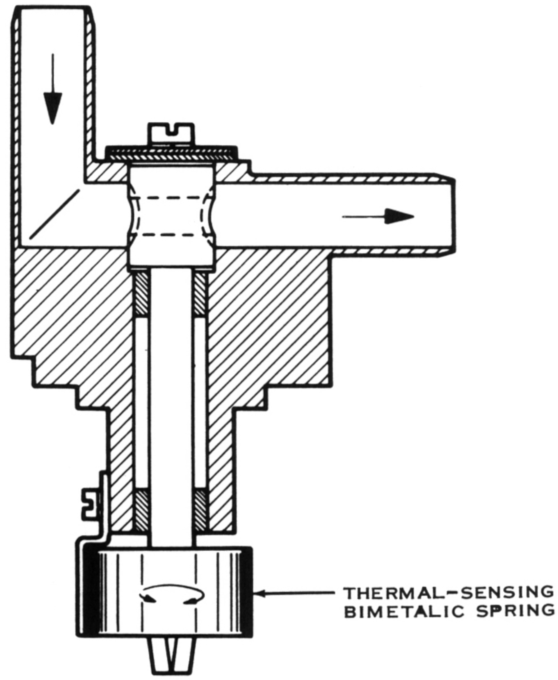
The function of the relief valve is to prevent pressure pulses in the inlet duct (from piston movement) from being conveyed to the pressure sensor. This valve has a small orifice which restricts the pulses. During sudden acceleration, when air rushes into the pressure sensor, the orifice in the valve is too small to react quickly so that the entire valve is moved away from the opening.

AUXILIARY AIR REGULATOR

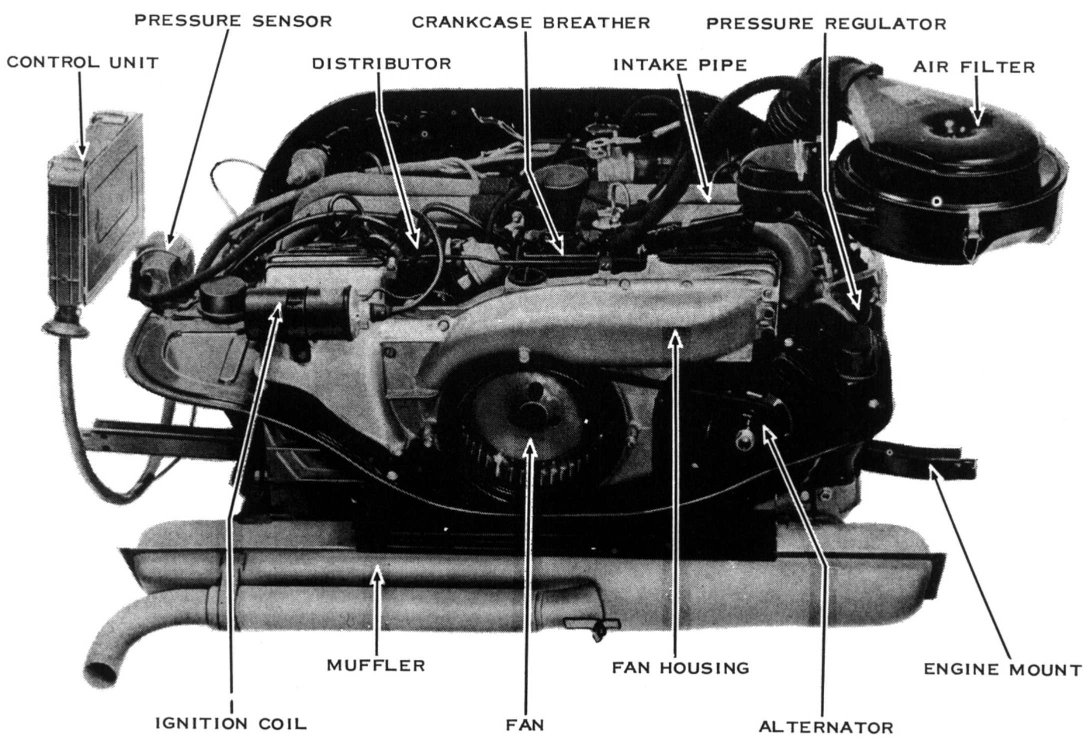
The auxiliary air regulator is located at the front end of the cylinder head and has its expanding element projecting into the coolant system on most engines. The regulator operating range is from — 13°F when it is fully open, to + 140°F when it is closed.

During cold starting, the auxiliary air regulator opens (depending on the temperature) and admits additional air into the inlet duct to increase engine speed to a fast idle. As the engine warms, the element expands and forces the regulator back which, at + 140°F, completely closes off the cross-sectional area of the auxiliary air pipe to return the engine to a normal curb.-idle speed.

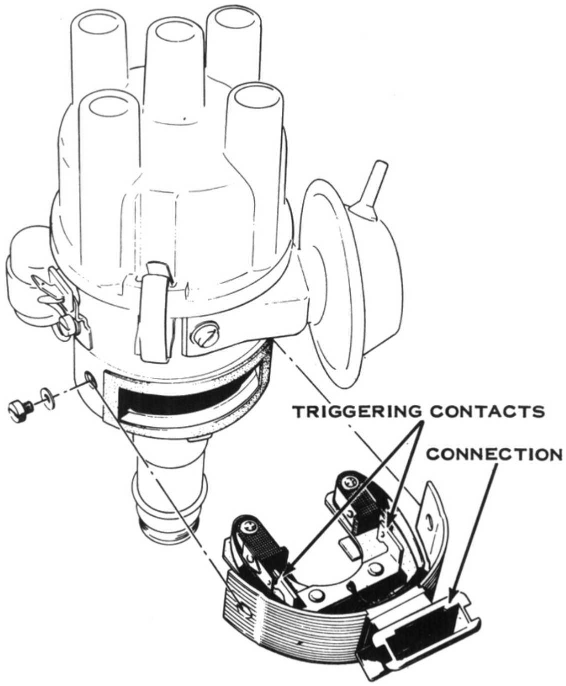
The auxiliary air regulator on VW air-cooled engines senses engine oil temperatures to respond in a similar manner.



Cross-sectioned view of the auxiliary air regulator used on Volkswagen engines. The thermal-sensing element extends into the crankcase oil chamber. At —22°F, the rotary valve is opened fully and at 122°F it is closed fully.



Type 4 Volkswagen engine showing the actual layout of the electronic fuel-injection components.



The triggering contacts are in the base of the distributor. They send signals to the computer to indicate the speed of the engine.

TRIGGERING CONTACTS

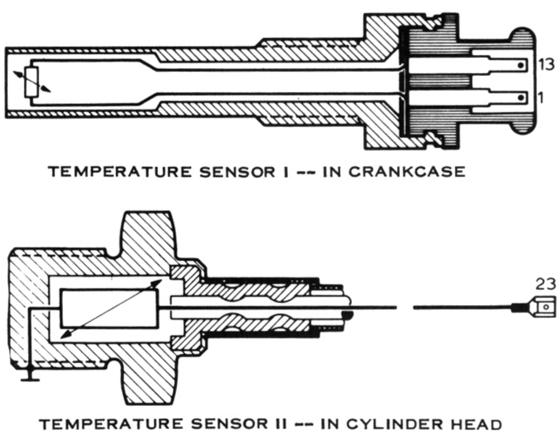
Two triggering contacts are located below the centrifugal governor in the distributor. The contacts are mechanically actuated by a cam on the distributor shaft.

The function of the contacts is to supply information to the control unit about engine speed to enable it to determine partly when injection should begin and partly the duration of injection; this with the help of information from the pressure sensor.

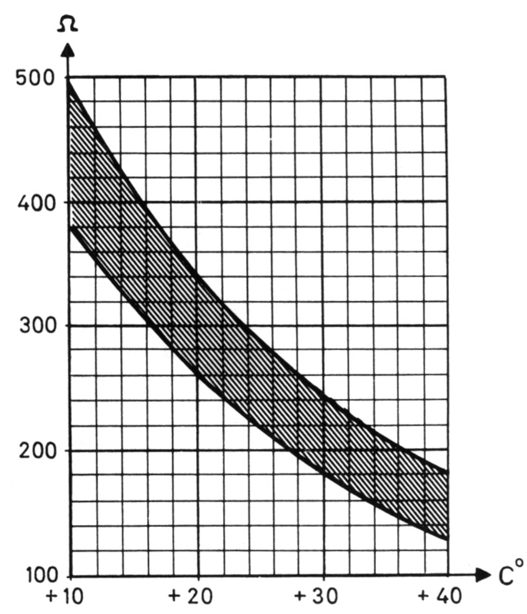
TEMPERATURE SENSORS

The coolant and/or oil temperature sensors provide the control unit with information concerning the engine temperature so that the control unit can adapt the injection interval and also determine how long the cold-start valve should remain open during engine starring. The temperature sensor for the intake air provides the control unit with information about the intake air temperature so that the

Compensation ceases when the temperature of the intake air is greater than 68° F.



The Volkswagen temperature sensors are located in the crankcase and cylinder head to change temperature variations into changes in electrical resistance.



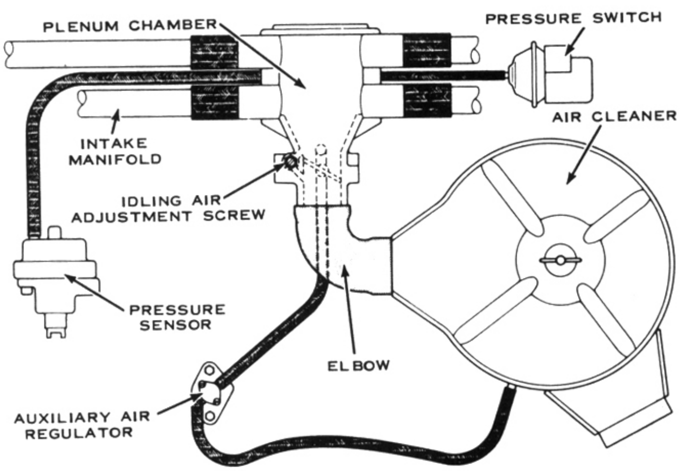
Graph showing how the resistance of the air intake temperature sensor changes with temperature.

The temperature-sensitive part of the sensor is a semi-conductor, with a negative temperature coefficient. That is, the resistance drops with increasing temperature. The resistance alters considerably. For example, the temperature sensor has a resistance of 15,000 ohms at -4° F but only 600 ohms at 140° F.

INLET DUCT

The inlet duct is cast in a single piece of aluminum. It consists of a common inlet duct from which individual induction pipes lead to each port in the cylinder head.

A throttle valve is mounted at the mouth of the common inlet duct. During idle, the throttle valve is completely closed. Air flows in through a bypass pipe under the throttle valve. Idling speed is adjusted by means of an idle air adjustment screw, never by turning the throttle-stop screw.



Position of the air system parts used on the Volkswagen engine with fuel injection.

AIR CLEANER

The paper insert in the air cleaner must be cleaned or replaced at the scheduled intervals.

CABLE HARNESS

All electrical components in the system are connected with numbered cables by a special cable harness. The connections between the cable harness and components are of the "Amp" plug type, which makes a good electrical contact as well as providing for rapid removal. The plugs have grommets to ensure proper installation in the various components.

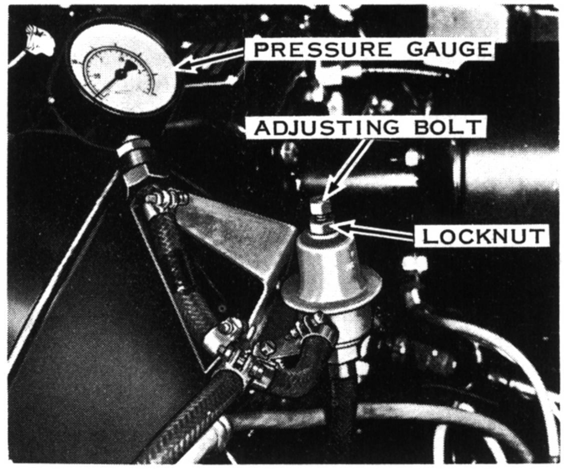
CAUTION: Make sure that the grommet enters the cutout on the control unit before pushing in the harness plug. The connections are **covered by** rubber protectors, which also serve as locks. These protectors can be removed by pulling on the tongues.

SERVICE PROCEDURES
CAUTIONS TO BE OBSERVED WHEN WORKING ON THE SYSTEM

- Never allow the engine to run without the battery connected.
- Never use a high-speed battery charger as a starting aid.
- When using a high speed charger to charge the battery in the vehicle, the battery must be disconnected from the rest of the electrical system.
- The control unit must not be heated over 185°F. The control unit must not be connected and the engine started when the ambient temperature exceeds 158°F. This might happen when the vehicle has been painted and dried in an oven. In this case, the car must be pushed out of the oven. If there is any risk of the temperature exceeding 185 °F, the control unit must be removed.
- The ignition should be turned OFF before connecting or disconnecting the control unit.
- When working on the fuel lines, great care must be taken to ensure that no dirt enters the system. Even a very small dust particle can jam an injector.

ADJUSTING THE FUEL PRESSURE REGULATOR

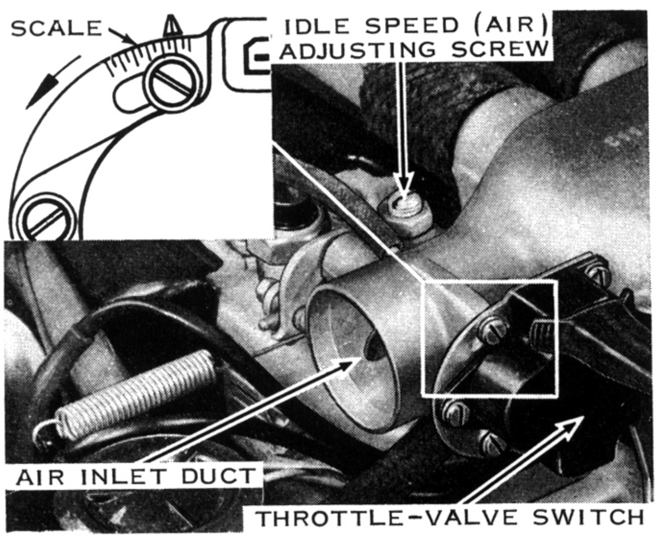
Install a pressure gauge as shown, and then start the engine. Loosen the locknut, and then turn the adjusting bolt to obtain an operating pressure of 28 psi. If you cannot adjust the pressure to this figure, check the fuel pump, which must have an output of 13.2 U.S. gallons per hour at a pressure of 28 psi. At this load, the current consumption should be 2.5 amperes.



To check and/or adjust the pressure in the fuel system, connect a pressure gauge into the fuel delivery line, as shown. Turn the adjusting bolt until the system pressure stabilizes at 28 psi for all engines.

ADJUSTING THE THROTTLE VALVE

Loosen the locknut, and then back out the throttle-stop screw a couple of turns; the throttle valve should close completely. Turn the throttle-stop screw in until it just touches the stop, and then turn it an additional 1/2 turn to keep the throttle valve from sticking in the housing. Tighten the locknut. **CAUTION**: The idle speed must not be adjusted with the throttle-stop screw.



This shows the throttle-valve switch and adjusting scale as mounted on a VW engine.

ADJUSTING THE THROTTLE-VALVE SWITCH

The throttle-valve switch is adjusted correctly when continuity between the contacts is made as the throttle lever is advanced slightly {about 1-4°). An ohmmeter can be used to check the continuity through the switch. If an adjustment is required, loosen the screws holding the switch in place, and then turn it clockwise as far as possible. Now, turn it counterclockwise until the contacts just break, and then a slight amount more (about 2°). Tighten the lock screw.

CHECKING THE THROTTLE SWITCH

Turn the ignition switch ON, but don't start the engine. Open and close the throttle valve slowly. Clicking sounds should come from a group of injectors to indicate that extra fuel is to be injected.

Start the engine and warm it to operating temperature. Pull off the hose between the intake duct and the auxiliary air regulator. The engine should "hunt or roll" between 900 and 1,700 rpm. This is an indication that the contacts in the switch are in good condition and that the section of the control unit that shuts off the fuel supply during deceleration is functioning properly.

CHECKING THE AUXILIARY AIR REGULATOR

Run the engine until it is warmed to operating temperature. Connect a tachometer and note the idling speed. Pull off the hose between the intake duct and the auxiliary air regulator. Cover the opening with your hand. Engine speed must not drop or there is a leak in the auxiliary air regulator, which must then be replaced.

CHECKING THE PRESSURE SENSOR

Measure the resistance between the terminals, which should be approximately 90 ohms between terminals 7 and 15 (primary winding) and approximately 350 ohms between terminals 8 and 10 (secondary winding). All other combinations should give an infinity (co) reading.

CHECKING THE DISTRIBUTOR

The distributor triggering contacts cannot be adjusted but should be replaced if defective. The distributor should be removed from the engine to install a new set of triggering contacts. Apply a little lubricant to the fiber deflecting blocks and make sure that the sealing ring is not damaged.

CHECKING THE INJECTORS

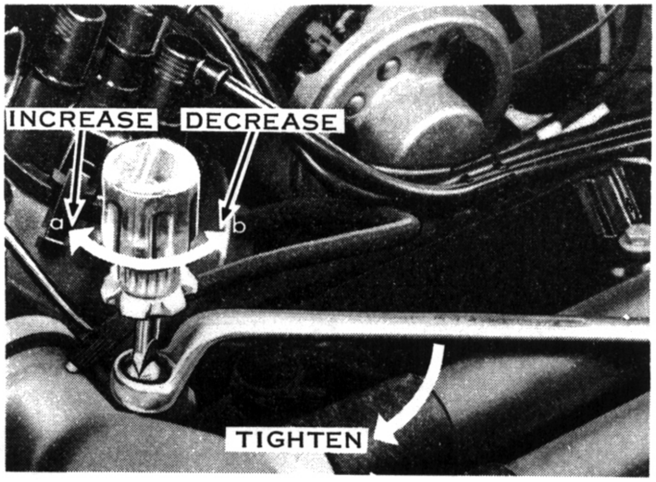
The injectors can be removed for testing purposes to see if the spray pattern is uniform and that no leakage is occurring. This should be done by removing pairs of injectors on the VW and all injectors as a unit on inline engines. Disconnect the high-tension wire from the ignition coil, ground it securely, turn ON the ignition switch, and then crank the engine to watch the spray pattern, which must be even and finely atomized. **CAUTION**: Make sure that the high-tension wire is securely grounded and that the engine is not hot; otherwise, you may start a fire.

Opening the throttle should cause the spray volume to increase. Maximum allowable leakage for an injector is two drops per minute at 28 psi. The resistance between the terminal pins on the injector units can be measured with an ohmmeter; it should be 2.4 ohms at room temperature. **CAUTION**: Never apply 12 volts to test an injector or you will burn it out; it is designed to operate on less than 3 volts.

ADJUSTING THE IGNITION TIMING

The distributor contact points must have been cleaned and the gap or dwell adjusted to specifications before making an ignition timing adjustment. **CAUTION**: These adjustments must be made before adjusting the idle speed and mixture.

Connect a tachometer and timing light. Disconnect the hose to the distributor vacuum-advance and/or retard unit. Plug the hose opening. Idle the engine at a slow enough speed to be sure that the mechanical advance weights have not started to move out. The idle speed of the engine can be slowed by turning the idle speed (air) adjusting screw as needed or by restricting the air intake with an adjustable bleed-type cap, as shown. **CAUTION**: Don't change the throttle-stop screw, or you will throw the system out of balance. Loosen the distributor clamp bolt, turn the housing to align the timing marks to specifications, and then tighten the clamp bolt. Reconnect the hose to the distributor vacuum unit.



To adjust the engine idling speed of a VW fuel-injected engine, loosen the locknut, and then turn the screwdriver counter-clockwise (b) to decrease speed or clockwise (a) to speed up the engine.

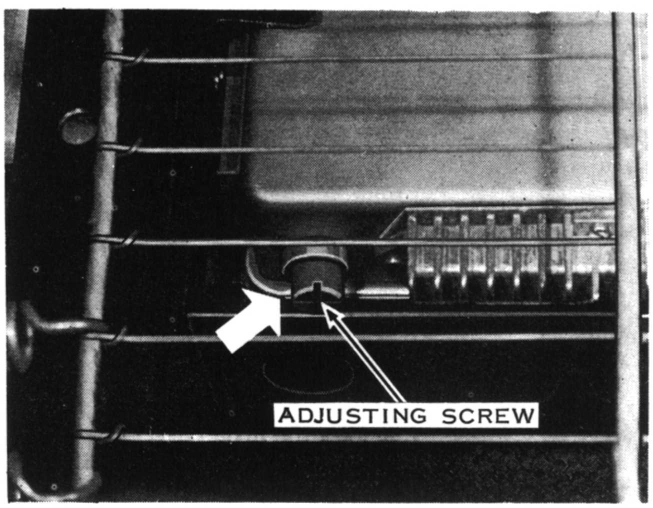
ADJUSTING THE IDLE SPEED AND MIXTURE

Adjust engine idling speed to specifications by loosening the locknut and turning the idle air (speed) adjusting screw on the air intake duct. **CAUTION**: Don't disturb the throttle-stop screw, or you will throw the system out of balance. Tighten the locknut.

On some late-models, the CO content of the exhaust can be adjusted to specifications by turning the adjusting screw on the control box, as shown.

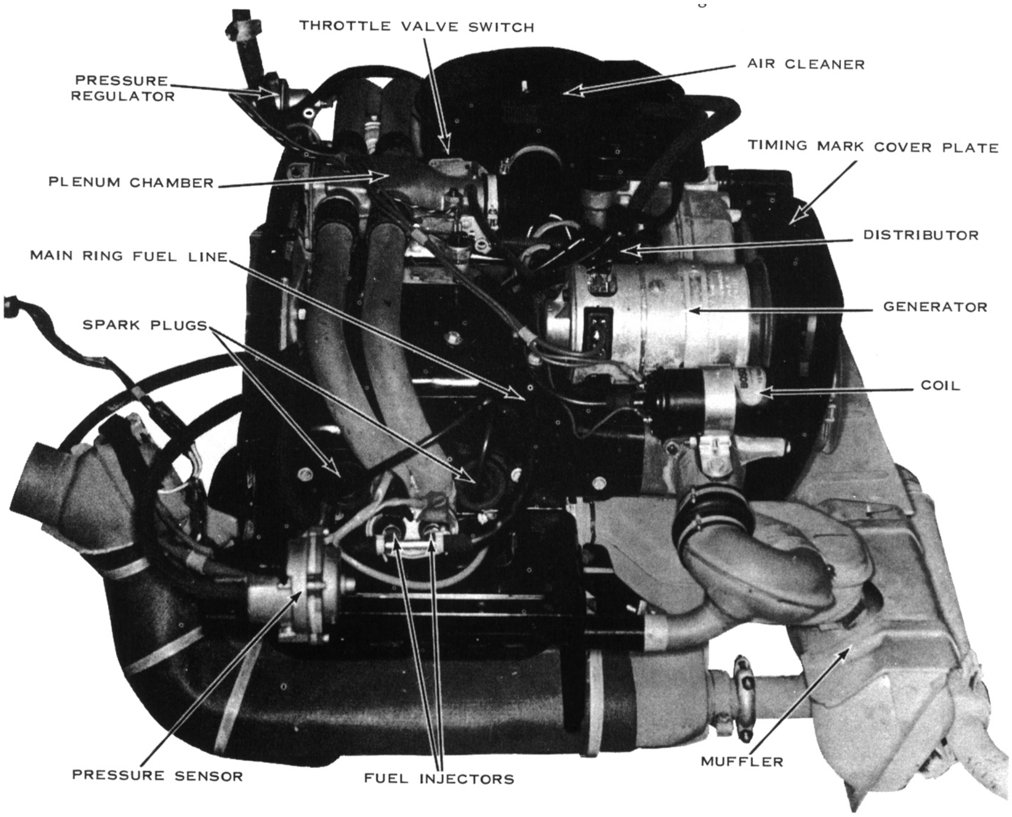
PRACTICAL TROUBLESHOOTING HINTS

One of the big problems associated with electronic fuel-injection systems is voltage losses in the electrical circuit of the vehicle as well as in the fuel injection circuit. Better than 95% of the trouble, which is actually in the fuel-injection system, is caused by voltage losses due to resistance connections. The sensitivity of the system is understandable when you consider the fact that it functions on the basis of small voltage changes from the various sensors, which are then sent to the computer to vary the fuel output of the injection nozzles.



The 1971-72 Volvo and the 1972 VW control boxes have an adjusting screw for making minor corrections to the CO content of the exhaust gas.

Ordinarily, a 0.2 volt loss in a lighting circuit connection or switch contacts is permissible. The effect is not generally discernible unless there are a great number of connections in a circuit, and then the total may be enough to adversely affect the electrical unit. In a sensitive electronic fuel-injection control system which functions on minute changes **in** voltage, such losses become significant. A voltage drop of 0.2 per connection or switch contacts is the limit of acceptance. And because heat raises the resistance of metals, the hot resistance may be 5-10 times higher and thus may become intolerable.



Placement of fuel-injection parts on a Type 3 VW engine.

SYSTEM VOLTAGE TEST

The main relay supplies voltage to the computer and through it to all other units of the system. Check the operating voltage at the computer from terminal 16 to ground, and you must have a minimum of 11.0 volts with the ignition switch turned on, but the engine not running. Energize the cranking motor, and you have have a minimum of 9.0 volts.

If you have less than 11.0 volts at terminal 16, you may have resistance connections at the battery terminals or a sulphated battery. If you have less than 9.0 volts with the cranking motor in operation, you may have an excessive current drain in the cranking motor circuit or a sulphated battery.

COMPUTER CONNECTIONS

Clean the connector with TV tuner cleaner whenever it is disconnected because there may be an invisible coating of oxide on the contacts. A small voltage loss at this point can be critical.

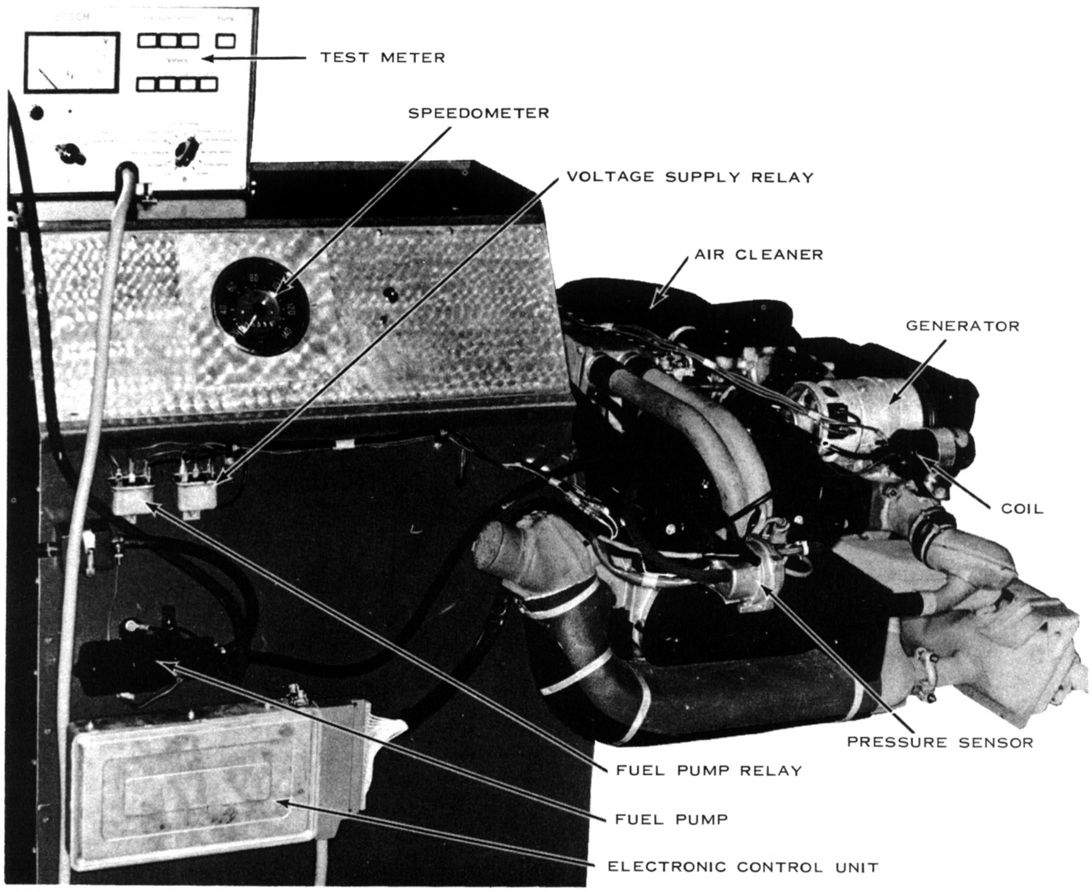
MAIN RELAY

Voltage losses across the main relay contact points or connections will adversely affect all functional units of the system, including the computer, and this will result in serious fuel delivery problems. Check the voltage at the relay input terminal 30/51 and at each of the output terminals when the system is hot and under load. *NOTE: The feed wire of each relay is the center terminal.* Replace the relay if the voltage drop across any connection is over 0.2 volt. There must be no measurable loss between the 30/51 and 87 terminals.

FUEL PUMP RELAY

This is a typical problem area in which the output of the fuel pump may be adversely affected by resistance connections or contact points. Check the voltage at the relay input terminal (30/51) and each of the output terminals when the system is hot and operating under load. Replace the relay if the voltage drop across any connection is over 0.2 volt. There must be no measurable loss between the 30/51 and 87 terminals.

Poor ground connections will cause the relays to burn out, and this is a prime cause of intermittent problems.



Bosch supplies a test bench for making all tests and adjustments to an electronic fuel-injection system. This picture shows a VW engine mounted on such a test bench.

TRIGGERING POINTS

These should have no measurable resistance when measured cold; an acceptable value is 5-6 ohms when measured hot. Some of the problems result from dirt or oil, or binding of the points on the pivot pins. This is generally caused by swelling because of the oil. The result is a flat spot on acceleration.

AUXILIARY AIR REGULATOR-VW

This is controlled by crankcase temperature. Excessive wear in the bushing will cause oil to be sucked into the induction system, and it may also draw oil out of the air cleaner. Check the level if in doubt. Since 1970, a thermostatically heated-coil type unit has been used on vehicles with an automatic transmission.

A defective bi-metallic spring will cause the engine to idle roughly when hot.

TEMPERATURE SENSORS-VW

The crankcase temperature sensor should measure 500 ohms resistance when cold and 100 ohms when hot. The temperature sensor in the left cylinder head should measure 2,500 ohms when cold and 60 ohms when hot. Excessively high resistance values will be translated into richer-than-normal air-fuel mixtures. Intermittent engine operation can be caused by a loose sensor connection.

INJECTOR NOZZLES

Each injector operates 9 times per second at 1,000 rpm and the plunger moves 1/12,000" total travel. The difference in the amount of fuel that is injected depends on the amount of time that the nozzle remains open, and this is 2-10 milliseconds for the entire lean/ rich mixture range. Dirt or carbon in the nozzle will scatter the injection pattern and affect the mixture. You can check the pattern by pulling out an injector and energizing it while cranking the engine, as described previously.

FUEL FILTER

This filter is located ahead of the fuel pump intake and must be clean to supply all of the fuel needed by the system at high speeds. The filter must be changed every 12,000 miles or high-speed problems will develop.

THROTTLE SWITCH

This switch sends signals to the computer to tell it the throttle position, and this switch works in conjunction with the triggering contacts in the distributor for the needed speed signals as the throttle is advanced. The condition of the contacts and the adjustment of the switch are extremely important in obtaining good mileage.

On acceleration, the throttle switch contact points must separate at 4° throttle valve opening to signal the computer that a richer mixture is required for acceleration. If the switch is out of adjustment, a flat spot will occur on acceleration. Excessive resistance in the contact points at the idle position will falsely signal the computer that the engine is coming off idle, and the air-fuel mixture will be excessively enriched.

If engine speed is erratic and the idle condition is rough, remove the wires to the throttle switch. If the engine idle smooths out, replace the switch because of excessive contact resistance.

PRESSURE SENSOR

This unit monitors intake manifold vacuum and sends voltage signals to the computer for acceleration and high-speed enrichment. Excessive resistance in the contact points will cause a lean mixture and highspeed surge.

Any air leak in the induction system, including the crankcase ventilation circuit, or in the diaphragm of the sensor will cause the air-fuel mixture to be excessively rich at idle. Engine hunting at idle speeds indicates such an air leak.

TROUBLESHOOTING CHART BASED ON OCCURING DEFECTS (fuel injection system only)

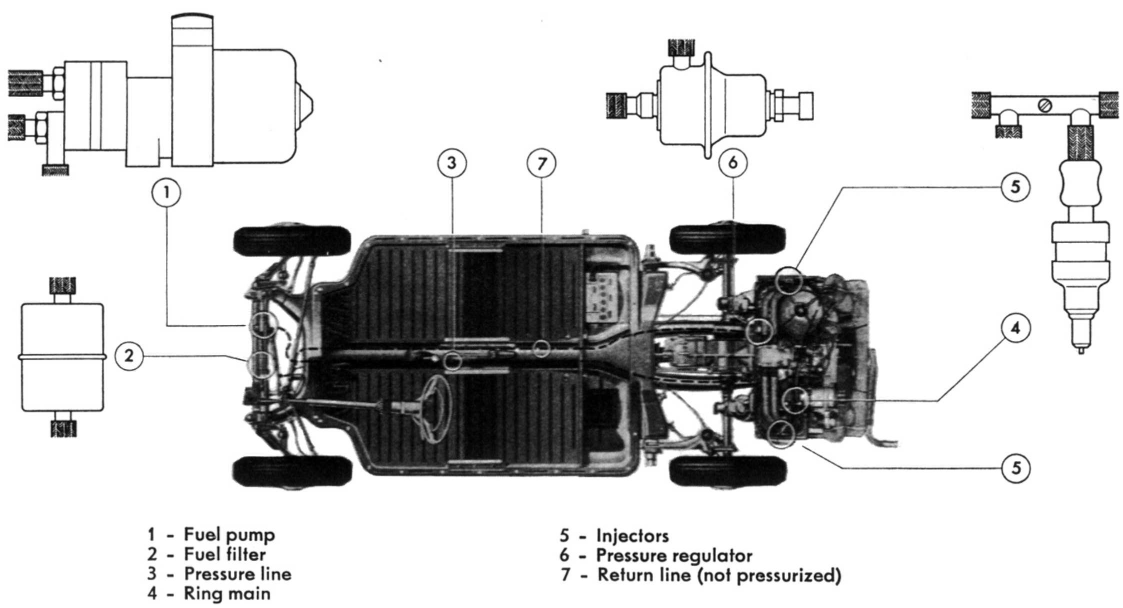
SYMPTOMS	CAUSE	REMEDY
Engine cannot be started. Fuel pump inoperative	Cables to pump, pump relay or cables on pump relay defective. Check pump plug for good connection.	Check if pump relay operates (switch ignition on and off and listen for relay sounds), if necessary adjust with voltmeter.
	Pump relay has no voltage at terminal 86 (+12 volts) because main relay inoperative or cable defective.	Test with voltmeter, eliminate open circuit.
	Pump relay has +12 volts at terminal 86 but no ground at 85.	Important: Relay operates only approximately 1-2 seconds after switching ignition on. Test with voltmeter, relay is wired from ground via control unit. Do not connect ground cable to terminal 85 before disconnecting cable 19 to control unit. Otherwise control unit will be damaged. If no ground connection to cable 19 (switch ignition off and on), replace control unit.
Engine cannot be started, fuel pump operational	Connection from cable harness (cable 18) to starter terminal 50 defective.	Check with tester while operating starter.
	Cable connector at pressure sensor not pushed on or open circuit (engine "floods").	Push on or repair. Important: Before restarting, purge engine (pull out injector plugs).
	No pressure builds up in fuel ring main (squashed line, defective pressure regulator).	Check pressure with gauge (28psi/2kg/cm with starter operating). If necessary, replace pressure regulator.
	Starting difficulties on vehicles with cold starting device: Thermostat remains ineffective below +5°F (-15°C).	Replace thermostat.
	Electro-magnetic valve or cables: Open circuit.	Test with ohmmeter according to wiring diagram.

Engine can be started when cold, but stalls	Cable connector for distributor contacts not pushed on at distributor, or cable has open circuit.	Connect tester if necessary and carry out test stages 8 and 9. If necessary, replace wiring harness or trigger contacts.
	Trigger contacts defective.	Replace.
	See also "engine cannot be started."	
	Pressure sensor defective.	Replace.
Engine cuts out during operation, (usually preceded by misfiring)	Trigger contacts have excessive contact resistance or are dirty.	Connect tester. If test stages 8 and 9 are not all right, replace trigger contacts.
	Push-on connections not in order.	Check.
	No fuel pressure.	Check pressure, correct fault.
Complete system fails. Pump relay ineffective from time to time	Loose contact in voltage supply to pump relay or ground connection for control unit.	Test pump relay and appropriate cable guides with voltmeter.
Engine runs irregularly, one cylinder not firing, exhaust gas white	An injector sticking.	Replace.
	Connection to injector or injector windings not in order.	Check connections; if necessary, replace injectors.
Engine misfires and this is not caused by ignition system	Loose connections, also ground contact at injectors (if ground defect, two injectors fail to operate).	Check connections. If necessary, tighten ground screw.
	Check whether fault lies in ignition system. Otherwise: from time to time voltage too low (voltage I and II) at control unit (loose contact).	Test cable guide of cables 16 and 24 with voltmeter.
	Injector sticking.	Replace.
	Injector winding not in order.	Check with Ohmmeter, replace injector.
Engine not reaching full output	Pressure sensor defective.	Replace.
	Fuel pressure too low.	Check pressure regulator.
	Pressure sensor defective (Full load enrichment).	Replace.
	Throttle valve not opening fully.	Check and correct.
Poor performance, bad flat spots	Quantity of injected fuel over whole range too small because injectors are clogged by fuel deposits.	Install new injectors.

Fuel consumption too high	Sensors not working properly or high contact resistance.	Check connecting hoses, connect tester and carry out test stages 1-13. Replace defective parts after additional check.
	Cooling air flaps are adjusted incorrectly causing prolonged engine warm-up period (temperature sensors continue to signal for cold starting fuel enrichment).	Correct setting as detailed on page M 4.2/2-2.
Engine hunts excessively at idle speed (between 1000 and 2000 rpm).	Leaking hoses/seal between auxiliary air regulator, intake manifolds and throttle valve housing.	Check connecting hosts/seal. Replace if necessary.
Uneven idling, bad flat spots when accelerating	Plugs for trigger contacts/injectors connected incorrectly.	Check for correct positioning of plugs.

VOLKSWAGEN ELECTRONIC FUEL INJECTION SYSTEM

The Bosch electronic fuel-injection system described in the previous pages has been used on Volkswagen Type 3 engines since 1968. Since that time, some changes have been made in the system to make it more efficient. Also, variations in the basic system have been used on Type 4 engines.



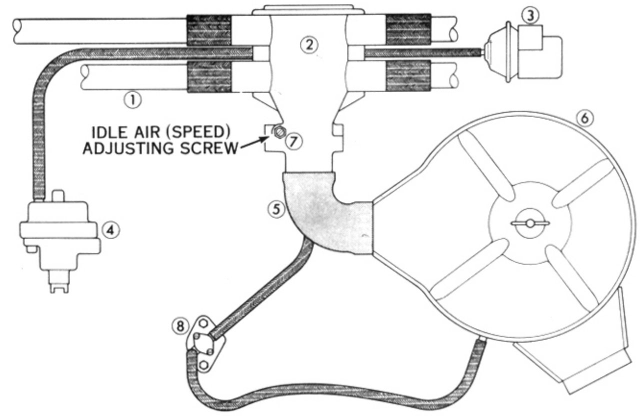
Basic fuel-injection system used on all Type 3 and 4 Volkswagens.

FUEL SYSTEM

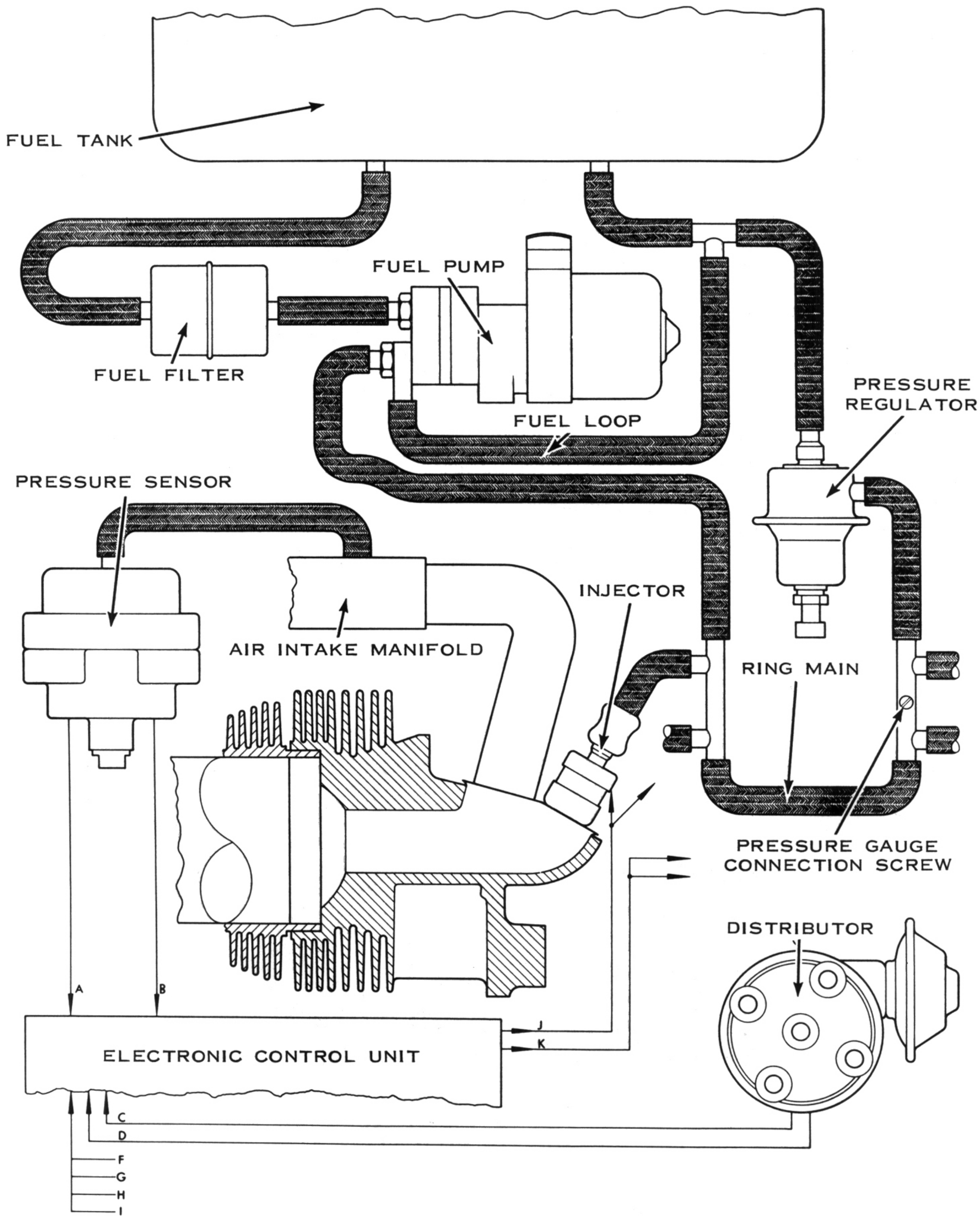
Fuel is forced into the pressure line (3) via the filter (2) by an electric fuel pump (1). The main fuel ring (4), which is connected to the pressure line routed in the frame, provides the four injectors (5) with fuel. The pressure regulator (6) maintains the fuel pressure in the main fuel ring at approximately 28 psi. From here, surplus fuel can flow back to the fuel tank through the fuel return line (7), which is not pressurized.

AIR SYSTEM

Four intake manifolds (1) are connected to an intake air distributor (2) to supply the four combustion chambers with air. A pressure switch (3), a pressure sensor (4), and the vacuum unit on the distributor are also connected to the intake air distributor.



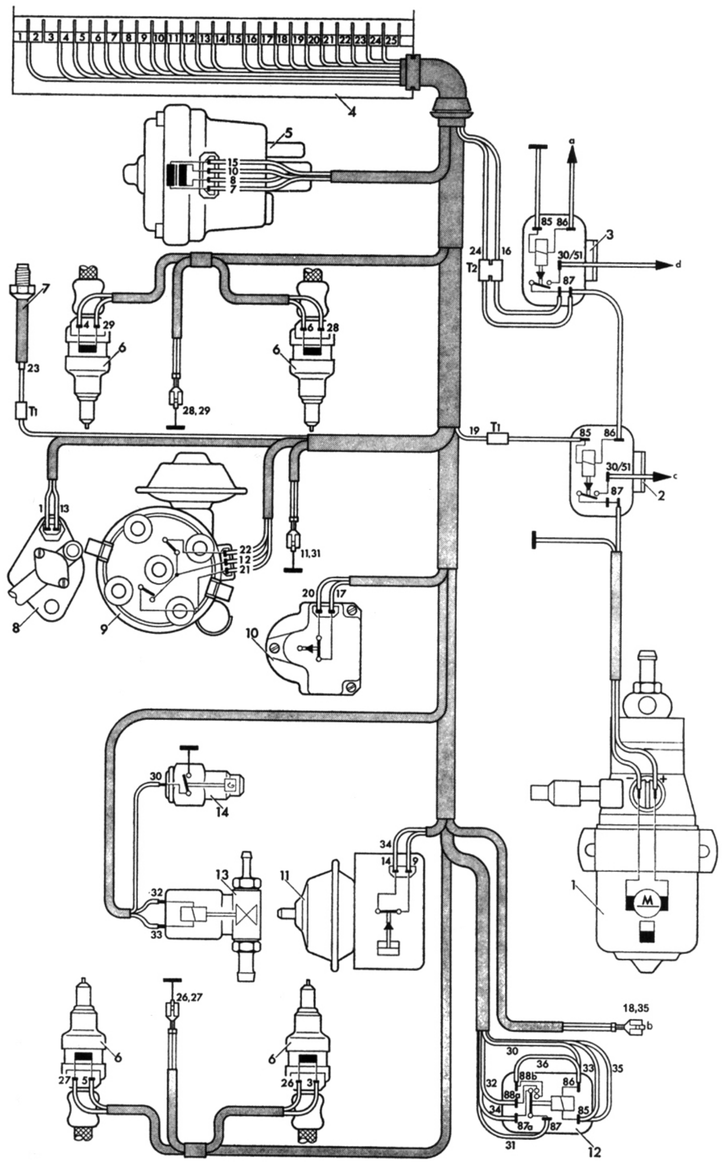
Early Volkswagen air supply system. Later models do not have the pressure switch (3). (1) intake manifolds, (2) intake air distributor, (3) pressure switch, (4) pressure sensor, (5) elbow, (6) air cleaner, (7) idle air (speed) adjusting screw, (8) auxiliary air regulator (rotary valve).



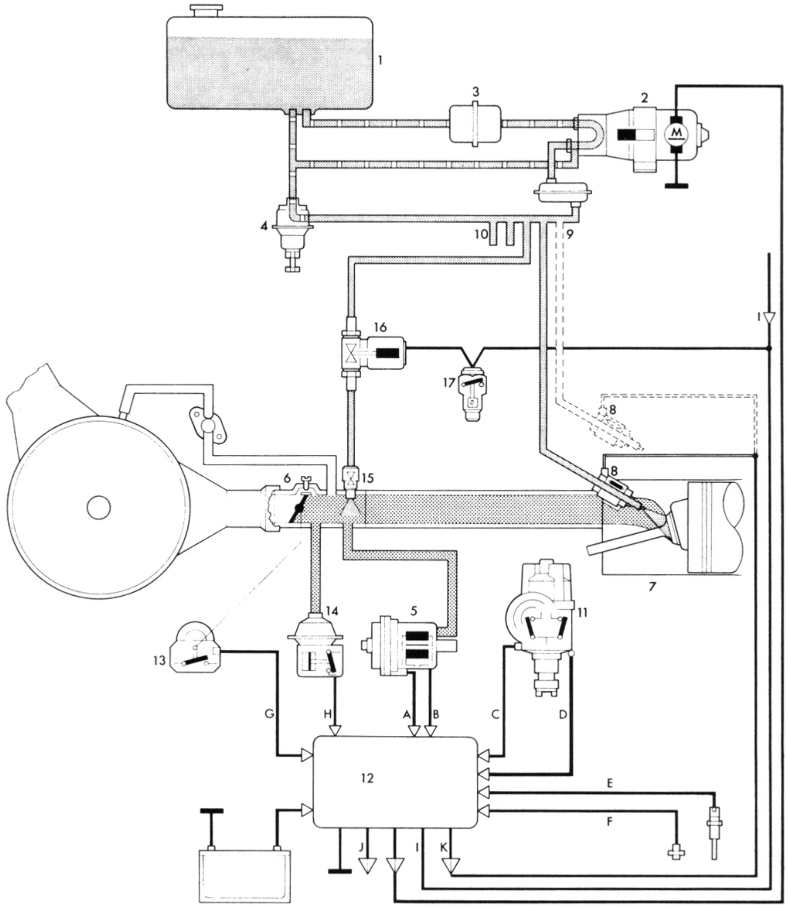
**The fuel system of the Volkswagen fuel-injected engine.
This basic circuit has been used since 1968.**

Key:

1 – Electrically operated fuel pump
2 – Pump relay (relay I)
3 – Voltage supply relay (relay II)
4 – Electronic control unit
5 – Pressure sensor
6 – Electro-magnetic fuel injectors
7 – Temperature sensor I (on cylinder head)
8 – Temperature sensor II (on crankcase)
9 – Distributor with trigger contacts
10 – Throttle valve switch
11 – Pressure switch
12 – Cold starting device relay
13 – Electro-magnetic valve for cold starting device
14 – Thermostat for cold starting device
a – to ignition/starter switch, terminal 15
b – to starter, solenoid switch, terminal 50
c – to terminal 30
d – to battery +



Schematic wiring diagram of the electronic control system. The control unit (4) is the most important part of the fuel injection system. It controls the correct amount of fuel depending on the engine speed, the pressure in the intake system (engine load) and the engine temperature. When the ignition is switched on, the control unit receives its operating voltage directly from the battery via a voltage supply relay (3). By means of a time switch, the electronic control unit also provides current to the fuel pump via the voltage supply relay, allowing the pump to run for approximately 1-2 seconds after the ignition is switched on. Once the engine is running, the fuel pump receives its current via the pump relay (2). The control unit is connected to all the sender units by a special wiring harness coupled to a 25-point multiple plug.



Schematic diagram of the functional parts of the VW fuel-injection system, with the cold-start valve (15 & 16) which was one of the first improvements. Key to the schmatic diagram of the system:

1 – Fuel Tank
2 – Fuel pump
3 – Fuel filter
4 – Pressure regulator
5 – Pressure sensor
6 – Intake air distributor
7 – Cylinder head
8 – Injectors
9 – Fuel distributor pipe
10 – Fuel distributor pipe with connection for cold starting device
11 – Distributor with trigger contacts (Distributor contact I & II)
12 – Electronic control unit
13 – Throttle valve switch
14 – Pressure switch
15 – Cold starting jet
16 – Electro-magnetic valve for cold starting device
17 – Thermostat for cold starting device

A+B – from pressure sensor (load condition signal)

C+D – from distributor contacts (engine speed and triggering contacts)

E+F – from temperature sensors (warming up and cold starting signals)

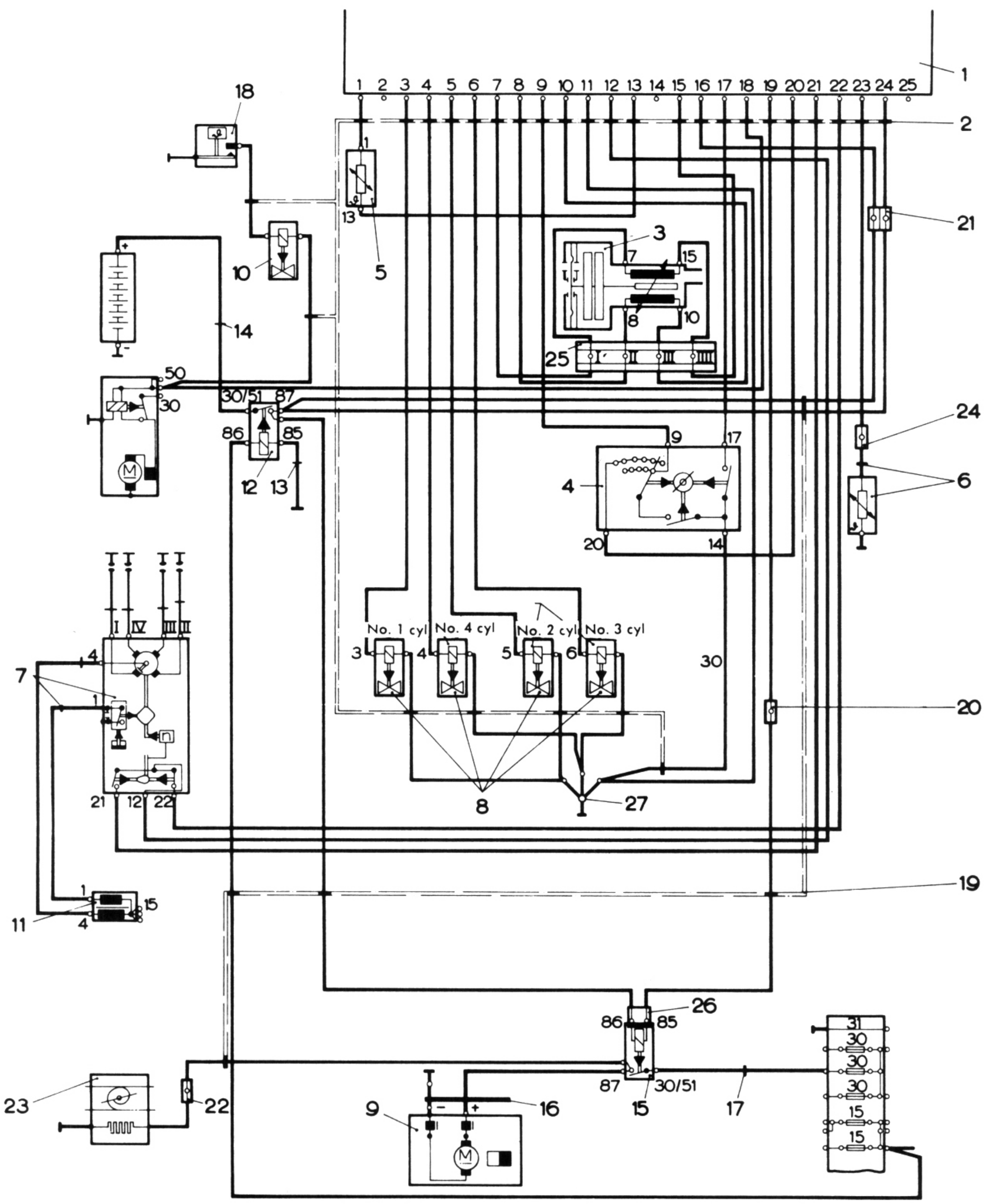
G – from throttle valve switch (fuel supply cut-off when coasting

H – from pressure switch (enrichment signal at full throttle)

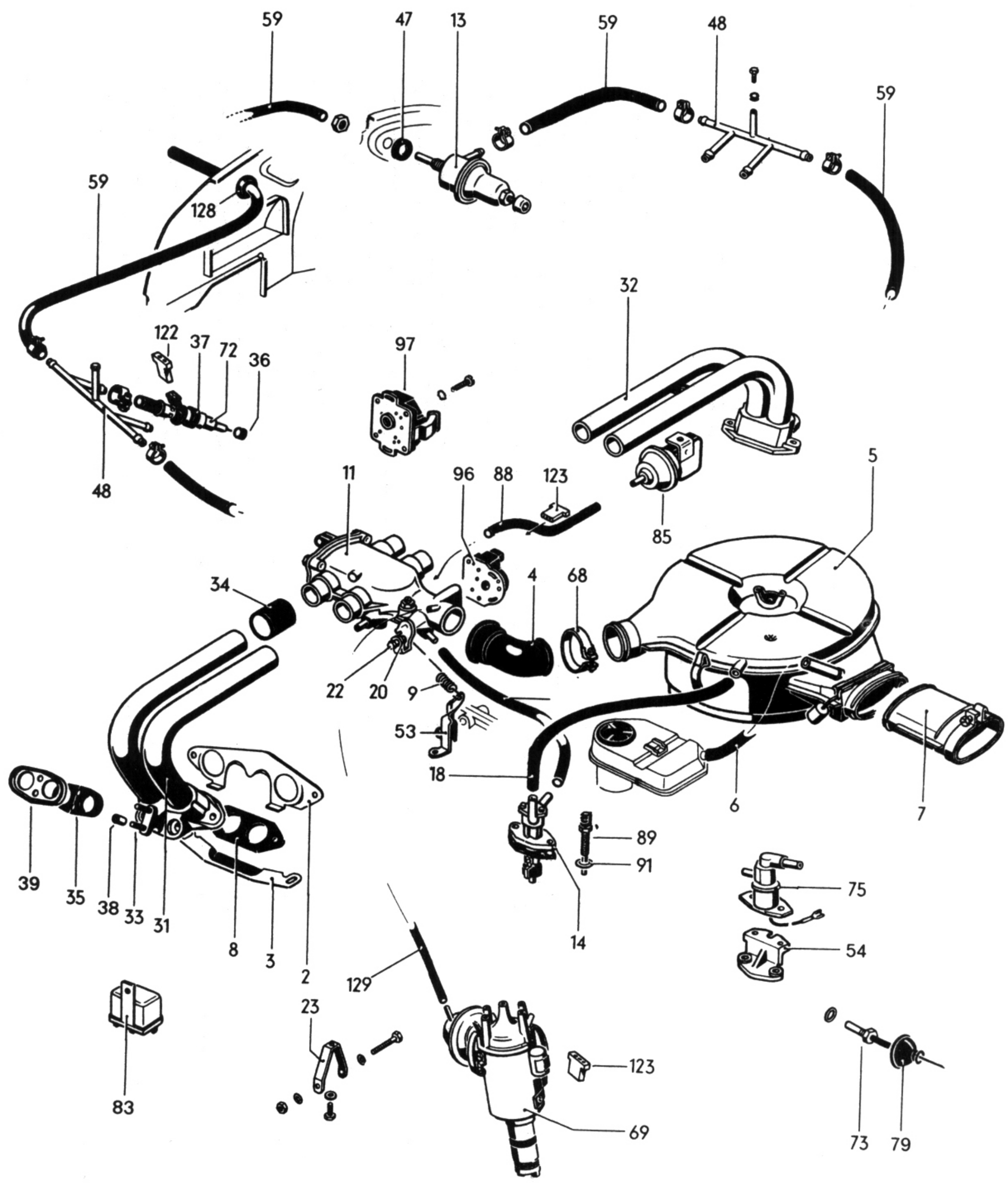
I – from starter, terminal 50 solenoid switch (enrichment signal when starting cold engine)

J – to the injectors, cylinders 1 and 4

K – to the injectors, cylinders 2 and 3

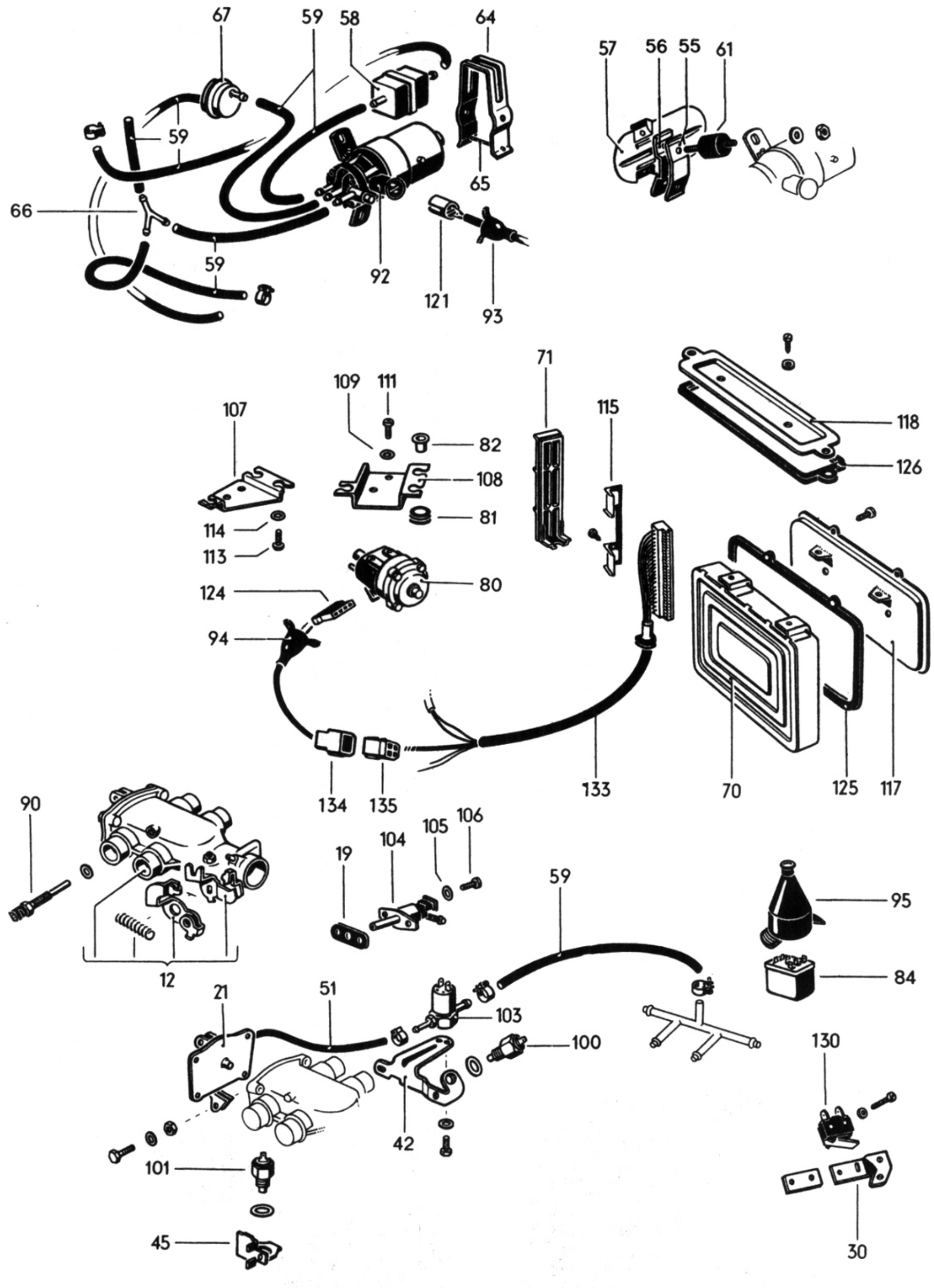


Electrical wiring diagram for late Type 3 Volkswagen fuel-injection systems. (1) control unit, (2) wiring connection to the control unit, (3) pressure sensor, (4) throttle-valve switch, (5) temperature sensor, (6) temperature sensor, (7) ignition distributor, (8) fuel injectors, (9) fuel pump, (10) cold-start valve, (11) ignition coil, (12) supply relay, (13) connecting wire, (14) connecting wire, (15) pump relay, (16) connecting wire, (17) connecting wire, (18) cold-start switch, (19) main wiring loom, (20-22) wire connectors, (23) auxiliary air regulator, (24) wire connector, (25) four-prong connector, (26) receptacle, (27) ground connection.



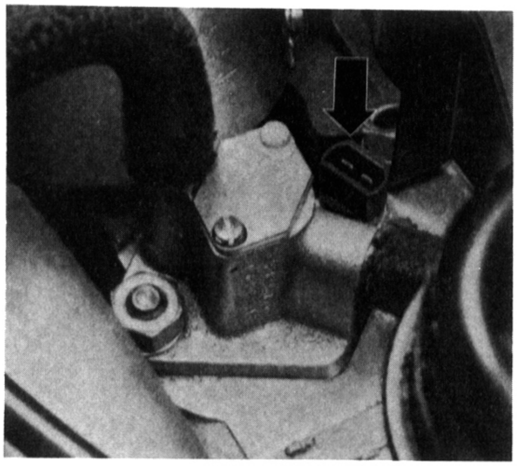
Main air and fuel components of the Type 3 Volkswagen engine.
See next page for parts of the electrical system.

(2) inner cover plate, (3) outer cover plate, (4) elbow, (5) air filter, (6) vacuum hose, (7) connection, (8) gasket, (9) return spring, (11) air distributor, (12) air distributor, (13) fuel-pressure regulator, (14) auxiliary air regulator, (18) hose, (19) gasket, (20) throttle cable pin, (21) cover and cold-start jet, (22) screw, (23) support bracket, (30) kick-down switch support, (31) left manifold, (32) right manifold, (34) hose, (35) retainer plate, (36) inner bushing, (37) outer bushing, (38) sleeve, (39) retainer plate, (42) bracket, (45) thermostat bracket as of chassis 310 200 001, (47) insulator, (48) fuel line distributor, (51) hose, (53) bracket, (54) auxiliary air regulator bracket,

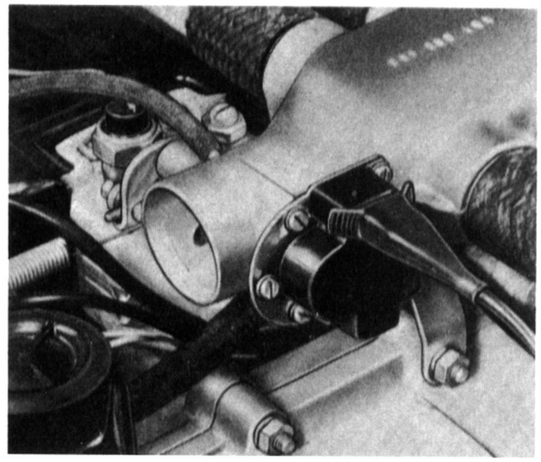


Main electrical components of Type 3 engines.
See previous page for other parts of the system.

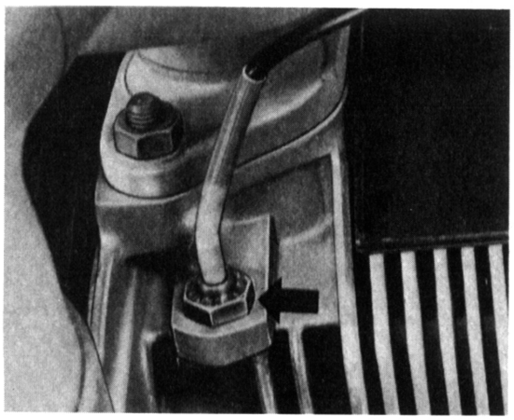
(55) bracket, (56) clamp, (57) shield, (58) fuel filter, (59) hose, (61) rubber mount, (64) clamp, (65) pin, (66) Y-piece, (67) damper, (69) distributor, (70) control unit, (72) injector, (73) cylinder head temperature sensor, (75) auxiliary air regulator, (80) pressure sensor, (81) grommet, (82) spacer, (83) relay, (84) cold-start relay, (85) pressure switch used only on early models, (89) crankcase temperature sensor, (90) air intake temperature sensor, (92) fuel pump, (93-95) cap, (96) early throttle-valve switch, (97) late throttle-valve switch, (100 & 101) temperature switch, (103 & 104) fuel-cutoff valve, (107 & 108) bracket, (121) plug receptacle, (122-124) receptacles, (125 & 126) gasket, (130) kick-down switch, (133) wiring harness, (134) receptacle, (135) receptacle housing.



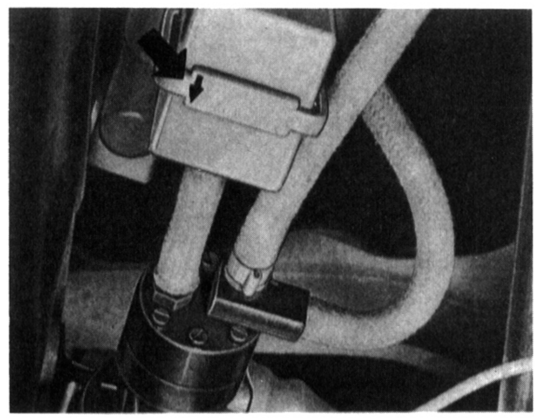
TEMPERATURE SENSOR II



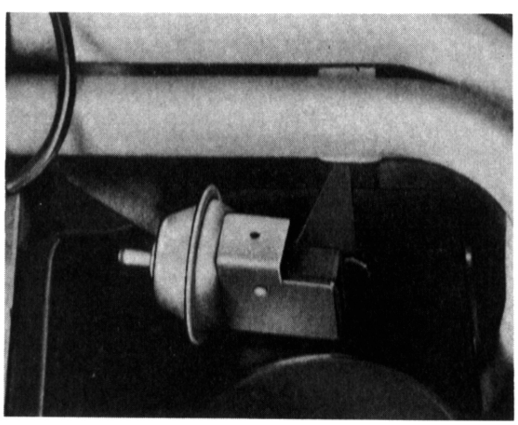
THROTTLE-VALVE SWITCH



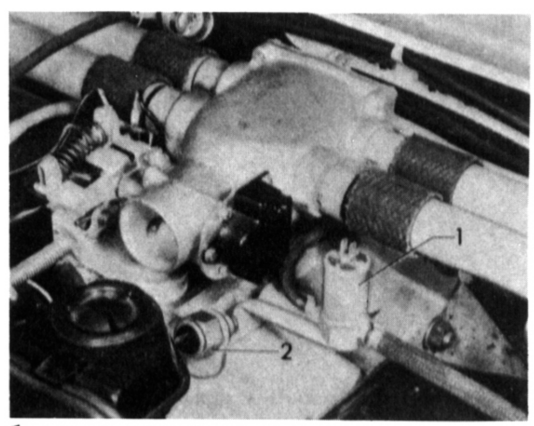
TEMPERATURE SENSOR I



FUEL PUMP AND FILTER



PRESSURE SWITCH

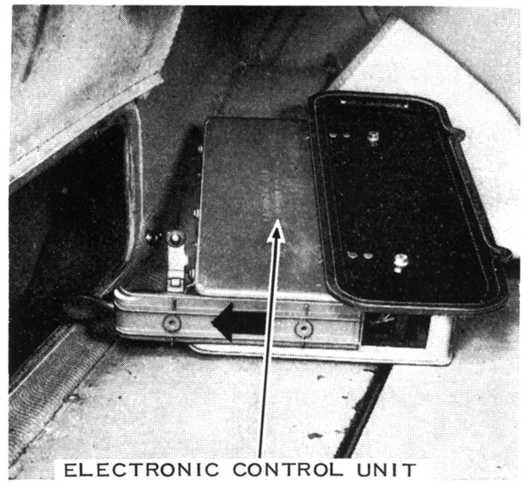


1 COLD-START VALVE 2 THERMOSTAT

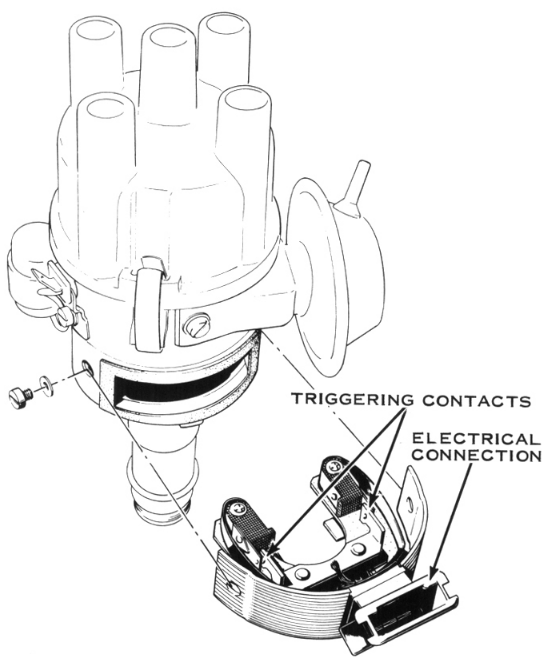
COLD-START VALVE

Placement of the various control units on a Type 3 Volkswagen engine.

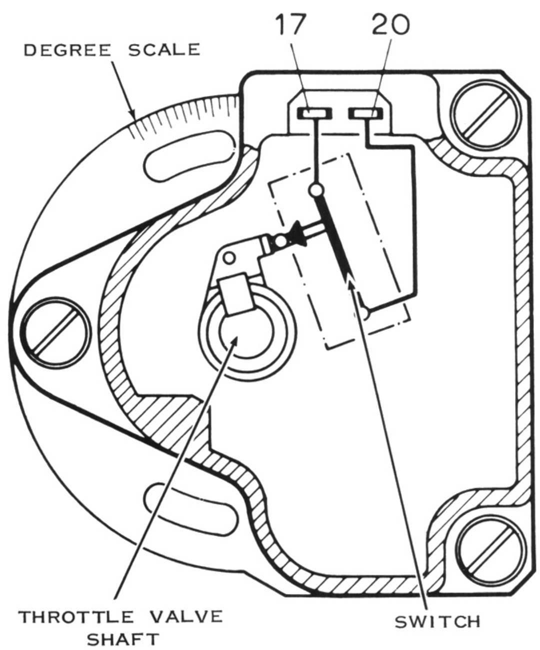
The computer has an adjusting screw on 1972 models for changing the CO content of the exhaust. The specifications are 0.7% CO, and this low value can be achieved only if the engine is tuned properly.



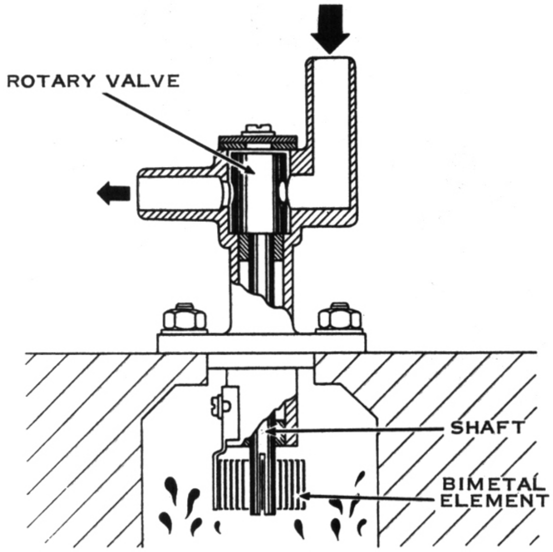
The control box on the VW is located on the left quarter panel. Take out the two Phillips-headed screws, tilt the control unit and panel, and then slide out the control box and cover.



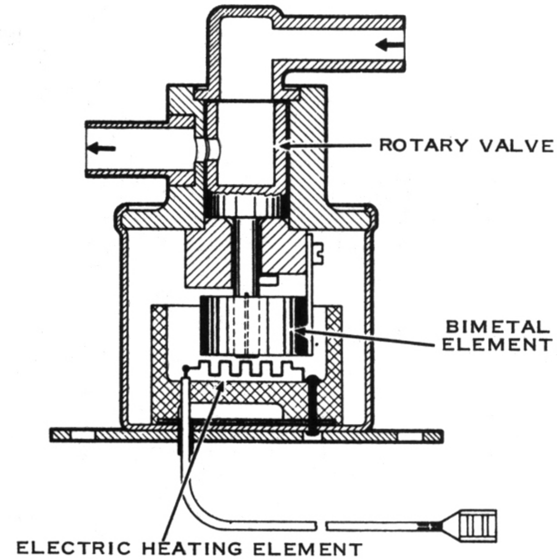
The triggering contacts are located in the distributor. They sense engine speed and transmit this information to the control box.



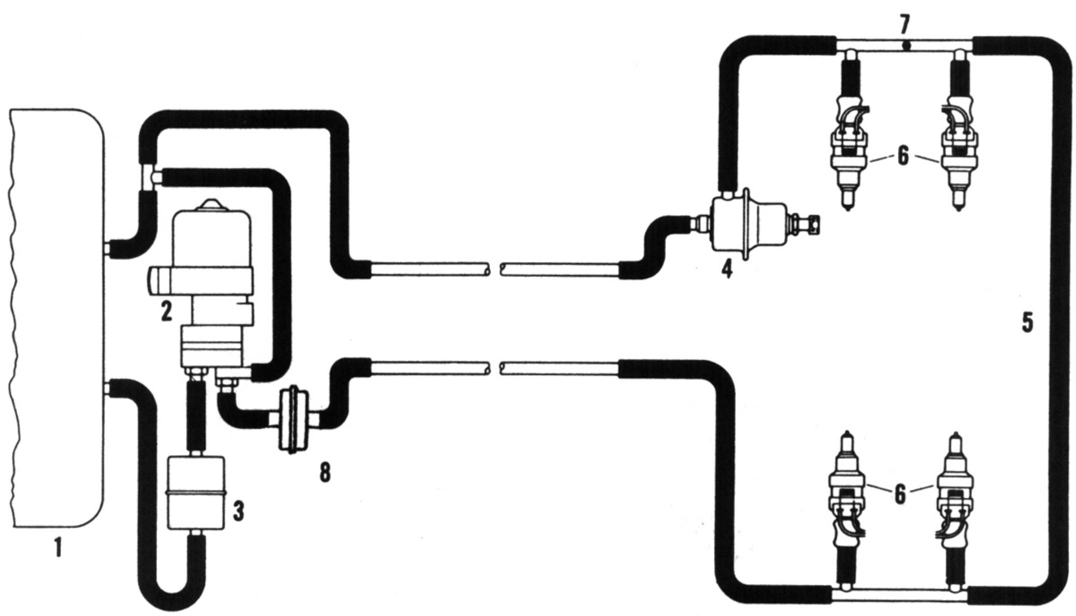
The throttle valve switch sends acceleration and deceleration signals to the computer for regulating the amount of fuel to be injected. The deceleration contacts were used only on early models.



The rotary valve (auxiliary air regulator) protrudes into the crankcase to sense changes in oil temperature, which varies the amount of extra air admitted to the intake manifold during engine warm-up.



Since 1970, some engines use this type of rotary valve. Note the electric heating element, which influences the bimetal thermostat. Its purpose is to make the engine return to normal curb-idle conditions quicker in order to reduce emissions during the warm-up phase of operation.



Schematic diagram of the fuel-delivery part of the electronic fuel-injection system used on VW engines. (1) fuel tank, (2) fuel pump, (3) filter, (4) pressure regulator, (5) loop line, (6) injectors, (7) tap for pressure gauge connecxtion, (8) damper.

SYSTEM IMPROVEMENTS

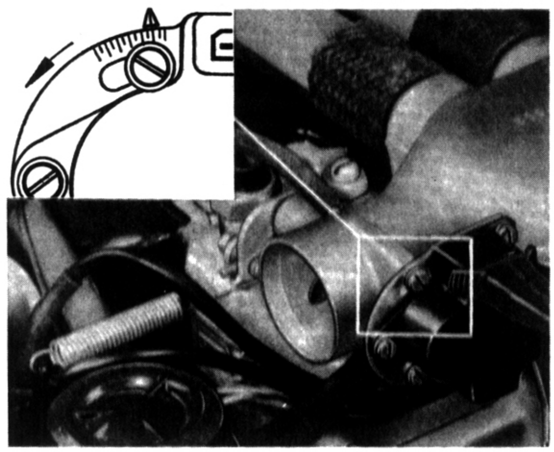
As is usual with automotive equipment, modifications have been made to the original fuel-injection system and will be made in future models as research and development continues.

COLD-STARTING DEVICE

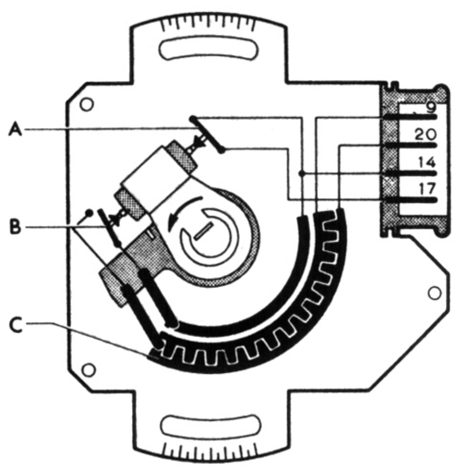
To eliminate cold-starting problems, a cold-starting device has been added to the system. This valve is mounted so as to spray extra fuel into the air intake distributor for about 10 seconds during the initial starting phase. This valve does not function when engine temperature is normal. The cold-start valve operates only when the cranking motor is running.

THROTTLE-VALVE SWITCH

Several types of throttle-valve switches have been used to improve peiformance, each of which requires changes in the wiring so that they are not interchangeable. Basically, the second-generation throttle-valve switch incorporates a series of contact strips to send varying signals to the computer for regulating the amount of injected fuel according to engine needs. The latest models do not have the fuel cutoff contacts for deceleration. Instead, an air bypass valve has been added to the system to provide additional air during deceleration to lean the mixture for emission control during this operating mode.



Throttle-valve switch and adjusting scale, as discussed in the text.



Late-model throttle-valve switch used on 1970–71 models. (A) deceleration fuel-cutoff contacts, (B) off-idle contacts, (C) contact strips for acceleration.

ADJUSTING THE THROTTLE-VALVE SWITCH

Early Models

Initial models required that the switch contacts close just as the throttle valve opens 4° from its fully closed position. To make the adjustment, turn the throttle-valve switch fully to the right, and then back to the left until you hear the contacts operate. Now, turn the switch one additional graduation to the left and tighten the securing screws.

Late Models

Hook up an ohmmeter across the contacts. Turn the switch to the left until the contacts come together, and then slowly to the right until the contacts just open. Now, turn the switch an additional 2° to the right and tighten the securing screws.

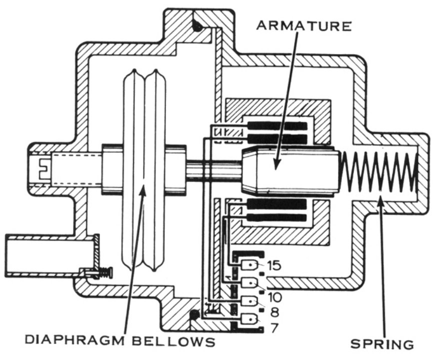
OTHER CHANGES

Several types of control units have been used as well as pressure and temperature sensors. A complete list of the changes as well as interchangeability of parts will follow.

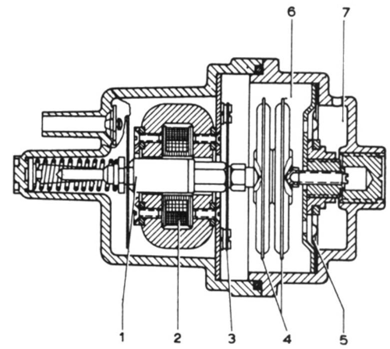
TYPE IV

These engines use a similar Bosch electronic fuel injection system, with a slightly different circuit and with the throttle-valve switch mounted under the throttle-valve housing instead of alongside of it. All of the components previously described can be found on these two engines, but the part numbers may vary according to the year. See the list of system modifications at the end of this chapter.

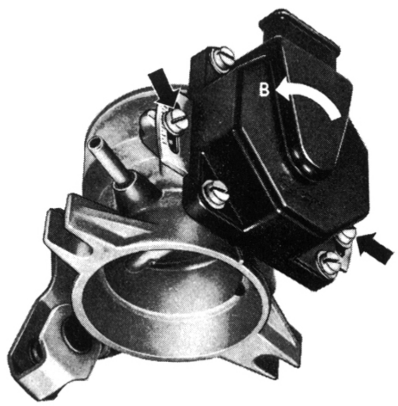
The following pages will be devoted to the circuits and parts that differ from the Type 3 system parts.



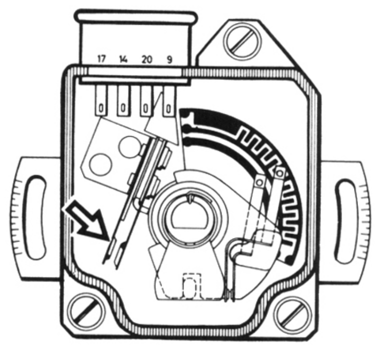
Sectioned view through the first type pressure sensor.



Pressure sensor used since 1970. It replaces the pressure switch on early models. (1) armature, (2) winding, (3) aneroid bellows, (4) diaphragm, (5) pressure-sensitive compartment, (6) atmospheric pressure compartment.



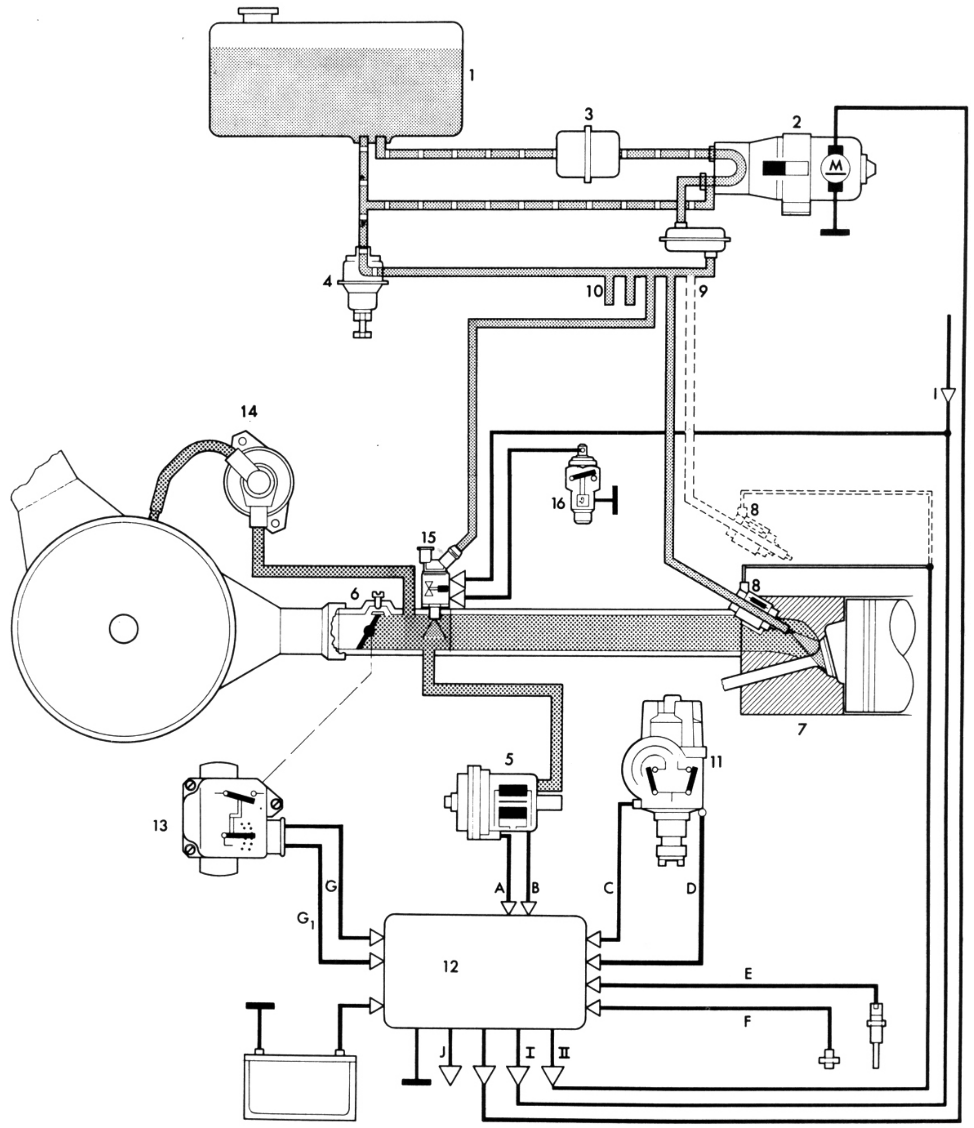
The throttle-valve switch used on Type IV engines is mounted under the throttle-valve body. The arrow shows the direction to rotate the switch body when making the adjustment discussed in the text.



Sectioned view of the throttle-valve switch used on Type IV engines.

Temperature °F	(°C)	Temperature Sensor I Resistance ±10 %	Temperature Sensor II Resistance ±10 %
+14	(−10)	960 Ohm	9200 Ohm
32	(0)	640 Ohm	5900 Ohm
50	(10)	435 Ohm	3700 Ohm
68	(20)	300 Ohm	2500 Ohm
86	(30)	210 Ohm	1700 Ohm
104	(40)	150 Ohm	1180 Ohm
122	(50)	110 Ohm	840 Ohm
140	(60)	80 Ohm	600 Ohm
158	(70)	80 Ohm	435 Ohm
176	(80)	80 Ohm	325 Ohm
194	(90)	80 Ohm	250 Ohm
212	(100)	80 Ohm	190 Ohm

To test the temperature sensors, suspend the units and a thermometer in a container filled with oil. Heat the oil and take resistance measurements to compare with the table above. **CAUTION**: Don't allow the sensors or the thermometer to touch the heated bottom of the container or you will obtain a false reading.

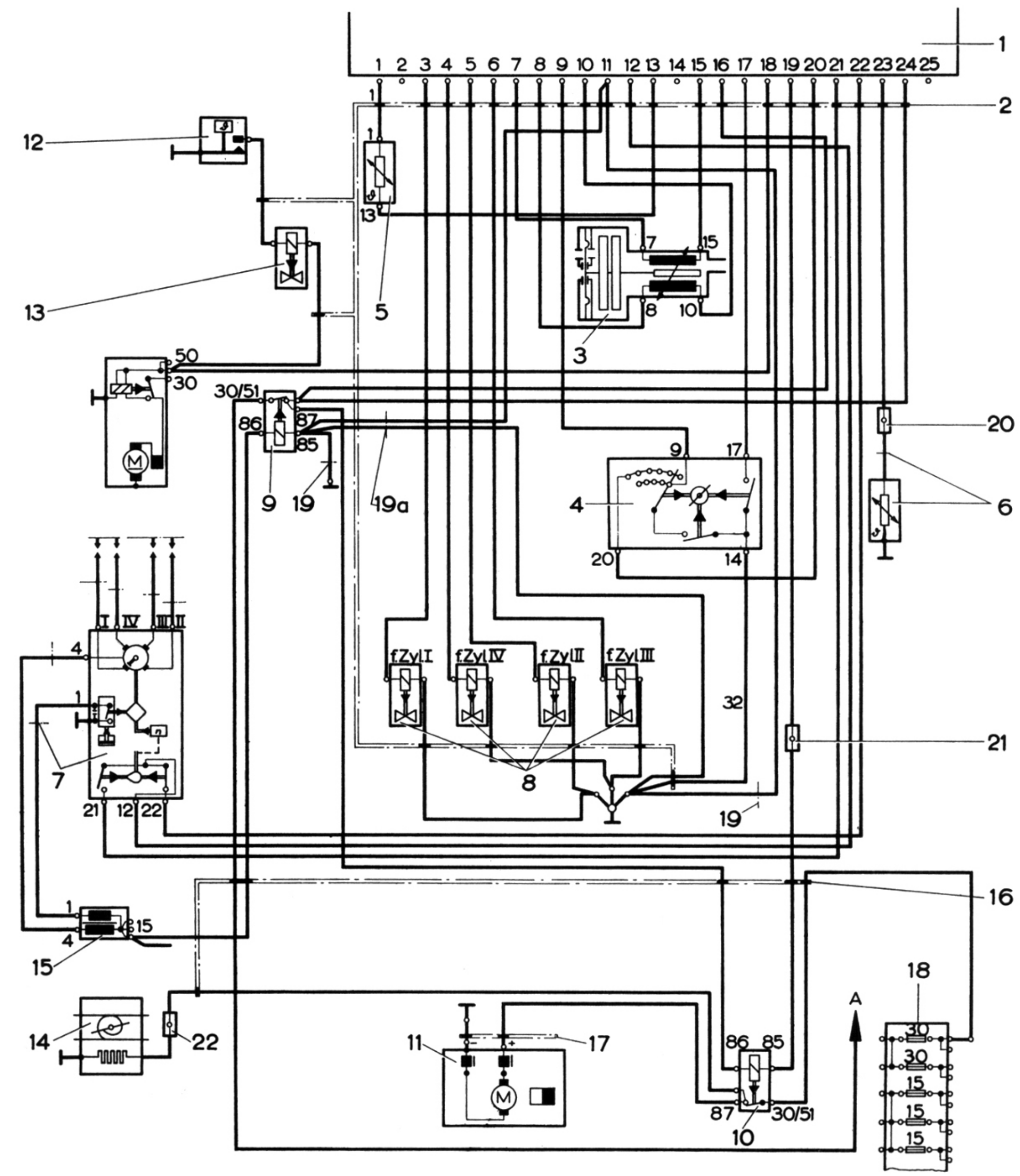


Circuit Diagram

1 – Fuel tank
2 – Fuel pump
3 – Fule filter
4 – Pressure regulator
5 – Pressure sensor
6 – Intake air distributor
7 – Cylinder head
8 – Injectors
9 – Fuel distributor lines
10 – Fuel distributor lines
11 – Ignition distributor with trigger contacts
12 – Control unit
13 – Throttle valve switch with acceleration enrichment
15 – Cold starting valve
17 – Temperature switch for cold starting
18 – Auxiliary air regulator

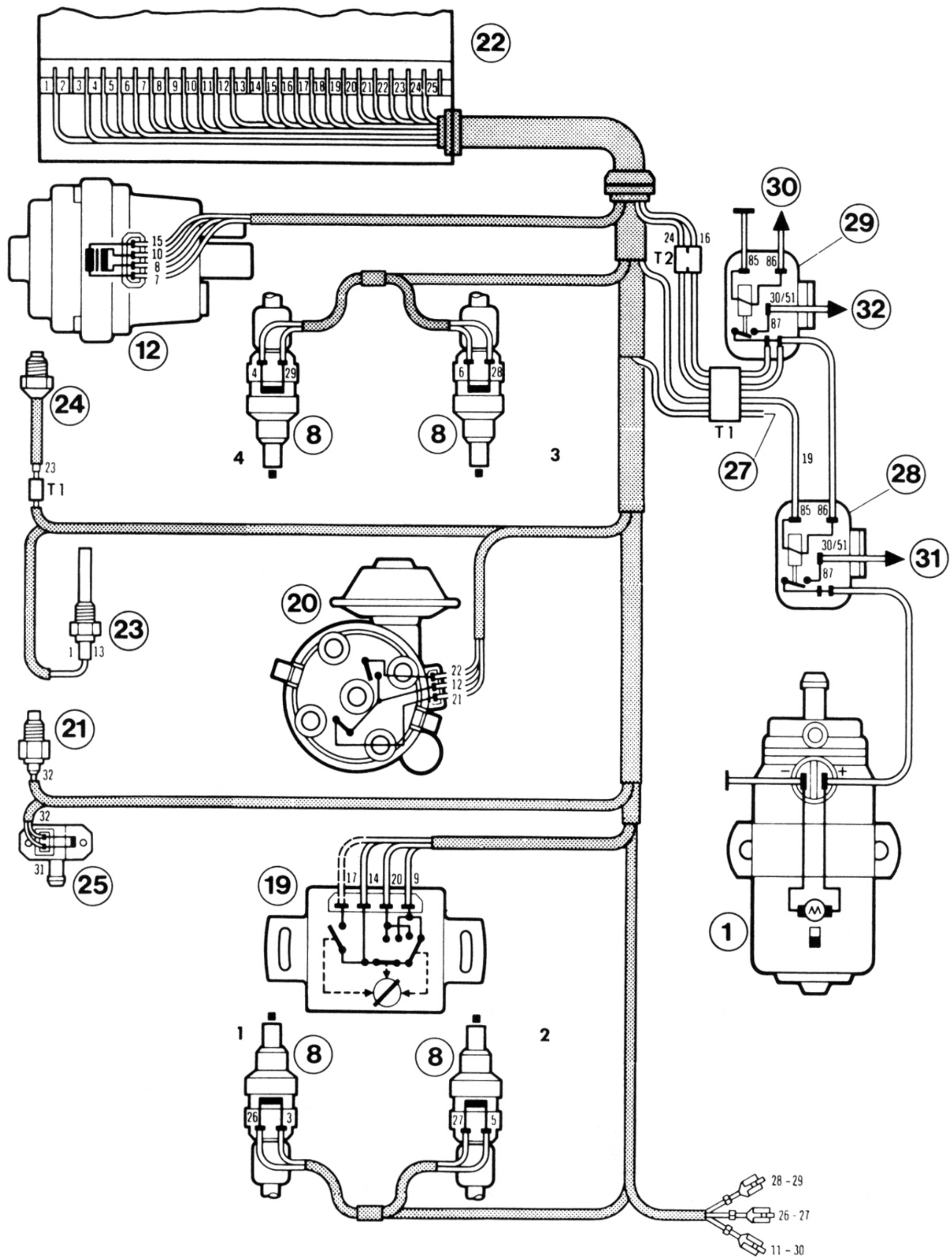
A+B – from pressure sensor (engine load)
C+D – from trigger contacts (engine speed and start of injection)
E+F – from temperature sensors (warming up)
GI – from throttle valve switch (acceleration enrichment)

Schematic diagram of the fuel-injection system used on late Type 3 and 4 engines. Note the latest model throttle-valve switch, with acceleration-enrichment contacts.

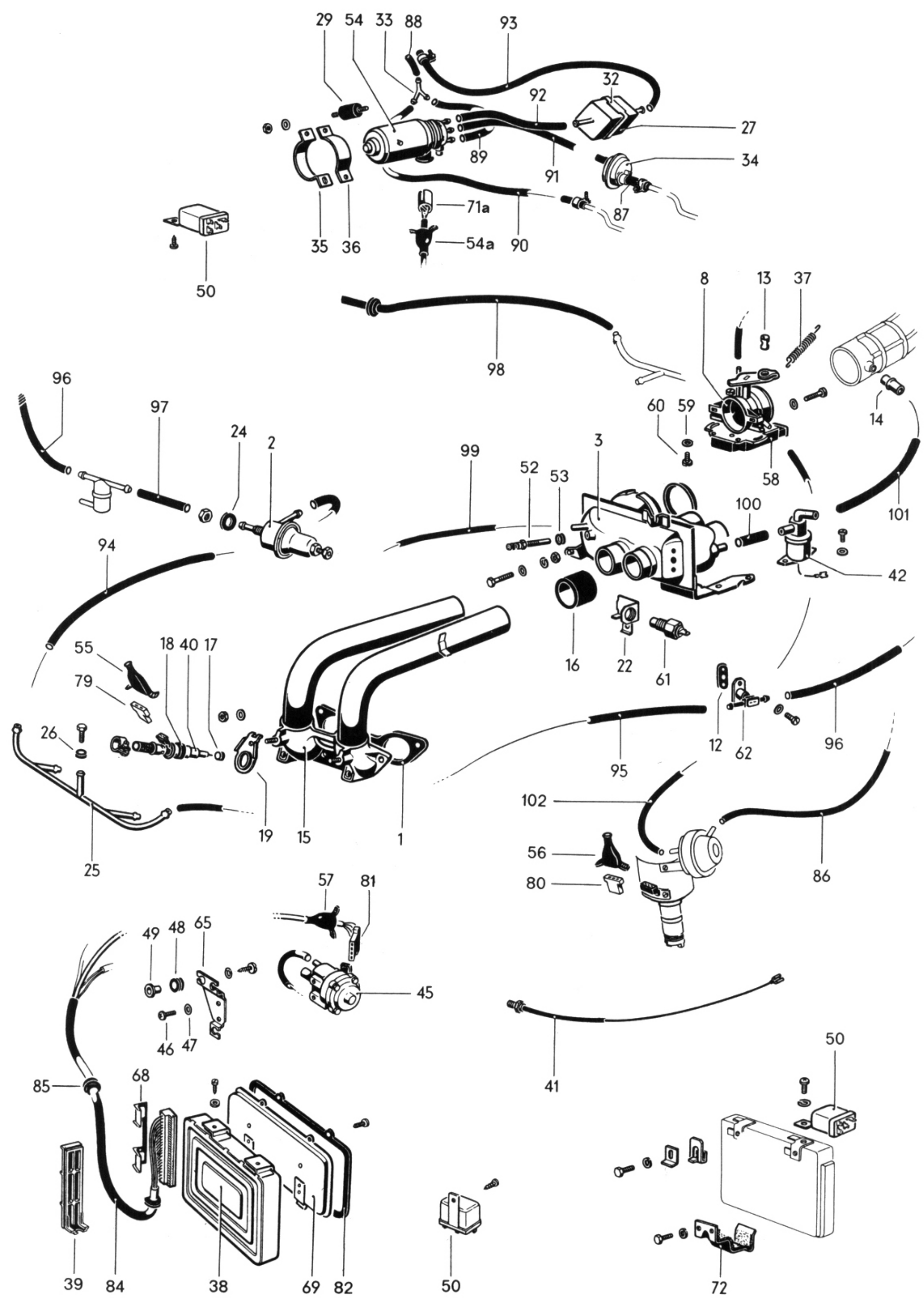


Wiring diagram for the Type 4 Volkswagen engine.

1 – Control unit
2 – Electronic cable harness
3 – Pressure sensor
4 – Throttle valve switch with acceleration enrichment
5 – Temperature sensor I on intake air distributor
6 – Temperature sensor II on cylinder head
7 – Distributor with trigger contacts
8 – Injectors
9 – Power supply relay
10 – Pump relay
11 – Fuel pump
12 – Thermostat for cold starting device
13 – Cold start valve (in intake air distributor)
14 – Auxiliary air valve
15 – Ignition coil
16 – Cables routed in main harness
17 – Fuel pump harness
18 – Fuse box
19 – Ground cable, Sedan
19a – Ground cable, Squareback
20 - |
21 - |-- Cable connector, single
22 - |



Schematic wiring diagram of the electronic fuel-injection system used on Type 4 engines. Note the similarity between this and previous systems, including the use of the same numbered terminals in most cases. (1) fuel pump, (8) injectors, (12) pressure sensor, (19) throttle-valve switch, (20) ignition distributor, (21) thermo-switch, (22) control unit, (23) air temperature sensor, (24) cylinder head temperature sensor, (25) cold-start valve, (27) wire #'s 18 and 31 from terminal 50, (28) pump relay, (29) main relay, (30) to ignition terminal 15 in the fuse box, (31) to terminal 30 in the fuse box, (32) to battery positive (+).



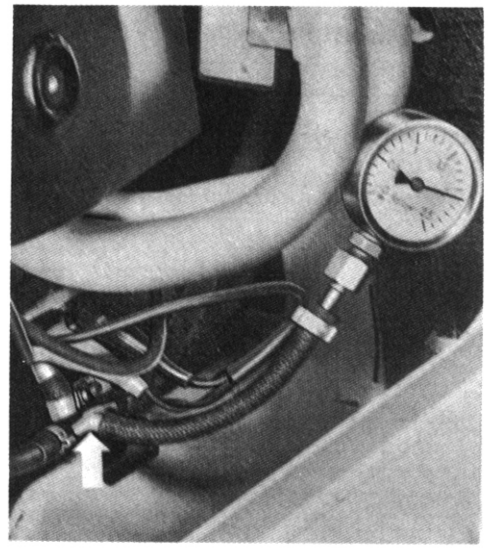
Main components of the fuel-injection system used on Volkswagen Type IV engines. (1) gasket, (2) pressure regulator, (3) air distributor, (8) throttle-valve body, (12) gasket, (13) pin, (14) intermediate piece, (15) left manifold, (16) connecting hose, (17 & 18) inner and outer bushings for injectors, (19) retainer, (24) insulator, (25) fuel line distributor, (26) gasket, (27) fuel filter, (28) rubber mount, (32) bracket, (33) Y-piece, (34) damper, (37) return spring, (38) control unit, (40) injector, (41) cylinder head temperature sensor, (42) auxiliary air regulator, (45) pressure sensor, (48) grommet, (49) spacer, (50) relay, (52) air distributor temperature sensor, (53) sealing washer, (54) fuel pump, (58) throttle-valve switch, (61) thermo-switch, (62) cold-start valve, (79-81) receptacles, (82) cover gasket, (84) wiring harness, (85) grommet, (86-102) hoses.

CHECKING OUT THE SYSTEM

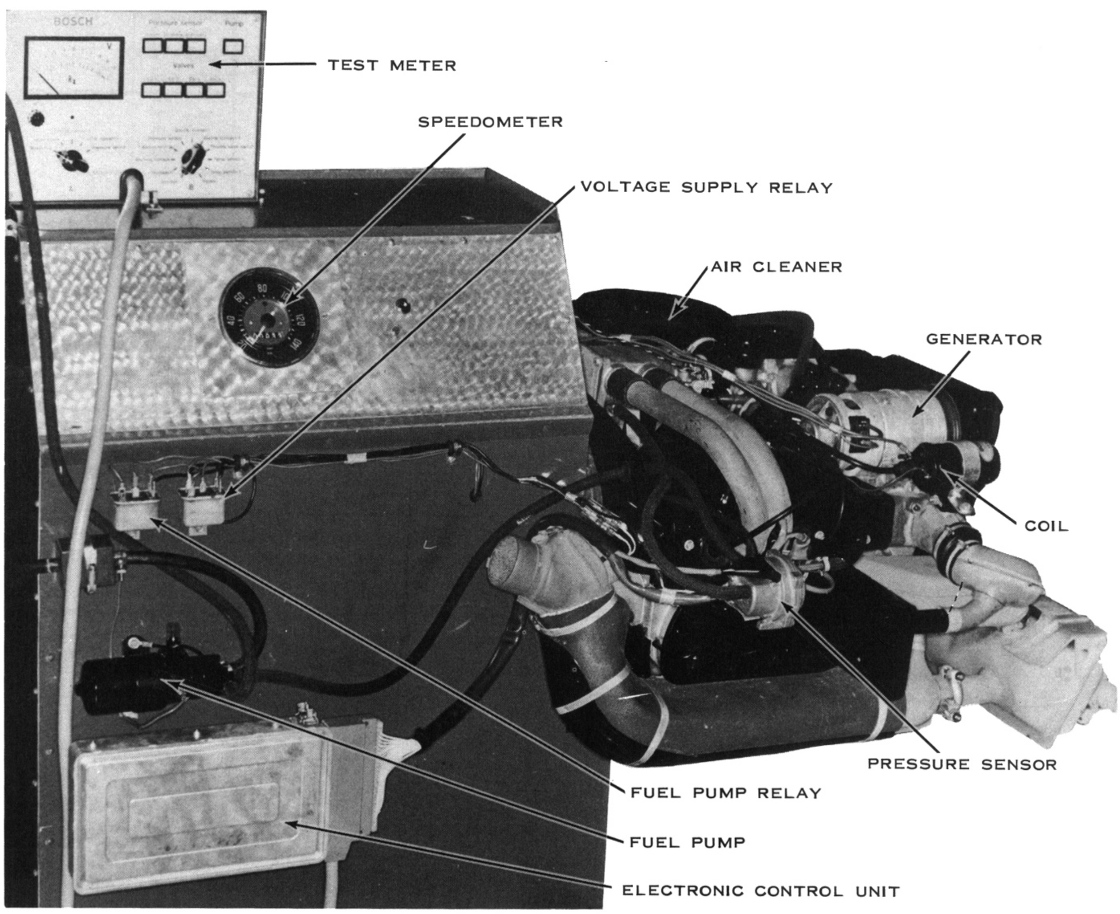
Checking out the system must be performed in three steps: electrical, hydraulic, and dynamic (engine running). For the following tests, it is essential that you use the Bosch tester EFAW 228 or tester EFAW 193 with an adapter. The first 16 steps refer to the electrical tests, followed by steps 17-21 for the hydraulic checks. Steps 22 and 23 refer to they dynamic tests made with the engine running.

TROUBLESHOOTING CHARTS

After making the 23 tests, the troubleshooting charts which follow should be used to pinpoint the problem.



Hook up a fuel pressure gauge as shown to check out the hydraulic system.



This illustration shows the Bosch tester and Volkswagen engine mounted on a test stand for making the electrical, hydraulic, and dynamic tests which are on the following pages.

Checklist for testers EFAW 193 with adapter or EFAW 228

1 – Electrical testing (control unit **NOT** connected)
Position of switches on tester: Switch A in position "measure"
Switch B see checklist

Test Stage	**Tester EFAW 193 With adapter EFAW 248**		**Tester EFAW 228**		Measure:	Reading (Nominal Value)
	Switch B position	Operate:	Switch B position	Operate:		
1	Voltage I	Switch ignition on and leave it on for the following testing sequence	Voltage I	Switch ignition on and leave it on for the following testing sequence	Voltage supply for control unit	11-12.5 (11-12.5V)
2	Voltage II		Voltage II			
3	Starting Voltage	Starter	Starting Voltage	Starter	Voltage at terminal 50 of solenoid switch	9.5-12 (9.5-12V)
4	Adjustment	Set tester to ∞ by turning knob	Adjustment Pressure Sensor	***	Adjust Tester	∞
5	Pressure Sensor	***		Set tester to ∞ by turning knob	Adjust tester	∞
		Push button "ground"		Push button "ground"	Resistance between pressure sensor windings and ground (short circuit to ground)	Resistance (∞Ω)
6		Push button "primary"		Push button "primary"	Resistance of primary windings of pressure sensor	0.5-1.5 on Ω scale (~ 350Ω)
7		Push button "secondary"		Push button "secondary"	Resistance of secondary windings of pressure sensor	3-4 on Ω scale (~ 350Ω)
8	Distributor contact I*	Distributor by turning over starter briefly	Distributor contact I	Distributor by turning over starter briefly	Resistance of trigger contacts in distributor – Pair I and Pair II	Alternately between 0 and ∞ Ω (0Ω / ∞Ω)
9	Distributor contact II		Distributor contact II			
10	Throttle valve switch. Adapter in throttle valve switch position I	Open throttle valve slowly	Throttle valve switch I	Open throttle valve slowly		Alternates between 0 and ∞ 10 times (0/∞Ω)
11	Same as 10, but turn adapter to throttle valve switch position II	Open throttle valve slowly	Throttle valve switch II	Open throttle valve slowly		Same as 10

* The label "Distributor Contact" on the test equipment refers to the testing of the trigger contacts in the ignition distributor.

Test Stage	Tester EFAW 193 With adapter EFAW 248		Tester EFAW 228		Measure:	Reading (Nominal Value)
	Switch B position	Operate:	Switch B position	Operate:		
11a	Adapter to throttle valve switch position II	Close throttle valve	Throttle valve switch II	Close throttle valve		As throttle valve closes the needle should remain on ∞ (∞Ω)
12	Same as 10, but adapter to throttle valve switch position III	Throttle valve in idling position (closed)	Throttle valve switch	Throttle valve in idling position (closed)		0 (0Ω)
13		Open throttle valve more than 1°		Open throttle valve more than 1°		∞ (∞Ω)
14	Temperature sensor I		Temperature sensor I		Resistance of temperature sensor	2-5 (~300 Ω) strongly affected by temperature, higher temperature, lower value Test value when removed: See K 7.3
15	Temperature sensor II (cylinder head)		Temperature sensor II (cylinder head)		Resistance of temperature sensor	0.5-2.5 (~2.5 KΩ) strongly affected by temperature, higher temperature, lower value
16	Fuel injectors	Push buttons Cyl 1 Cyl 2 Cyl 3 Cyl 4	Fuel injectors	Push buttons Cyl 1 Cyl 2 Cyl 3 Cyl 4	Resistance of injector windings and cable	approx 2-3 (~2.4Ω)

Visual check:

That injectors are correctly connected (gray protective caps at rear, black protective caps at front, viewed in driving direction).

That all protective caps are correctly installed.

II – Hydraulic check (sequence for both EFAW 193 and EFAW 228)

Checking injectors

Preparatory work: Connect pressure gauge and switch ignition on again.
Position of switches on tester: **Switch A to injector check**
Switch B is ineffective

Test Stage	Operate	To check	Reading
17	Push button "pump"	Pressure in fuel ring main	Test value: 28-31psi (2-2.2 kg/cm^2)
18	Push button "pump" briefly	Fuel system for leaks (pressure side)	Pressure may drop to 17 psi (1.2 kg/cm^2) at first, but after this the pressure should only drop very slowly
19	Push button "pump" and operate starter briefly	Cold starting valve and temperature switch, engine compartment temperature above 42°F (5°C)	Pressure must not drop below 17psi (1.2 kg/cm^2)
20	Ground temperature switch connection, press "pump" button and operate starter briefly	As 19	Cold starting valve should inject, pressure will drop
21	Press "pump" button, operate starter briefly, temperature switch is connected	Cold starting valve at engine compartment temperatures **below** 42°F (5°C)	Cold starting valve should inject, pressure will drop

Remove pressure gauge and close connection with screw and sealing washer. Ensure connection does not leak.

III – Dynamic test

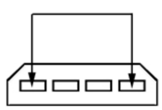
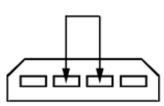
Important

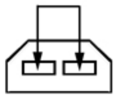
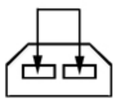
Never run engine with battery disconnected. Do not use quick charger for starting engine.
Starting the engine: Connect control unit to plug on tester (wiring harness remains on tester plug). Turn switch A on tester to Distributor Contact 1, switch B is ineffective. Switch ignition on. If the test stages 19 to 21 have already been performed, the engine must be purged. To do this, remove pump fuse (red fuse in vehicle fuse box), start engine and let it run until it stops. Reinstall pump fuse, start engine again and run it at idling speed.
Position of switches on tester: **For switch A see troubleshooting chart**
Switch B is ineffective

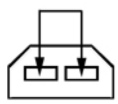
Test Stage	Switch A in position *	Operate	Reading V scale
22	Distributor contact I	Let engine idle (if necessary, increase engine speed)	~18 (average value)
23	Switch over from distributor contact I to distributor contact II	Switch A	Difference between I and II must not be greater than ~2 graduations on voltage scale

*Note: Switch positions for distributor contact III and IV do not apply to 4 cylinder engines.

The fuel injection system can only be tested accurately with the EFAW 193 or EFAW 238 tester. When testing according to the checklist, deviations from the nominal values can be ascertained. Additional checks to be carried out in such cases are listed below.

Test stage	Result	Possible Fault
1 – Voltage I	No recording	Open circuit: cable relay I – control unit; relay I inoperative, ignition switch defective. (Check for voltage at terminal 86, 30/51 and 87 of relay, check cable 16)
	Voltage below 11 volts	Battery discharged contact resistance in cable 16 or at relay contacts (check cable, replace relay I).
2 – Voltage II	Same as test stage 1, but check cable 24	
3 – Starting Voltage	No voltage, starter operates	Open circuit from starter solenoid switch to control unit (check cable 18).
	No voltage, starter does not operate	Ignition/starter switch defective, open circuit in cable. Battery discharged.
	Voltage below 9 volts	Battery flat, voltage drop in cable from ignition/starter switch to terminal 50 of starter solenoid switch too great (test cable with voltmeter).
4 – Adjustment to ∞	If needle of tester does not move to end position, battery voltage in vehicle too low. See also test stages 1 and 2.	
5 – Pressure sensor, short circuit to ground	Resistance 0	Short circuit to ground in cable or at pressure sensor (pull plug out of pressure sensor and if tester shows ∞, replace pressure sensor. If tester remains at 0, cables 7, 8, 10, 15 are shorted. Replace cable harness).
	Tester on needle below ∞ but not on 0	Damage to insulation (proceed as above with resistance 0).
6 – Pressure sensor, primary 	Nominal value ~90Ω, resistance considerably smaller	Damage to insulation (pull plug out of pressure sensor and if tester shows ∞, replace pressure sensor).
	Resistance 0	Short circuit to ground, short circuit in primary windings (pull plug out of pressure sensor and if tester shows ∞, replace pressure sensor).
	Nominal value ~90Ω, resistance considerably larger	High contact resistance (test plugs and cables for corrosion or open circuit).
	Resistance ∞Ω	Open circuit. (Bridge at plug as shown in illustration. If tester shows 0, replace pressure sensor. If tester shows ∞, repair cable).
7 – Pressure sensor, secondary 	Same as 6, but with ~350Ω nominal value	Same as 6. With resistance at ∞, bridge other two terminals as shown in illustration.
8 – Distributor contact I	Resistance larger than 0Ω, or smaller than ∞Ω	If needle of tester does not swing when "starting" (i.e., remains at – ∞ or O, replace the trigger contacts. (Replace contact holder)
9 Distributor contact II		
10, 11, 11a – Throttle valve switch I, then throttle valve switch II	Needle does not swing between 0 and ∞, remains an intermediate value on the individual contacts	Contact deck dirty. (Replace throttle valve switch)
	Impulse (needle swings) or constant resistance less than ∞	Sliding switch in throttle valve switch defective. (Replace throttle valve switch)

Test stage	Result	Possible Fault
12 – Throttle valve switch III 	Resistance ∞ with throttle valve lever in "idle" position	Throttle valve switch incorrectly adjusted or open circuit in cable (check adjustment, pull out plug, bridge. If still at ∞, replace cable harness, otherwise replace throttle valve switch).
13	Resistance 0Ω with throttle valve open more than 2°	Throttle valve switch incorrectly adjusted or short circuit in cable. (Pull out plug, if tester still shows 0, replace cable harness, adjust or replace throttle valve switch)
14 – Temperature sensor I 	Nominal value 300Ω, resistance larger or smaller	Nominal value is for 68°F (20°C). At higher temperature resistance is smaller. If 0 or ∞ is not shown, sensor in order. If in doubt, remove sensor and test as described on page…
	Tester shows ∞Ω	Open circuit (bridge, if tester shows 0, replace temperature sensor or wiring harness)
	Tester shows 0Ω	Short circuit (pull out plug, if reading is same, cable defective. If reading ∞, replace temperature sensor).
15 – Temperature sensor II (cylinder head)	Same as 14 but with following deviations: Nominal value 2.5K Ω. Instead of bridging, hold plug of cable harness on ground. When in doubt, remove sensor and test on described on page K 7.5/1-8 and K 7.2/1-2	
16 – injectors (resistance)	Resistance 0Ω	Short circuit in cable or at injector (pull plug out of appropriate injector and if tester shows ∞, replace injector, otherwise replace cable harness).
	Resistance ∞Ω	Open circuit in cable or in injector windings (bridge contacts in injector plug and if tester then shows ∞, cable harness defective. If 0, injectors defective).
	Nominal value: 2.4Ω at 68°F (20°C), resistance larger but not ∞	Injector ground cable makes poor contact with crankcase or flat terminals not properly connected (use contact spray, tighten ground connection screw).
17 – Pressure in fuel line	Pressure above 31psi (2.2 kg/cm^2) or pressure below 28psi 2kg/cm^2)	Pressure regulator maladjusted (adjust); if adjustment not possible, pressure regulator defective (replace).
	No pressure build-up (pump does not start)	No voltage to pump (disconnect two-pin plug at pump housing and measure voltage with voltmeter). Must be voltage when "pump" button on tester is pressed. **Reading 12 volt**: replace pump **Reading 0 volt**: Listen to determine whether relay under instrument panel operates. **If yes**: Open circuit in cable from pump relay terminal 87 to two-pin plug or from two-pin plug to ground connection or pump relay (contacts) defective. If **no**: Open circuit in cable from terminal 87 of voltage supply relay to pump relay terminal 86 or 85 to cable 19 in harness. If cable is OK, replace pump relay.
18 – Pressure drops immediately to below 17psi or down to 0psi when pump button is released	Leakage in pressure system. Pinch fuel line in front right injectors. Build pressure up again. If pressure still drops, the leak is in the pump or in the line between pump and right fuel distributor. If pressure does not drop, pinch fuel line in front of the cold starting valve (on right, near) and build pressure up again. If pressure drops, a valve on the right side is leaking. (Remove and repeat test, see below). If no pressure drop, pinch fuel line behind cold start valve and build up pressure. If pressure drops, the cold start valve is defective. If it does not drop, one of the left injectors or the pressure regulator is defective. If necessary, pinch fuel line behind the left fuel distributor and build up pressure. Pressure drop now indicates a leak in one of left injectors or the pressure regulator. **Injectors are considered to be leaking if more than two drops of fuel are emitted per minute.**	

Test stage	Result	Possible Fault
19 – Cold starting valve - Temperature above 42°F ±9°F (5°C ± 5°C)	Pressure drops	Temperature switch defective (measure with Ohmmeter: At given temperature, the temperature switch should show a resistance).
20 – Same as 19	Pressure does not drop	Connect voltmeter to cable 31 of cold starting valve and ground. When starter is operated meter should record 12 volts. If it does not, replace cable harness.
21 - Cold starting valve - Temperature **below** 42°F ±9°F (5°C ± 5°C)	Pressure does not drop	Thermo switch or cold starting valve defective (Check cold start valve with Ohmmeter). Winding resistance at 68°F (20°C) should be 4.2 Ohms.
22 – Trigger contacts	Voltage difference in excess of two graduations	Trigger contacts defective (replace contact holder).
23 	Voltage 2-3 volts with engine running	Pressure switch not working or open circuit in cable (disconnect cable, bridge. If tester shows 2-3, replace cable harness, otherwise test pressure switch).

SYSTEM MODIFICATIONS

PRESSURE SENSORS

Type III	**Year**	**Type IV**
311 906 051 B	**1968**	**-**
311 906 051 B	**1969**	**-**
311 906 051 C	**1970**	**022 906 051 A**
311 906 051 C	**1971**	**022 906 051 B**
311 906 051 E	**1972**	**022 906 051 (Brown)**

Blank lines indicate non-interchangeability.

TEMPERATURE SENSORS

Type III		**Year**	**Type IV**	
Crankcase	**Cylinder Head**			
311 906 081	**311 906 041 A**	**1968**		
311 906 081	**311 906 041 A**	**1969**		
Air Intake	**Cylinder Head**		**Air Intake**	**Cylinder Head**
311 906 081 A	**311 906 041 A**	**1970**	**311 906 081 A**	**311 906 041 A (022 906 041 A)**
311 906 081 A	**311 906 041 A**	**1971**	**311 906 081 A**	**311 906 041 A (022 906 041 A)**
311 906 081 A	**311 906 041 A**	**1972**	**311 906 081 A**	**311 906 041 A (022 906 041 A)**

Blank line indicates non-interchangeability

FULL-LOAD ENRICHMENT

Switch	Year	Part Numbers	
Separate Pressure switch	68/69	311 906 071 A	
		Type III	Type IV
Built into pressure	1970	311 906 051 C	022 906 051 A
Sensor	1971	311 906 051 C	022 906 051 C (Brown)
Built into throttle-Valve switch	1972	311 906 111 E	022 906 111 E

Blank lines indicate non-interchangeability.

COMPUTERS

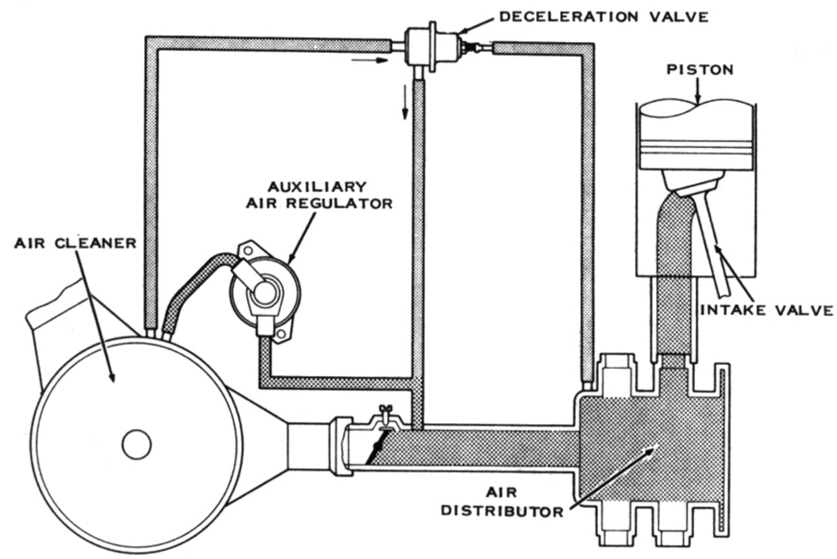
Type III	Year	Type IV
311 906 021 A	1968	
311 906 021 B	1969	
311 906 021 C	1970	022 906 021 A 022 906 021 A (Blue) (each of these "A" computers require thermoswitch 311 906 161 C)
311 906 021 D (D modified) (black) (Requires air intake temperature sensor 311 906 081 A)	1971	022 906 021 B (Yellow) (Requires cylinder head temperature sensor 311 906 041 A)
311 906 021 E (Black)	1972	022 906 021 E (Brown) (CO adjustable = 0.7%)

Blank lines indicate non-interchangeability.

THROTTLE-VALVE SWITCH

Type III	Year	Type IV
311 906 111 A	1968	
311 906 111 B	1969	
311 906 111 C	1970	022 906 111 A
311 906 111 D	1971	022 906 111 A
311 906 111 E	1972	022 906 111 E

Blank lines indicate non-interchangeability.



In 1972, a deceleration (overrun) valve was added to the Type IV engines to allow air to enter the manifold during deceleration. The fuel is not cut off on these models, because the extra air minimizes the emissions during this operating mode.

TUNE-UP SPECIFICATIONS—VOLKSWAGEN

TYPES & YEARS	SPARK PLUGS Type (Bosch)	SPARK PLUGS Gap (Inches)	DISTRIBUTOR Point Gap (Inches)	DISTRIBUTOR Dwell (Degrees ± 3)	IGNITION TIMING (1) B = Before TDC A = After TDC	VALVE LASH H = Hot Intake (Inches)	VALVE LASH C = Cold Exhaust (Inches)	IDLE SPEED Auto. Stick Shift (Rpm-Neutral)	IDLE SPEED Man. Trans. (Rpm-Neutral)	IDLE CO%
TYPE 1										
1968-69	W145T1	.028	.016	47	TDC (2)	.006C	.006C	950	850	2.0-3.5
1970	W145T1	.028	.016	47	TDC	.006C	.006C	950	850	2.0-4.0
1971-72	W145T1	.028	.016	47	TDC (3)	.006C	.006C	950	850	1.5-3.0
TYPE 2										
1968-70	W145T1	.028	.016	47	TDC	.006C	.006C	—	900	2.0-3.0
1971	W145T1	.028	.016	47	5A (4)	.006C	.006C	—	900	1.5-3.0
1972	W145T2	.028	.016	47	5A (4)	.006C	.006C	—	900	2.0 max.
TYPE 3										
1968-70	W145T1	.028	.016	47	TDC	.006C	.006C	950	850	4.0 max.
1971	W145T1	.028	.016	47	TDC	.006C	.006C	950	850	4.0 max.
1972	W145T1	.028	.016	47	5B	.006C	.006C	950	850	2.0-3.0
TYPE 4										
1971-72	W175T2	.028	.016	47	27B @ 3,500 rpm	.006C	.006C	900	850	0.5-1.5

(1) With the vacuum hose(s) to the distributor disconnected and the ends plugged, except where specifically noted to the contrary.
(2) Adjust the ignition timing on 1,500cc engines to TDC after engine number H5 000 001.
(3) Adjust the ignition timing on 1,600cc engines to 5° ATDC, with the vacuum hoses connected after engine number AE 0 000 001 (1972 models—49 states) or AH 0 000 001 (1972 California models with EGR).
(4) With the vacuum hoses to the distributor connected.